Accepted for publication 16 November 2009. Published 16 February 2010.

Canada Goose Weed Dispersal and Nutrient Loading in Turfgrass Systems

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Ayers, C. R., DePerno, C. S., Moorman, C. E., and Yelverton, F. H. 2010. Canada goose weed dispersal and nutrient loading in turfgrass systems. Online. Applied Turfgrass Science doi:10.1094/ATS-2010-0212-02-RS.

Abstract

High populations of Canada geese (*Branta canadensis* L.) can lead to feces accumulation in areas adjacent to surface waters, creating concern about aquatic eutrophication. Further, turf managers and livestock farmers work to keep their facilities free of noxious or toxic weeds that geese potentially disperse. We investigated the prevalence of viable seeds and nitrogen and phosphorus content in resident Canada goose droppings. During spring, summer, and fall of 2008, we collected 127 fresh individual droppings which were placed in seedling trays within an irrigated greenhouse and allowed 30 days for weed seed to germinate. Trays were cold stratified for 30 days and returned to the greenhouse for an additional 30 days. Also, during summer and fall of 2007 and 2008, we tested 304 fecal samples from 8 sites for total Kjeldahl nitrogen (TKN) and total phosphorus (TP). Out of 127 droppings planted, 4 plants germinated (3.1%): Pennsylvania smartweed (*Polygonum pennsylvanicum* L.), annual bluegrass (*Poa annua* L.), and 2 *Kyllinga* spp. The average amounts of TKN and TP in fecal samples were 24.2 mg/g (range = 12.6 to 55.7) and 3.6 mg/g (range = 1.4 to 8.3) of dry matter, respectively. The results indicate that Canada geese in suburban and urban areas are not frequent vectors of viable seeds, but do have potential to contribute nutrients to adjacent surface waters.

Introduction

Populations of resident Canada geese (*Branta canadensis* L.) have increased in North America over the past 50 years, especially in suburban areas (1,10). Population growth has resulted from an increase in suitable habitats (e.g., golf courses, parks, corporate facilities, airports, and residences), which often contain ponds or lakes surrounded by managed turfgrass (10). Concentrated goose grazing and fecal build-up can create a variety of management challenges (10). For example, high concentrations of goose grazing could lead to weed dispersal in areas of managed turfgrass or livestock pastures. Turfgrass managers work to eliminate unwanted plants from turf, and livestock managers must protect livestock from toxic and malnourishing plants invading pastures (13,14). Additionally, excessive fecal buildup could contribute to aquatic eutrophication of adjacent and downstream surface water (11).

Resident Canada goose movements vary widely, ranging from < 1 km to 109 km within a given year (31). During these movements, geese may translocate nutrients and viable weed seeds (2,10). Endozoochory, the process of ingesting and dispersing viable seeds, has been recorded in mammals (18) and birds (2,6,22,29). Soons et al. (29) demonstrated that mallards (*Anas platyrhynchos* L.) could disperse viable seeds of 19 different aquatic plant species. Also, viable seeds have been detected in the droppings of migratory Canada geese (2), but research on viable weed dispersal by resident Canada geese in suburban areas is lacking.

Eutrophication is a primary cause of decreased water quality in coastal and inland waters (17). Nitrogen and phosphorus are the two most common causes of harmful algal blooms, which can cause declines in aquatic biodiversity (11). In many urban and suburban habitats, goose feces are deposited on hard surfaces or lawns directly adjacent to surface water (10). If runoff is not filtered or retained, the nutrients from fecal deposits enter the waterway.

Fecal deposits from migratory waterfowl have been identified as potential causes of poor water quality (19,20,26). However, Pettigrew et al. (27) and Unckless and Makarewicz (30) concluded that migratory geese had little or no negative effect on water quality. To our knowledge, our study was the first to focus on nitrogen and phosphorous content of feces from resident Canada geese. Because resident Canada geese spend much of the year in one area, large congregations may lead to higher levels of nutrient loading than documented by previous studies of migratory geese. We measured the amount of total Kjeldahl nitrogen (TKN), a measurement of organic nitrogen and ammonia content (25), and total phosphorus (TP) (later converted to phosphates) in feces deposited by resident Canada geese. Our objectives were to survey resident Canada goose feces for viable weed seed and measure the amount of TKN and TP in goose feces.

Investigating Seed Prevelance and Nutrient Content In Resident Canada Goose Droppings

We collected feces samples at eight sites in the Triangle (Raleigh-Durham-Chapel Hill) region of North Carolina. Sites included three corporate facilities, a park, a suburban residence, a greenway (vegetated area with a path used for recreation), a college, and a dairy farm. The residence and one corporate facility were dominated by bermudagrass (*Cynodon dactylon* L.) and the other sites were dominated by tall fescue [*Schedonorus phoenix* (Scop.) Holub. synonym *Festuca arundinacea* Schreb.]. Each site had at least 0.4 ha of turf adjacent to or nearby a pond or lake and had daily use by geese on a portion of the grounds during early summer, early fall, or both according to site managers. During summer and fall of 2007 and 2008, we counted the number of geese at each site upon daily arrival for 37-day sessions. Goose counts were conducted to verify the presence of geese at sites during the study. At least 0.4 ha of turfgrass used by geese was mowed every 4 to 8 days at heights recommended by site managers as part of an ongoing study on the efficacy of a chemical repellent to deter geese under multiple mowing regimes. Six of the eight sites were sloped toward the pond or lake from goose-grazed lawns, seven of the eight sites did not have complete riparian buffers or grass filter strips separating water from goose-grazed lawns, and three of the sites had impermeable surfaces (e.g., walking paths and parking lots) interspersed among goose-grazed lawns.

Evaluation of Germination Potential. We collected fresh individual goose droppings in March, June, July, and October of 2008. Each dropping was placed on top of a single cell of a seedling germination tray containing Miracle-Gro potting mix (sphagnum peat moss, forest products compost, and perlite). In each tray, 24 to 43 of the available cells received potting mix with a dropping and the remaining control cells (7 to 20) received only potting soil to test for weed seed contamination of the potting soil or inadvertent contamination. Within 24 hours of fecal collection, each tray was placed into an auto-irrigated greenhouse lighted from 6:00 to 20:00 daily and watered three times per day totaling 3.8 cm/week. Trays were monitored weekly and remained in the greenhouse for 30 days before being placed into 4°C refrigeration for cold stratification (16). After 30 days of cold stratification, the trays were returned to the greenhouse for 30 additional days.

Evaluation of Nitrogen and Phosphorus Content. From each site, we collected multiple fresh goose droppings where available. The sampling periods were 10 to 12 days apart during each summer (June/July) and fall (September/October) of 2007 and 2008. Samples were stored in a resealable plastic bag and placed on ice immediately after collection and refrigerated or frozen within 12 hours until testing began. From each of the samples, three to five, 50-g subsamples were used to measure the amount of TKN and TP through a persulfate digestion, ammonia salicylate method using an Auto analyzer III

(15). This decomposition method allows the measurement of nitrogen and phosphorus compounds isolated from raw organic materials. Extrapolated values for fecal deposition per hectare were based on the daily total mass of feces collected on a 2-m by 21-m transect. Daily collections were conducted during summer and fall of 2007 and 2008 for the 37 consecutive-day sessions at the previously described study sites.

Germination Results

We potted 43 goose droppings in March with seven control cells, 30 in June with 20 controls, 30 in July with 20 controls, and 24 in October with 12 controls. Four (3.1%) dropping cells and zero control cells germinated a plant. One Pennsylvania smartweed (*Polygonum pennsylvanicum* L.) grew before cold stratification in a sample collected in March. One annual bluegrass (*Poa annua* L.) grew after cold stratification from a sample collected in March. One *Kyllinga* sp. grew before cold stratification in a sample collected in July and one *Kyllinga* sp. grew after cold stratification from a sample collected in October. We were unable to distinguish between *K. brevifolia* L. and *K. gracillima* Rottb. due to lack of seeds for inspection of teeth on the scale keel (4).

Only 2.2% of the total cells and 0% of control cells germinated a plant. The plant species that germinated are common in turfgrass or moist habitats similar to our fecal collection sites (5,12,23). Also, the cold stratification requirements and seed production periods for the plants we detected correspond with the time of dropping collection and greenhouse germination (5,12,23). The plants that germinated are not wind or expulsion dispersed and likely would not have come from adjacent experiments in the greenhouse (5,12,23).

Although three species of plants were germinated in our survey, only annual bluegrass and *Kyllinga* spp. are common weeds in turfgrass systems in the southeastern United States. *Kyllinga* spp. can become a problem in turfgrass systems with wet soils if established and allowed to extend rhizomatous growth (12,21). Annual bluegrass is a common weed in turfgrass systems throughout the world and has been shown in this study and by Best and Arcese (2) to germinate from seeds in Canada goose feces. Also, annual bluegrass is not a valued plant for livestock pastures in most of the United States (13). We detected a very low percentage of viable seeds in resident Canada goose feces, most likely indicating that geese are not ingesting many seeds from the frequently mowed turf areas in residential areas where they typically feed. However, because annual bluegrass can produce seeds at heights as low as 0.25 cm, it may have relatively high potential to be dispersed from even frequently mowed turf (5). Nevertheless, because geese feed primarily on young grass, their feces should not contain high numbers of seeds (8). Hence, resident Canada geese feeding primarily on managed turfgrass do not pose high risk of dispersing viable weed seeds.

Nitrogen and Phosphorus Content

We tested 304 fecal samples for TKN and TP content. The average moisture content of fecal samples was 80%. The average amounts of TKN and TP in fecal samples were 24.2 mg/g (range = 12.6 to 55.7) and 3.6 mg/g (range = 1.4 to 8.3) of dry matter, respectively.

An average of 4.32 kg/ha/day (range 0.04 to 246.91) of dry feces was deposited at our study sites (extrapolated from 2-m by 21-m transects) equating to 104.3 g/ha/day of TKN and 15.5 g/ha/day of TP in dry feces deposited by geese. There was a daily average of 42 geese/site, indicating that each goose deposited an average of 103.9 g/ha/day of dry feces, 2.5 g/ha/day of TKN, and 0.4 g/ha/day of TP. Turfgrass fertilizers contain organic sources of nitrogen similar to those in animal waste (5). In North Carolina, and in the absence of a soil test, the recommended rate of nitrogen application for turfgrass is 222.28 kg/ha/year for bermudagrass and 123.48 to 148.19 kg/ha/year for tall fescue (3). Our average daily fecal collection and goose count results indicate that 42 geese deposited 17% of the yearly nitrogen application for bermudagrass and 26 to 31% of the yearly nitrogen application for tall fescue (Fig. 1). Recommended turfgrass fertilizers are commonly formulated with a 3:1 or 4:1 ratio of nitrogen to available phosphates, which are 44% elemental phosphorus (14). Based on 44% elemental phosphorus, our results indicate that 42 resident Canada geese would deposit the equivalent of 12.85 kg/ha/year of phosphates. Further, the fecal material collected had a nitrogen-to-phosphate ratio of almost 7:1, similar to the 8:1 ratio in waterfowl feces as described by Post et al. (28). Based on rates recommended by the North Carolina Cooperative Extension Service (3), phosphate application should be 55.57 to 74.09 kg/ha/year for bermudagrass and 33.96 to 45.28 kg/ha/year for tall fescue. Our results indicate that average resident populations of Canada geese deposit 17 to 23% of the annual phosphate application for bermudagrass and 28 to 38% of the annual phosphate application for tall fescue (Fig. 1).

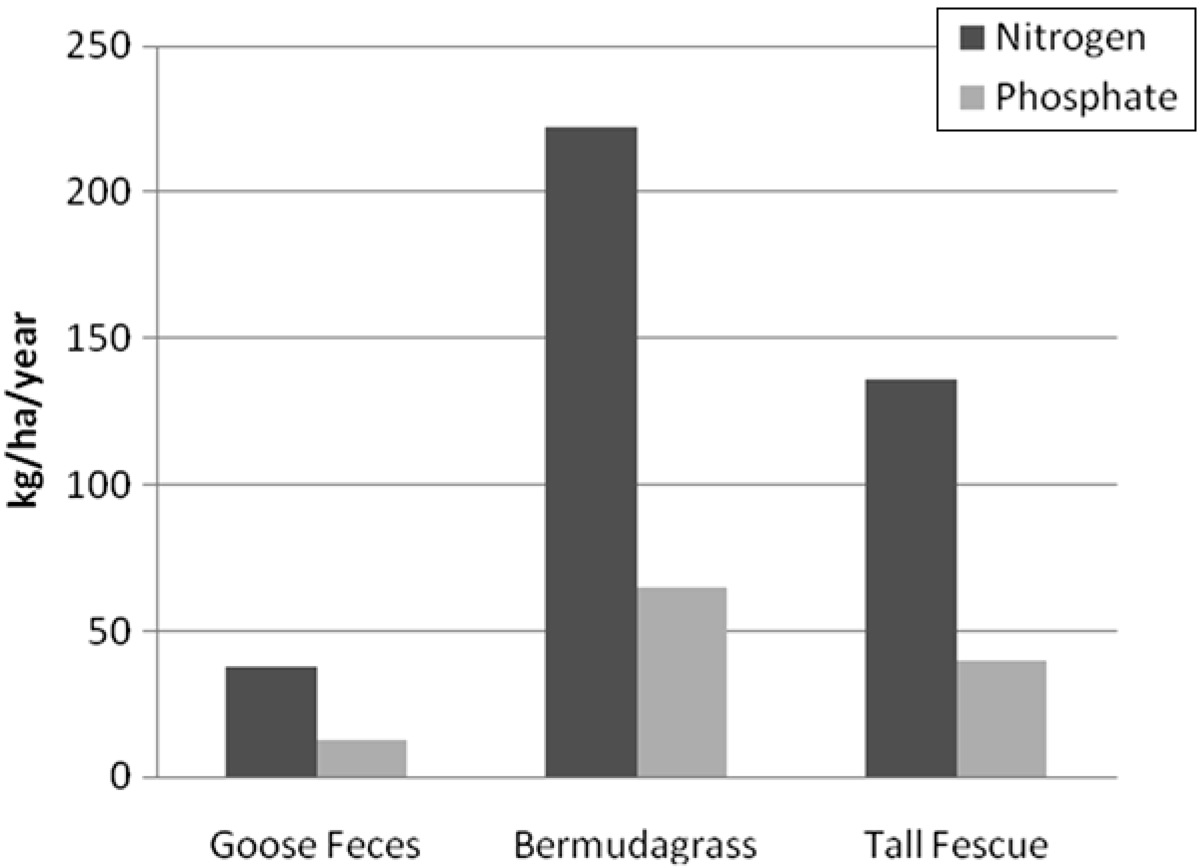

Fig. 1. Nitrogen and phosphate contributions from ~42 resident Canada geese/site compared to the recommended nitrogen and phosphate fertilization rates for bermudagrass (*Cynodon dactylon* L.) and tall fescue (*Festuca arundinaceae* L.) in North Carolina.

Currently, some states regulate phosphorus fertilizers to protect against eutrophication of adjacent surface waters. State law may restrict the use of fertilizers containing phosphorus unless a soil test determines a deficiency, during lawn establishment, or for use on a golf course or sod farm by a professional (24). Where phosphorus application is restricted, the relative contribution of phosphorus by populations of Canada geese would be higher than the 17 to 38% annual contribution reported in this study.

Excess fecal nutrient runoff will increase with fecal deposition on hard surfaces or turf areas directly adjacent to unbuffered surface waters (7). We recommend creating and/or maintaining riparian buffers or vegetative filter strips between surface waters and turfgrass to reduce runoff and eutrophication. Also, thick hedges, tall trees, and unpalatable ground cover may reduce goose use (9). During our study, concentration of Canada goose grazing pressure varied from site to site and should be considered when determining the fecal nutrient deposition/ha and subsequent effects on aquatic eutrophication. Further research should investigate the nutrient absorption from goose feces by turfgrass, the amount of nutrient runoff reaching surface waters, and the effects of these levels of nutrient runoff on local and downstream water quality.

Acknowledgments

Funding was provided by the Department of Forestry and Environmental Resources and Department of Crop Science at North Carolina State University, SePro Corporation, and Arkion Life Sciences. We thank A. Raybuck, M. Sandfoss, H. Shively, W. Ricks, D. MacLennon, M. Fine, W. Paugh, M. Wood, A. Griffith, C. Matthews, E. Jones, E. Rutledge, M. Chitwood, C. Shake, S. Rodriquez, J. Birkhead, K. Golden, A. Savage, S. Hutchens, and J. Krahe for assisting with field work. Site management was coordinated by C. Lewis, L. Barnes, J. Kitchen, K. Snyder, D. Broad, M. Clark, A. Shettler, F. Babich, and M. Jones. T. Gannon assisted with equipment acquisition and maintenance. Thanks to M. Poore, M. Levy, R. Huie, H. Morell, and H. Tajiri for lab space and testing. Thanks to D. Carley for professional consultation and C. Burke and E. Erickson for providing assistance with account management.

Literature Cited

1. Ankney, C. D. 1996. An embarrassment of riches: Too many geese. J. Wildlife Mgt. 60:217-223.
2. Best, R. J., and Arcese, P. 2009. Exotic herbivores directly facilitate the exotic grasses they graze: Mechanisms for an unexpected positive feedback between invaders. Oecologia 159:139-150.
3. Bruneau, A. H. 2001. Water quality and home lawn care. Coop. Ext. Serv. AG:626. North Carolina State Univ., Raleigh, NC.
4. Bryson, C. T., Carter, R., McCarty, L. B., and Yelverton, F. H. 1997. Kyllinga, a genus of neglected weeds in the continental United States. Weed Technol. 11:838-842.
5. Christians, N. 2004. Fundamentals of Turfgrass Management, 2nd Edn. John Wiley, Hoboken, NJ.
6. Clausen, P., Nolet, B. A., Fox, A. D., and Klaassen, M. 2002. Long-distance endozoochorous dispersal of submerged macrophyte seeds by migratory waterbirds in northern Europe: A critical review of possibilities and limitations. Acta Oecol. 23:191-203.
7. Cole, J. T., Baird, J. H., Basta, N. T., Huhnke, R. L., Storm, D. E., Johnson, G. V., Payton, M. E., Smolen, M. D., Martin, D. L., and Cole, J. C. 1997. Influence of buffers on pesticide and nutrient runoff from Bermudagrass turf. J. Env. Quality 26:1589-1598.
8. Conover, M. R. 1991. Herbivory by Canada geese: Diet selection and effect on lawns. Ecol. Appl. 1:231-236.
9. Conover, M. R. 1992. Ecological approach to managing problems caused by urban Canada geese. Pages 110-111 in: Proc. of the 15th Vertebrate Pest Conf. J. E. Borrecco and R. E. Marsh, eds. Univ. of California, Davis, CA.
10. Conover, M. R., and Chasko, G. G. 1985. Nuisance Canada Goose populations in the eastern United States. Wildlife Soc. Bull. 13:228-233.
11. Correll, D. L. 1998. The role of phosphorus in the eutrophication of receiving waters: A review. J. Env. Quality 27:261-266.
12. Cudney, D. W., Elmore, C. L., Shaw, D., and Wilen, C. 1998. Green Kyllinga. Pages 39-41 in: Proc. of the UCR turfgrass and landscape management conference and field day. Univ. of California, Riverside, CA.
13. DiTomaso, J. M. 2000. Invasive weeds in ranglands: Species, impacts and management. Weed Sci. 48:255-265.
14. Emmons, R. 2008. Turfgrass Science and Management, 4th Edn. Thomson Delmar Learning, Clifton Park, NY.
15. Environmental Protection Agency. 1983. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020. EPA, Washington, DC.
16. Grime, J. P., Mason, G., Curtis, A. V., Rodman, J., Band, S. R., Mowforth, M. A. G., Neal, A. M., and Shaw, S. 1981. A comparative study of germination characteristics in a local flora. J. Ecol. 69:1017-1059.

17. Heisler, J., Glibert, P. M., Burkholder, J. M., Anderson, D. M., Cochlan, W., Dennison, W. C., Dortch, Q., Gobler, C. J., Heil, C. A., Humphries, E., Lewitus, A., Magnien, R., Marshall, H. G., Sellner, K., Stockwell, D. A., Stoecker, D. K., and Suddleson, M. 2008. Eutrophication and harmful algal blooms: A scientific consensus. Harmful Algae 8:3-13.
18. Howe, H. F., and Smallwood, J. 1982. Ecology of seed dispersal. Ann. Rev. Ecol. Syst. 13:201-28.
19. Manny, B. A., Johnson, W. C., and Wetzel, R. G. 1994. Nutrient additions by waterfowl to lakes and reservoirs: predicting their effects on productivity and water quality. Hydrobiologia 279/280:121-132.
20. Marion, L., Clergeau, P., Brient, L., and Bertru, G. 1994. The importance of avian-contributed nitrogen (N) and phosphorus (P) to Lake Grand-Lieu, France. Hydrobiologia 279/280:133-147.
21. McElroy, J. S., Yelverton, F. H., and Brownie, C. 2005. Habitat delineation of green and false-green kyllinga in turfgrass systems and interrelationship of elevation and edaphic factors. Weed Sci. 53:620-630.
22. Meisenburg, M. J., and Fox, A. M. 2002. What role do birds play in dispersal of invasive plants? Wildland Weeds 2:8-14.
23. Michigan State University. 2005. Pennsylvania smartweed and lady thumb. Online. MSU Weed Sci., Michigan State Univ., Lansing, MI.
24. Minnesota Department of Agriculture (MDA). 2009. Phosphorus lawn fertilizer law. Online. Water Protection, MDA, St. Paul, MN.
25. Morgan, G. B., Lackey, J. B., and Gilcreas, F. W. 1957. Quantitative determination of organic nitrogen in water, sewage, and industrial waste. Analyt. Chem. 29:833.
26. Olson, M. H., Hage, M. M., Binkley, M. D., and Binder, J. R. 2005. Impact of migratory snow geese on nitrogen and phosphorus dynamics in a freshwater reservoir. Freshwater Biol. 50:882-890.
27. Pettigrew, C. T., Hann, B. J., and Goldsborough, L. G. 1998. Waterfowl feces as a source of nutrients to a prairie wetland: responses of microinvertebrates to experimental additions. Hydrobiologia 362:55-66.
28. Post, D. M., Taylor, J. P., Kitchell, J. F., Olson, M. H., Schindler, D. E., and Herwig, B. R. 1998. The role of migratory waterfowl as nutrient vectors in a managed wetland. Conserv. Biol. 12:910-920.
29. Soons, M. B., van der Vlugt, C., van Lith, B., Heil, G. W., and Klaassen, M. 2008. Small seed size increases the potential for dispersal of wetland plants by ducks. J. Ecol. 96:619-627.
30. Unckless, R. L., and Makarewicz, J. C. 2007. The impact of nutrient loading from Canada Geese (*Branta canadensis*) on water quality, a mesocosm approach. Hydrobiologia 586:393-401.
31. VerCauteren, K. C., and Marks, D. R. 2004. Movements of urban Canada geese: Implications for Nicarbazin treatment programs. USDA Natl. Wildlife Res. Center, USDA-APHIS, Washington, DC.