CANADA GOOSE (BRANTA CANADENSIS*)* SURVIVAL AND HARVEST RATES IN DEVELOPED AND RURAL LANDSCAPES OF CENTRAL INDIANA & URBAN CANADA GOOSE MANAGEMENT RESEARCH

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Canada goose (Branta canadensis) Survival and Harvest rates in developed and rural landscapes of Central Indiana

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Introduction

Canada Geese (Branta canadensis*)* may be among the most recognizable examples of a game species that have flourished within "developed" landscapes. The vast amounts of turf grass for foraging, a lack of natural predators and year-round, open water creates prime molting, nesting, and wintering habitat for adults and goslings and has been a critical factor in their success within developed habitats. The year-round presence of these habitats within temperate climates may even discourage long-distance migration to more traditional wintering habitats (Raveling 1978, Baldassare 2014). Canada goose management during the 19th and early 20th century has been challenging due to the lack of empirical data that resulted in population estimates which were calculated exclusively via anecdotal evidence (McAlister et al. 2017). This led to inaccurate representations of many incipient Canada goose populations. Subsequent declines in populations across the entire North American range were observed, attributed primarily to habitat loss and overharvesting. In response to the decrease in Canada goose populations, legislation was enacted that regulated waterfowl hunting and created protected habitat areas that would serve as wildlife refuges (McAlister et al. 2017). Where Canada goose populations were extirpated or dwindled, adult Canada Geese were reintroduced from neighboring populations. Those individuals used to repopulate were chosen based off like subspecies classification (Balkcom 2008, Flockhart & Clarke 2017, McAlister et al. 2017).

The reintroduction and legislative efforts have proven to benefit current Canada goose populations, evidenced by growth in the population over the subsequent 5 decades. Currently, goose populations continue to expand across their entire North American range with the largest component of this growth being attributed to populations occurring in developed habitat (Baldassare 2014, Balkcom 2010, Flockhart & Clarke 2017, McAlister et al. 2017). As this segment of geese continue to grow, so too does the occurrence of goose-human conflict. This manifests itself in a myriad of health and safety issues. These risks include interference with aircraft, water contamination through fecal matter, disease transmission, aggressive nest defense behaviors that may result in human injury, and damage to property, natural resources, and quality of life (Caudell et al. 2008, Rutledge et al. 2015, Clermont et al. 2019). This was illustrated in the now famous 2009 incident when a commercial airplane flying above New York collided with a flock of geese over the Hudson River resulting in an emergency water landing on the river (Rutledge et al. 2015). Wildlife managers are increasingly tasked with finding long-term solutions to these conflicts (Caudell et al. 2008, Flockhart & Clarke 2017). Solutions that managers develop must work on two fronts. First, the management solutions must mitigate conflicts associated with excessive human-goose interactions. Secondly, they must help sustain Canada goose populations at great enough values to promote proper gene flow within that populations. This is not of great concern currently as the minimum viable population for Canada geese too low to feasibly reach under current population characteristics (Flockhart & Clarke 2017). These superficially conflicting objectives may present a management challenge, depending on the extent to which geese inhabiting developed landscapes contribute to total hunting opportunities and harvest. (Luukkonen et a. 2008, McAlister at al. 2017, Flockhart et al. 2017, McAlister et al. 2017).

While a vast amount of research has been conducted on Canada geese, gaps in our understanding of the species are still present (Baldassare 2014). Studies that have investigated populations within developed habitat often lack long-term timeframes and results, thus limiting the applicability of their findings when constructing management strategies. (Clermont et al. 2019, Hestbeck et al. 2019).

An understanding of what factors facilitate Canada goose population growth within developed landscapes is imperative in the effort to accurately understand the complex relationship between Canada goose populations occupying developed habitat and the larger Canada goose population. When defining this relationship, one of the most important factors to define are those dealing with mortality. Rural goose mortality is influenced in large part by hunting pressure and natural threats. The influence these factors have upon populations in developed areas appears to be greatly reduced. Geese in these populations experience decreased hunting-related mortality pressure compared to rural populations as a result of local gun laws/ordinances (Homer et al. 2015). developed habitats also offer fewer natural predators caused by the intentional removal/exclusion by humans (Raveling 1978, Baldassare 2014, Luukonen et al. 2017).

The Indiana DNR has extensively banded and collected data on Canada geese throughout the state but have yet perform necessary analyses upon the data that can then be use inform goose-related management, specific to Indiana. Research centered on calculating the precise magnitude of impact that geese in developed areas have upon the greater Indiana Canada goose population has yet to be completed due to lack of data but has become of increasing importance to inform sound management action within the state. The objective of this study is to compare survival and harvest rates for Canada geese among banding locations, between geese banded in developed and rural habitat, and between age class in order to identify any trends within Indiana. The hypothesis that was undergoing testing was that survival and harvest rate would differ among banding locations, with those individuals inhabiting developed habitats possessing higher survival than those in rural locations. Additionally, a difference between survival and harvest rate will exist between age cohort classes, with hatch year (HY) individuals possessing lower survival and higher harvest rates than after hatch year (AHY) birds.

Materials and Methods:

Banding and direct recovery data for banded Canada geese within the state of Indiana from 2010 to 2020 was obtained from the Indiana Department of Natural Resources (INDNR) and the United States Geological Survey's (USGS) Bird Banding Laboratory (BBL). The data collected from a banded individual includes age cohort, sex, year of banding, and location of banding. The pooled data was constrained to ensure only individuals banded within Indiana appeared in the data. Additional constraints were used to mitigate the impact that nuisance goose removal and/or control efforts have upon survival estimates. This was performed prior to analysis by exclusion of any recovery data originating from depredation events or control efforts possessing a HOW code of 44. Exclusion also occurred on any records that did not contain information related to sex, age, or banding location (Ladin et al. 2020). Site classification was then performed for each distinct banding location as either developed or "rural". A banding site is deemed developed if it, either in part or in full, occurs within a municipality. All banding locations that fail to meet these criteria are classified as rural. Banding locations occurring within the same municipality as another were treated as one banding location during subsequent analysis of survival and harvest rates for specific banding locations. All sampled individuals were also assigned one of two age cohort classes, hatch year (HY) and after hatch year (AHY). Individuals that are <1 year old were designated as HY and all other individuals aged >1 year old were designated as AHY (Ladin et al. 2020).

Annual survival rate estimates were determined for unique banding locations by fitting the Seber joint live-dead recovery model to the count data for the years 2010 – 2020 (Seber

1970), using Program MARK via the RMark- R package (White and Burnham 1999, Laake 2013). The use of the joint live-dead recovery model instead of an exclusively dead-recovery model was made to ensure the inclusion of resight data, denoted by HOW codes 66 (previously banded bird trapped and released during banding operations), 52 (federal band read while bird was free), and 29 (identified by the color of the band or other marker while bird was free). The general survival and recovery rates were then estimated for each banding location every year between 2010 – 2020 (Ladin et al. 2020).

Models were then designed that incorporated covariates including banding site location, site classification (developed or rural), age (HY or AHY), and time (year that individual was banded). Global interactive models were then used to estimate annual survival that also took into account the process of recovery: $S(-1 + age{:}location{:}site\ classification{:}time)r(-1 + age{:}location{:}site\ classification{:}time)$, where *S* represents survival and *r* represents the process of recovery.

Linear models containing a response variable of estimated mean annual survival were then fitted to assess for differences in survival between individuals banded at developed and rural locations. The model residuals were assessed for any departures from normality by usage of quantile-quantile plots in program R. In accordance with Ladin et al. (2020), the effect that the variation of time has upon each covariate is unequal and was controlled for by adding independent covariates with interaction terms for each categorical covariate coupled with time. The resulting independent covariates would resemble: $banding\ location{:}time + site\ classification{:}time + age{:}time$. Generalized linear models were then used to identify any significant trends or differences in the estimated survival rate over time independently within each banding location, within each site classification, and within all age classes. The model estimated rates for annual survival and direct recovery were then able to be used to calculate annual harvest rates via the equation:

$$h = \frac{(1 - S) * r}{0.775}$$

where *h* is the annual harvest rate, *S* is the annual survival probability, *r* is the annual recovery probability, and 0.775 is the estimated reporting rate for Canada geese (Zimmerman et al. 2009, Ladin et al. 2020). Annual harvest rate represents the probability that a deceased, marked individual is recovered and reported to the appropriate location/individuals within a specified year. Typically, annual harvest rate is not able to be directly observed and instead can only be determined by either measuring the probability of recovery along with the probability of band reporting or through usage of estimates for total population size along with total harvest (Nichols et al. 1991, Arnold et al. 2020). Generalized linear regressions were then utilized to identify any correlations between annual harvest rates and time (Ladin et al. 2020).

Evaluation of models was then performed by using likelihood ratio test statistics, generated by approximation methods of either X^2 or of *F*-distributions, to determine if two models differ based on the impact of time-varying covariates upon the overall variance within the models (Halekoh and Højsgaard 2014, Ladin et al. 2020). A parametric bootstrapping technique that estimates the null distribution and tail probabilities directly was used to account for imbalances within the categorical data and because the abundance of available data mitigates the chances of producing erroneous inferences. Consequently, differences between full and reduced models were tested using the pbkrtest package which removed each covariate independently and then compared that covariate to the entire, full model (Halekoh and Højsgaard

2014, Ladin et al. 2020). The simulation was then performed 1,000 times for each model comparison and produced calculations for tail probabilities. Additionally, a determination of support for the null distribution was able to be made by using the raw parametric bootstrap test (PBtest) and *P*-value ($\alpha = 0.05$) based upon the ratio of extreme simulation results compared to non-extreme simulation results. When a significant difference was found to exist between full and reduced models for the covariates with >2 factor levels, the multcomp package was utilized to perform Tukey's *post hoc* tests. Identification of significant pair-wise comparisons among covariate groups was then made possible (Hothorn et al. 2016).

Urban Canada Geese (*Branta canadensis)* Management – Additional Research

Temperate-nesting (Giant) Canada goose populations have increased substantially in size and density during the last 5 decades (Belrose 1976, Hanson 1997). Historically, the species was negatively impacted by human overexploitation and loss of suitable habitat. These pressures were so impactful upon the species and its populations that Canada goose populations were largely considered extirpated from much of their historic range starting as early as the late 1930's (Hanson 1965, Hanson 1997, Jones and Hancock 2014). Within Indiana, the species was considered to be extremely rare throughout the state, following similar trends in Canada goose populations observed in other Midwest states (Wood et al. 1996, Jones and Hancock 2014, Luukkonen et al. 2021). A remnant population of Canada geese were discovered in Rochester, Minnesota in the early 1960's (Hanson 1997). The discovery of the remnant population served as the catalyst for Canada goose conservation across North America (Hanson 1997). The formation of protected wildlife areas/refuges, a tightening on hunting restrictions, captive rearing programs, and translocation events were implemented across North America and resulted in the successful reintroduction of the species to Indiana (Hanson 1997, USFWS 2019). Indiana estimates that its annual, breeding population of Canada geese over the last 20 years ranged in size from 80,000 – 125,000. The average annual estimate for breeding geese during this same period was found to be 102,500. The most recent annual breeding pair estimate produced by Indiana listed the population as being 113,000 (IN DNR 2021). Indiana's Department of Natural Resources (DNR) has set their state's target population size for breeding Canada geese at 80,000 (USFWS 2019, IN DNR 2021). Estimates on breeding Canada goose populations within Indiana do not consider the geese that may migrate through the state annually (USFWS 2019, IN DNR 2021). Canada geese compose a significant portion of the yearly waterfowl harvest within the state, ranking just below mallards as the second most harvested waterfowl species (Raftovich et al. 2019, USFWS 2019).

The consistent increase observed in Canada goose populations within Indiana, as well as nationally, has warranted a shift in the focus of goose management (Luukkonen and Leafloor 2017, Luukkonen et al. 2021). Modern goose management now focuses much less on restoration of the species and more so on increasing harvest while mitigating human-goose conflict (Luukkonen and Leafloor 2017, Luukkonen et al. 2021). Canada geese have adapted to urban environments within Indiana and elsewhere (Balkcom 2010, Beston et al. 2014, Dorak et al. 2017). Urban goose populations continue to increase subsequently resulting in increased occurrence of human-goose conflict (USFWS 2005). Human-goose conflict includes degradation of local water quality, crop depredation, decreased landscape aesthetic value caused by over-grazing and fecal concentrations, and safety concerns relating to aircraft and automobile collisions (Conover and Chasko 1985, Ankney 1996, Dolbeer et al. 2000, Coluccy et al. 2001, Luukkonen and Leafloor 2017, Luukkonen et al. 2021). Despite the risk of these human-goose conflicts, informed management of the species remains important as Canada geese hold significant economic, ecological, and social value. Ecological functions provided by the species include seed dispersal, cycling of environmental nutrients, as well as a source of prey for predators (Unckless and Makarewicz 2007, Reiter and Anderson 2011, Nichols 2015, Buij et al. 2017). The social and economic value of the species is found in the opportunities it provides to both birdwatchers and waterfowl hunters. Waterfowl represent the most-watched group of birds by traveling birders (birdwatching at some location other than their residence) in 2011, with total expenditures pertaining to birdwatching estimated at over $40 billion (Carver 2013, Carver 2015). In 2011, the total expenditures of waterfowl hunters (direct and indirect) was estimated at nearly $3 billion (Carver 2015). Modern Canada goose management, while attempting to mitigate human-goose conflict, must also consider the ecological, economic, and social value of the species and how that value would be influenced by their management actions.

Management of overabundant populations has often been accomplished through hunting (Conover 2001, Luukkonen et al. 2021). The influence of hunting upon Canada goose populations is significant, representing one of the primary causes of goose mortality (Trost and Malecki 1985). Those populations of geese that occur within urban environments may experience a decreased likelihood of hunter-harvest caused by local gun ordinances which often heavily restrict or ban entirely the discharge of firearms within and/or in a specified proximity around certain municipalities (Clermont et al. 2019, Luukkonen et al. 2021). The results found by other researchers that examined and compared the survival and recovery rates of urban and rural Canada goose populations have been mixed based on the geographic location, cohort, or differing, specific cities within the same geographic region. It is also likely that winter severity significantly influences survival and harvest of the species year-to-year (Heller 2010, Beston et al. 2014, Connover et al. 2015, Dorak et al. 2017, Shirkey et al. 2018, Ladin et al. 2020). The identification and understanding of the variables influencing survival and harvest rates of urban geese is imperative when attempting to consider management techniques related to that species. The information gathered pertaining to the vital and harvest rates specific to the state of Indiana will aid in informing management of the species at the state-level, particularly those populations occupying urban areas. Any findings produced from studies examining the survival and harvest rates would allow for managers to assess whether the survival differs between Canada geese marked in urban areas versus those marked in rural areas. Additionally, the degree to which hunter-harvest influences the mortality of these two groups can also be determined. All this information will aid in serving the greater purpose of informing management decision-making both within Indiana, as well as across the species' North American range.

To maximize the effectiveness and success of goose management, identification of the site characteristics most attractive to the nuisance population is of significant importance (Flegg 1980, Smith et al. 1999). The selection of which management technique(s) ought to be implemented can then be accomplished by looking at how effective each management strategy is at reducing and/or eliminating the site characteristics responsible for attracting the geese to that location. Failure to identify site characteristics that attract Canada geese to a particular location can lead to the selection and implementation of management techniques that ignore the biology and/or behavior of the geese and subsequently, will often not provide a solution for the problem at hand. Selection of a management technique with the animal's ecology and behavior in mind is referred to as an ecological approach to management (Colvin et al. 1983, Smith et al. 1999). An example of management drafted from an ecological approach may be seen when trying to encourage problem geese to move from an area where their presence is unwanted to an alternative site. Once at the alternative site, the original site should undergo modification and management to make the area as unappealing as possible for geese, thereby discouraging the return of the unwanted geese to the original location for use in the future (Colvin et al. 1983, Conover and Chasko 1985, Smith et al. 1999, Conover 2001). If the problem geese in this scenario were only hazed off the original location, the flock would likely just relocate and cause future issues to nearby areas and/or return to the original site where they will continue to create the same issues as they were prior to hazing (Zu. Failure to develop a management strategy that integrates goose biology and behavior will likely result in a solution that does not work over a long period of time (Zucchi and Bergman 1975, Blokpoel 1976, Ruger 1985, Cooper 1986, Swift 1998, Smith et al. 1999).

In addition to goose biology and behavior, the attitude of the public towards the geese within an area that is to undergo management should be considered. Modern Canada goose management is undertaken predominantly, as an attempt to meet human interests and may involve campaigns that try to change the attitudes and/or behaviors of stakeholders (Addison and Amernic 1983, Conover 1985). The varying personal belief systems and opinions on animal welfare held by the public may result in conflict when attempting the management of problematic flocks of geese. Attempting to understand how the public in the area that is to undergo management feel about the geese can be of great benefit in mitigating potential conflicts when proposing and implementing solutions to manage problem geese (Addison and Amernic 1983, Conover 1985, Fairaizl 1992, Smith et al. 1999). The stakeholders in the area where management is to occur should also be able to involve themselves in several steps of the management process such as goal/objective setting, determining which potential management techniques they are most comfortable with, interaction and communication with the public about the management plan throughout the various stages of development and implementation, as well as evaluation of the strategies' achievements during and after implementation (Addison and Amernic 1983, Conover 1985, Conover 1992, Cooper and Keefe 1997, Smith et al. 1999). If the professional management officials propose a management technique that is strongly opposed by the public, the formation of a citizen task force may be necessary (Smith et al. 1999). A citizen task force is composed of local, representative stakeholders from the area and is created to aid in resolving conflicts and proposing management techniques that are acceptable to the largest portion of the public within the problem area (Smith et al. 1999). The stakeholders making-up the citizen task force may possess varying beliefs about the management issue at hand therefore, inclusion of viewpoints centered on animal welfare are encouraged (Smith et al. 1999). The task force's responsibilities in developing management strategies includes reviewing all relevant biological information, identification and selection of appropriate management techniques that are biologically informed and socially acceptable, determining any potential sources of financial and/or manpower to implement any proposed management techniques, and the coordination of information dissemination to the media with the primary aim being to keep the community as informed as possible about their ongoing deliberations and decisions (Addison and Amernic 1983, Conover 1985, Conover 1992, Keefe 1996, Cooper and Keefe 1997, Smith et al. 1999).

The integration of goose biology and behavior as well as the viewpoints and opinions of the public in the immediate area when developing a management strategy is known as an integrated management strategy (Flegg 1980, Conover 1992, Cooper and Keefe 1997, Smith et al. 1999). An integrated management strategy will include information about the time(s) of the year that the problem(s) occur, feasible options for managing the problem geese given their biology as well as the characteristics of the area(s) involved in management, estimations about the probable effectiveness of a given management technique, community support for taking action, as well as the acceptability, cost, and legality of control methods (Flegg 1980, Conover 1992, Cooper and Keefe 1997, Smith et al. 1999). Regardless of the specific goose-related problems a community may be experiencing, there is rarely a "silver-bullet" strategy or technique that can be implemented everywhere. The complexities of urban Canada geese and their associated issues in conjunction with the current restrictions/limitations present on some available techniques makes it so the usage of "quick-fix" management technique(s) are unlikely to be successful (Flegg 1980, Colvin et al. 1983, Smith et al. 1999). It is often necessary to integrate two or more management techniques in order to achieve intended management objectives. The most effective combinations of management techniques will vary case-to-case, emphasizing the importance of identifying the site characteristics, biology, and public opinion prior to selection of any management technique(s) (Flegg 1980, Colvin et al. 1983, Conover 1992, Cooper and Keefe 1997, Smith et al. 1999).

References

Addison, L. R., and J. Amernic. 1983. An uneasy truce with the Canada goose. International Wildlife 13:12–14.

Allan, J. R., J. S. Kirby, and C. J. Feare. 1995. The biology of Canada geese Branta canadensis in relation to the management of feral populations. Wildlife Biology 1:129–43.

Ankney, C. D. 1996. An embarrassment of riches: too many geese. Journal of Wildlife Management 60:217–233.

Arnold, T W, Alisauskas, R T, Sedinger, J S. 2020. A Meta-Analysis of Band Reporting Probabilities for North American Waterfowl. The Journal of Wildlife Management 84(3):534-541.

Baldassare, G. Ducks, Geese, and Swans of North America: Edition 2. 2014. *JHU Press.* 2, 685-797.

Balkcom, G. D. 2010. Demographic Parameters of Rural and Urban Adult Resident Canada Geese in Georgia. *The Journal of Wildlife Management* **74**, 120–123.

Bellrose, F. C. 1976. Ducks, Geese, and Swans of North America. Harrisburg, Pa.: Stackpole Books. 540 pp.

Beston, J. A., T. C. Nichols, P. M. Castelli, and C. K. Williams. 2014. Survival of Atlantic Flyway resident population Canada geese in New Jersey. Journal of Wildlife Management 78:612–619.

Blokpoel, H. 1976. Bird Hazards to Aircraft. Buffalo, N.Y.: Books Canada. 236 pp.

Buij, R., T. C. P. Melman, M. J. J. E. Loonen, and A. D. Fox. 2017. Balancing ecosystem function, services and disservices resulting from expanding goose populations. Ambio 46:301–318. Springer, Dordrecht, Netherlands.

Carver, E. 2015. Economic impact of waterfowl hunting in the United States: Addendum to the 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. U.S. Fish and Wildlife Service, Falls Church, Virginia, USA.

Caudell, J. N., Shwiff, S. A. & Slater, M. T. 2010. Using a Cost-Effectiveness Model to Determine the Applicability of OvoControl G to Manage Nuisance Canada Geese. *The Journal of Wildlife Management* **74**, 843–848.

Clermont, J., D. Réale, & J.-F. Giroux. 2019. Similarity in nest defense intensity in Canada goose pairs. *Behav Ecol Sociobiol* **73**, 108.

Coluccy, J. M., R. D. Drobney, D. A. Graber, S. L. Sheriff, and D. J. Witter. 2001. Attitudes of central Missouri residents toward local giant Canada geese and management alternatives. Wildlife Society Bulletin 29:116–123.

Coluccy, J., and D. Graber. 1994. Missouri Department of Conservation Unpublished Report. 12 pp.

Colvin, B. A., P. L. Hegdal, and W. B. Jackson. 1983. Public relations in environmental and vertebrate pest research. Proceedings of the Bird Control Seminar 9:295–98.

Conover, M. R. 1992. Ecological approach to managing problems caused by urban Canada geese. Proceedings of the Vertebrate Pest Control Conference 15:110–11.

Conover, M. R. 2001. Effect of hunting and trapping on wildlife damage. Wildlife Society Bulletin 29:521–532.

Conover, M. R., and G. G. Chasko. 1985. Nuisance Canada goose problems in the eastern United States. Wildlife Society Bulletin 13:228–233.

Conover, M. R., and G. G. Chasko. 1985. Nuisance Canada goose problems in the eastern United States. Wildlife Society Bulletin 13:228–233.

Conover, M. R., J. B. Dinkins, and R. E. Ruzicka. 2015. Consequences of hunter harvest, winter weather, and increasing population size on survival of non-migratory Canada geese in Connecticut. Journal of Wildlife Management 79:1239–1245.

Cooper, J. A., and T. Keefe. 1997. Urban Canada goose management: Policies and procedures. Transactions of the North American Wildlife and Natural Resources Conference 62:412–30.

Dolbeer, R. A., S. E. Wright, and E. C. Cleary. 2000. Ranking the hazard level of wildlife species to aviation. Wildlife Society Bulletin 28:372–378.

Dorak, B. E., M. P. Ward, M. W. Eichholz, B. E. Washburn, T. P. Lyons, and H. M. Hagy. 2017. Survival and habitat selection of Canada geese during autumn and winter in metropolitan Chicago, USA. Condor 119:787–799.

ESRI. 2017. ArcGIS Desktop: Version 10. Redlands, CA. Environmental Systems Research Institute.

Fairaizl, S. D. 1992. An integrated approach to the management of urban Canada goose depredations. Proceedings of the 15th Vertebrate Pest Conference. J. E. Borrecco and R. E. Marsh (eds.). Davis: University of California. 105-109.

Flegg, J. J. M. 1980. Biological factors affecting control strategy. Bird Problems in Agriculture. E. N. Wright, I. R. Inglis, and C. J. Feare (eds.). Croydon, England: BCPC.7-19.

Flockhart, D. T. T. and Clarke, J. B. 2017. Demographic consequences of translocation of overabundant Canada geese breeding in urban areas. *Wildlife Society Bulletin* **41**, 231–239.

Halekoh, U., and S. Højsgaard. 2014. A Kenward-Roger approximation and parametric bootstrap methods for tests in linear mixed models–the R package pbkrtest. Journal of Statistical Software 59:1–30.

Hanson, H. C. 1965. The Giant Canada Goose. Carbondale: Southern Illinois University Press. 226 pp.

Hanson, H. C. 1997. The giant Canada goose. Revised edition. Southern Illinois University Press, Carbondale, Illinois, USA.

Heller, B. J. 2010. Analysis of giant Canada goose band recovery data in Iowa and the Mississippi Flyway. Thesis, Iowa State University, Ames, USA.

Hestbeck, J. B., Nichols, J. D. & R. A. Malecki. 1991. Estimates of Movement and Site Fidelity Using Mark-Resight Data of Wintering Canada Geese. *Ecology* **72**, 523–533.

Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N.D., Wickham, J.D., and Megown, K. 2015. Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing, v. 81

Hothorn, T., F. Bretz, P. Westfall, R. M. Heiberger, A. Schuetzenmeister, S. Scheibe, and M. T. Hothorn. 2016. Package "multcomp."

Indiana Department of Natural Resources (IN DNR). 2021. Canada geese Behavior & Biology. U.S. Fish and Wildlife Service, Department of the Interior, Washington D.C. USA.

Jones, O., and A. Hancock. 2014. Iowa Canada Goose Management Plan. Iowa Department of Natural Resources, Des Moines, USA.

Keefe, T. 1996. Feasibility study on processing nuisance Canada geese for human consumption. Minnesota Department of Natural Resources, Section of Wildlife. 7 p. mimeo + 4 appendixes.

Laake, J. L. 2013. RMark: an R interface for analysis of capture-recapture data with MARK.

Ladin, Z. S., G. Costanzo, B. Lewis, and C. K. Williams. 2020. Long- term survival and harvest of resident Canada geese in Virginia. Journal of Wildlife Management 84:666–674.

Luukkonen B., Klaver, R., & Jones, O. 2019. Canada goose survival and recovery rates in urban and rural areas of Iowa. North American Duck Symposium, Winnipeg, Manitoba.

Luukkonen, B. Z., J. E. Orrin, and R.W. Klaver. 2021. Canada Goose Survival and Recovery Rates in Urban and Rural Areas of Iowa, USA. Journal of Wildlife Management 85:283-292.

Luukkonen, B., Avers, B., & Avers, D. 2017. Comparing direct recovery rates of mallards (Anas platyrhynchos) banded at developed and undeveloped sites in southern lower Michigan, USA.

Luukkonen, D. R., and J. O. Leafloor, editors. 2017. A management plan for Mississippi Flyway Canada geese. Mississippi Flyway Council, Traverse City, USA.

Luukkonen, D. R., Prince, H. H. & Mykut, R. C. 2008. Movements and Survival of Molt Migrant Canada Geese From Southern Michigan. *The Journal of Wildlife Management* **72**, 449–462.

McAlister, M. A. *et al.* Using Landscape Characteristics to Predict Distribution of Temperate-Breeding Canada Geese. **16**, 127–139 (2017).

Nichols, J. D., R. J. Blohm, R. E. Reynolds, R. E. Trost, J. E. Hines, andJ. P. Bladen. 1991. Band reporting rates for mallards with reward bands of different dollar values. Journal of Wildlife Management 55:119–126.

Nichols, T. C. 2015. Cooperative hunting of Canada geese (Branta canadensis) by gray wolves (Canis lupus) in northern Quebec. Canadian Field-Naturalist 129:290–292.

Ott, L. 1984. An Introduction to Statistical Methods and Data Analysis. Second Edition. Duxbury Press, Boston, Massachusetts, USA

Raftovich, R.V., K.K. Fleming, S. C. Chandler, and C.M. Cain, 2019. Migratory bird hunting activity and harvest during the 2017-18 and 2018-19 hunting seasons. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Raveling, D. G. 1978a. Dynamics of distribution of Canada Geese in winter. Transactions of the North American Wildlife and Natural Resources Conference 43:206-225

Reiter, M. E., and D. E. Anderson. 2011. Arctic foxes, lemmings, and Canada goose nest survival at Cape Churchill, Manitoba. Wilson Journal of Ornithology 123:266–276.

Richman, S. E., Leafloor, J. O., Karasov, W. H. & S. R. McWilliams. 2016. Ecological implications of reduced forage quality on growth and survival of sympatric geese. *Journal of Animal Ecology* 284–298.

Ruger, A. 1985. Extent and control of goose damage to agricultural crops. International Waterfowl Wetlands Research Bureau 4:1–48.

Seber, G. A. F. 1970. Estimating time-specific survival and reporting rates for adult birds from band returns. Biometrika 57:313–318.

Shirkey, B. T., R. J. Gates, and M. D. Ervin. 2018. Survival rates and harvest patterns of Ohio-banded Canada geese. Wildlife Society Bulletin 42:394–402.

Smith, A. E., G. F. Martz, M. C. Shieldcastle, G. M. Tori, and D. H. Rusch. In press. Survival, movement and harvest of translocated Canada geese. Journal of Wildlife Management.

Smith, A. E., S. R. Craven, and P. D. Curtis. 1999. Managing Canada geese in urban environments. Jack Berryman Institute Publication 16, and Cornell University Cooperative Extension, Ithaca, N.Y.

Smith, D. W. 1995. A Handbook for the Control of Problem Canada Geese. Environment Canada, Canadian Wildlife Service, Pacific Research Centre, Delta, MB, Canada. 25 pp.

Swift, B. 1998. Response of resident Canada geese to chasing by trained border collies. New York State Dept. of Environmental Conservation, Bureau of Wildlife, Wildlife Research Center. Delmar, N.Y. Unpublished report. 6 pp.

Thompson, S. K. 1992. Sampling. The Pennsylvania State University, University Park, Pennsylvania, USA

Trost, R. E., and R. A. Malecki. 1985. Population trends in Atlantic Flyway Canada geese: implications for management. Wildlife Society Bulletin 13:502–508.

U.S. Fish and Wildlife Service [USFWS]. 2005. Final environmental impact statement: resident Canada goose management. USFWS, Washington, D.C., USA.

U.S. Fish and Wildlife Service. 2019. Waterfowl population status, 2019. U.S. Department of the Interior, Washington, D.C. USA.

Unckless, R. L., and J. C. Makarewicz. 2007. The impact of nutrient loading from Canada geese (Branta canadensis) on water quality, a mesocosm approach. Hydrobiologia 586:393–401.

USGS Bird Banding Laboratory. 2017. Game bird banding and encounter data. Version July 13,

2017. Patuxent Wildlife Research Center, Laurel, MD.

Washburn, B. E. & Seamans, T. W. 2012. Foraging preferences of Canada geese among turfgrasses: Implications for reducing human–goose conflicts. *The Journal of Wildlife Management* **76**, 600–607.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46:S120–S139.

Wood, J. C., D. H. Rusch, and M. D. Samuel. 1996. Results of the 1996 spring giant Canada goose survey in the Mississippi Flyway. Wisconsin Cooperative Wildlife Research Unit. Unpublished report, 8 pp.

Zucchi, H., and H. H. Bergman. 1975. Long-term habituation to species specific alarm calls in a song-bird Fringilla coelebs. Experientia 31:817–18.