Density, Population Trends, and Economic Impacts of White-tailed Deer in Iowa

A report in response to Iowa Senate File 581, submitted to the Iowa Department of Natural Resources

Stephen J. Dinsmore, David M. Delaney, and John C. Tyndall
Department of Natural Resource Ecology and Management, Iowa State University, Ames, IA, 50011

30 September 2024

Advisory Board: Tyler Harms, Iowa Department of Natural Resources
Dan Kaminski, Iowa Department of Natural Resources
Jace Elliott, Iowa Department of Natural Resources
Andy Kellner, Iowa Department of Natural Resources
Adam Janke, Iowa State University Extension
Willy Sorenson, Iowa Department of Transportation
Michelle Tuchel, Iowa Insurance Division
Jared Kirby, Iowa Insurance Division

Summary

Senate File 581 (signed 17 June 2022) charged the Iowa Department of Natural Resources (DNR) to work with representatives from Iowa State University (ISU), the Iowa Department of Transportation, and Iowa Insurance Division to estimate the population size of white-tailed deer in each county of Iowa and update their economic impacts across the state. The ISU team worked closely with an advisory board comprised of Iowa DNR research staff and staff from other agencies listed above to address the three specific charges outlined in SF 581. Below, we summarize study findings related to each charge supported with relevant data; more detailed data summaries are provided in the report appendices. Our work revealed that Iowa has a healthy deer herd that recovered from population lows around 1900 and now fluctuates annually in response to available habitat, the prevalence of disease, and harvest patterns. We used the most recent spotlight survey data to estimate county-specific deer densities during 2023, which were highest in south-central and northeastern Iowa and lowest in a broad region across western to north-central Iowa. Not surprisingly, counties with the highest densities were in areas with the best deer habitat. Deer population trends varied by county with 87 counties showing stable or declining trends since 1996; trends in just 12 counties have increased since 1996. Our economic analysis revealed that the minimum tangible value of deer to Iowa is $181 million per year, although the true value may be much greater when accounting for wildlife viewing and other benefits. The cost of deer-vehicle collisions is minimally $129 million per year and deer-aircraft collisions add a cost of $10K per year. Crop damage related only to lost grain is estimated at $5.2 million per year (approximately 0.31% of harvested production). Our work estimated that specialty crop losses are $3.4 million annually with an additional $832K spent on deer management at these farms. Lastly, deer populations in Iowa experience losses due to Chronic Wasting Disease (CWD) and Epizootic Hemorrhagic Disease (EHD), both of which are management concerns.

History of White-tailed Deer in Iowa

Authored by Jace Elliott, State Deer Biologist

White-tailed deer were reported to be abundant when European settlers arrived in Iowa in the early 1800s. Although the clearing and cultivating of land for agriculture may have initially improved the suitability of the landscape for deer, uncontrolled exploitation for food and hides rapidly reduced deer numbers. By 1880, deer were rarely seen in much of the state and in 1898 the deer season was legally closed. By this time, deer had been nearly eliminated from all parts of the state.

Re-establishment of deer into the state can be traced back to escapes and releases from captive herds and translocation and natural immigration from deer herds in surrounding states. A conservative estimate of the population in 1936 placed statewide numbers between 500 and 700 animals. This small herd grew steadily. By 1950, deer were reported in most counties and the statewide estimate topped 10,000 animals. Concentrations in some areas were beginning to cause conflicts with Iowans including increased agricultural damage and collisions with vehicles. In response to these problems, the first modern deer season was held in December 1953, and 4,000 deer were harvested. The statewide harvest steadily increased, and in 1996 topped 100,000 for the first time.

Starting in the early 2000s, an aggressive statewide harvest strategy was formed as a response to increasing populations. This strategy primarily relied on increasing doe harvest via additional county antlerless licenses. From 2001 to 2011, total county antlerless licenses rose from 23,000 to 133,000, an increase of nearly 500%. While antlerless harvest remained high throughout these years, county antlerless license sales began dropping in 2009, most likely as a result of aggressive management strategies leading to less harvest opportunity in many parts of the state. By 2013, more than 25% of county antlerless licenses were left unsold.

In 2014, county antlerless quotas were decreased throughout much of the state where deer populations had achieved or fallen below an acceptable management level, as established by the newly-formed Deer Study Advisory Committee (see 2009 Review of Iowa's Deer Management Program: https://www.iowadnr.gov/Portals/idnr/uploads/Hunting/deerstudyreport.pdf). County quotas remained high throughout the core deer range of southcentral, southeast, and northeast Iowa. From 2014 to 2023, total county antlerless licenses have slowly increased in response to recovering deer populations in central and northern Iowa. During the last decade, deer numbers have remained relatively stable throughout much of the state, although populations continue to fluctuate regionally as a result of available habitat, disease activity, and harvest patterns.

Iowa DNR Deer Program Overview

Authored by Jace Elliott, State Deer Biologist

The Iowa Deer Program manages the white-tailed deer population through an engaged stakeholder process, which is carried out through the annual meeting of the Deer Study Advisory Committee. This committee includes a balanced number of stakeholder groups representing agricultural, recreational, and economic special interests. A series of DNR Listening Sessions is also held each spring to capture opinions and support from members of other key stakeholder groups, such as hunters and landowners, which are summarized and provided to the Natural Resources Commission.

The Iowa Deer Program aims to manage county deer populations within an acceptable management objective, which balances recreational hunting and viewing opportunity with negative impacts such as property and crop damage. Deer population management is mainly driven by hunter harvest of female deer. While a majority of Iowa's counties are considered within management objectives, issues such as habitat availability, property access, disease, and contrasting landowner interests has the potential to exacerbate localized deer-human conflicts.

The Iowa DNR collects and maintains more data on white-tailed deer than any other wildlife species in the state. The Iowa Deer Program is able to inform management decisions based on a number of independent datasets: bowhunter observation report, reported deer harvest, deer-vehicle collision data, as well as the addition of novel population estimates using spring spotlight survey counts. Fortunately, all of these data sources are collected annually at the county level. Due to relative strengths and weaknesses of each of these datasets, no single dataset is intended to be used exclusively. This system allows for county-based management to take place, a process which acknowledges that a "statewide" deer population is a composite of multiple regional deer populations that trend independently. For these reasons, managing a deer population on a statewide basis would inherently produce negative impacts to certain regional deer populations.

The Iowa Deer Program formally begins its annual management process by holding a series of DNR District Deer Meetings across the state. These meetings are led by the State Deer Biologist and involve direct engagement with relevant DNR research personnel, depredation staff, field staff, and law enforcement officers within each geographic district. Prior to these meetings, the State Deer Biologist reviews population and harvest trends within each county, using all available data to infer where each county deer population relates to management objectives. When appropriate, preliminary changes to harvest regulations (e.g., antlerless quotas, January antlerless seasons, buck-only restrictions, etc.) are proposed to guide discussion. A key component of this process involves insight from local staff, local hunters, landowners, and agricultural producers. This critical aspect of the meetings creates a formal opportunity for local sentiment to influence final regulatory proposals, which emphasizes the model of engaging stakeholders and maintaining public trust. Ultimately, the Iowa Deer Program presents the final list of proposed regulatory changes to the Natural Resources Commission. If approved, these changes are incorporated into the regulatory framework for the subsequent deer hunting season.

Because deer management issues are not evenly distributed across the state, it remains critical to have a flexible regulatory framework that can be applied on a local scale. The future success of deer population management in Iowa relies on the ability to consider all available sources of data and public input through an engaged stakeholder process in order to guide county-based harvest strategies.

Prelude on Wildlife Research

Authored by Dr. Adam K. Janke, Associate Professor, ISU

Wildlife populations are inherently difficult to observe. They live in remote places, they hide from humans and other predators, they seek cover from weather and dangers, and they live and die in pulses throughout the year. For these reasons, estimating the size of wildlife populations—such as Iowa's white-tailed deer—presents significant challenges. The task becomes more complex when attempting to measure a population size at finer-and-finer spatial scales, such as Iowa counties. To be successful, wildlife biologists must account for multiple sources of uncertainty and bias, balance costs of surveys with data accuracy, and convey this complexity to decision makers and stakeholders. Such is the challenge of wildlife research and effective wildlife management. And such was the challenge facing the authors of this report at its conception.

Exact counts, or **censuses**, are rarely feasible for wildlife. That is certainly the case with white-tailed deer. Therefore, wildlife biologists typically rely on **estimates** or **indices** of populations derived from one or more information sources. **Indices** are indirect measures of population size through time or space that, when certain assumptions about the observations are met, can give decision makers an idea of the overall **trend** of a population such as increasing, decreasing, or remaining stable. An index does not tell us the exact number of deer in a county but provides a reliable way to track changes over time. Indices referenced in this report include observations from the bow hunter observation survey, antlered buck harvest, and reported deer/animal-vehicle crashes from the Iowa Department of Transportation. **Estimates** are derived from **statistical models** that seek to account for factors that make animals hard to observe. Population estimates, when they are accurate, can provide the same information an index provides (i.e., trends) while also informing decision makers about the total **number of animals** in a given area (e.g., density or population size). Statistical models adjust for **imperfect detection**—the fact that not all animals present can be observed during a survey. For example, in spotlight surveys, deer farther from the road or hidden by vegetation or hillsides go undetected. Statistical techniques like distance sampling that account for those factors allow biologists to model these imperfections and produce more reliable estimates of population size.

Estimates from statistical models often come with some measure of precision, or the confidence in the predictions arising from the models. This **precision**, or its inverse **uncertainty**, is routine in any statistical model, but conveying that uncertainty and working to reduce it through study design or analytical techniques is the focus of volumes of wildlife and statistics textbooks and the focus of many academic wildlife researcher's careers. Biologists often combine multiple data sources into models, or look for agreement among many different estimates and indices to arrive at recommendations based on the **weight of evidence** across models or data, such as trends in populations or their response to change like harvest, land use, or disease. In this way, confidence in estimates and trends is strengthened by comparing each index (or estimate) against others, not relying on one measurement. Throughout this report, you will see the authors doing just that with many different data sources that collectively paint a picture of the status of white-tailed deer populations across Iowa's 99 diverse counties.

Deer management and deer populations are monitored in many ways in Iowa. Indeed, more data are collected on white-tailed deer than any other wildlife species in the state. Scientists and managers are seeking to learn about these inherently hard-to-observe animals to use the best available techniques and models to make the most informed decisions possible. State-of-the-art statistical models were used in this report, right alongside standardized counts of observations and reports provided by hunters and Iowa Department of Transportation staff. At their intersection are the insights needed to make decisions that help the Iowa Department of Natural Resources fulfill its mission of managing white-tailed deer for the people of Iowa and future generations. Moving forward, the information in this report will be a vital tool in the continued conversation with stakeholder groups representing all Iowans in making management decisions for white-tailed deer, balancing public demand for viewing and hunting with habitat limitations, highway safety, and agricultural interests.

Definitions

Census: Count of every single animal such as having numbered ear tags in a cow herd to keep track of the entire population.

Index: Indirect measure of a population that is difficult or impossible to count.

Trend: Use of indices to observe changes in a population through time often observing movements up, down, or staying the same.

Statistical Model: The use of advanced mathematics and computer programming to best estimate populations at specific points of time using data from surveys and indices.

Uncertainty: The degree of precision and confidence in the outcome of the model. Better data and multiple data sources help reduce uncertainty.

Charge 1: Determine the estimated deer population in each county in this state, which shall include historical population numbers and population trends and be supported by historical records dating back to 1970 if such data are available.

Work led by David M. Delaney, Postdoctoral Researcher, ISU
Stephen J. Dinsmore, Professor, ISU

Background

The Iowa Department of Natural Resources (DNR) uses four yearly sources of data to estimate annual deer population trends dating back to 1995, although data collection for two sources began more recently (Elliott 2024):

1) Number of reported deer/animal-vehicle crashes from the Iowa Department of Transportation (since 1995). This is a tally of incidents standardized by the total miles driven, by county, and is used as an index of Iowa deer population trends.
2) Number of antlered bucks harvested per county (since 1995). This is the estimated minimum deer harvest, reported annually, either from hunter surveys (before 2006) or from mandatory harvest reporting via Iowa's Electronic Licensing System (since 2006). This is also used as an index of Iowa deer population trends.
3) Nocturnal spring spotlight survey (data from 2006 – 2024; Kaminski et al. 2024). This is an annual spring roadside survey where DNR staff drive ~50 miles of gravel roads in each Iowa county. Surveys begin an hour after sunset, and two observers each use a spotlight to scan for deer. For each group of deer detected, observers record the number of deer in the group and the distance to the group of deer to estimate their probability of being detected, deer density, and deer population trends, each with a measure of uncertainty. As such, this is a direct measure of deer population trends and not an index.
4) Bow hunter observation survey (since 2004; Harms et al. 2022). This is a volunteer survey of Iowa archery deer hunters through which hunters are asked to record the number of deer seen on hunting trips during a portion of the hunting season (October 1 – early December), which is then standardized by hunter effort (i.e., hours hunted) annually into an index of deer population trends.

To summarize, sources 1, 2, and 4 above do not estimate the actual number of deer present, but instead provide an index to changes relative to other years. We focused on analyzing data from the spring spotlight survey (source 3 above), which is the best source to provide an estimate of the number of deer present and was necessary to meet this directive of SF 581.

We considered the spotlight survey the most appropriate source of information to estimate deer density for three reasons: (1) the goal of the spotlight survey is to estimate annual population trends of deer and other terrestrial mammals, (2) surveys are standardized to occur at the same time period each year (mid-March to mid-May) and under similar environmental (nights with temperature > 0° C, wind < 15 mph, and relative humidity > 40%) and sampling (drive < 20 mph) conditions, and (3) surveys are designed to sample deer populations at their most food limited time-of-year (early spring before vegetative green-up) and during nighttime when the majority of the population is thought to move from cover to open fields to feed.

Therefore, we expected that the majority of the deer population was available to sample during these surveys. One limitation of the spotlight survey data is that each county is only sampled one night each spring and random deer movements on that night could mean more or less deer are counted than would be representative of the local population.

The DNR has historically converted the spotlight survey deer counts in each county to an index of the population size by standardizing by the number of miles driven (Kaminski et al. 2024). We sought to build on those efforts by analyzing the spring spotlight survey data using distance sampling (Miller et al. 2019), which enabled us to account for imperfect detection (i.e., deer that are missed during survey efforts) and estimate the density of deer in each county annually.

Utility of other indices

The three indices described earlier each provide valuable information on Iowa deer population trends. The **bow hunter observation survey** documents the number of deer observed per 1,000 hours of hunting during the first split of the archery season. Therefore, data are collected during a span of ~2 months and are not restricted to near-road habitats. Observations may vary as a result of the habitat quality in the location of each hunter, which is not recorded. The **number of antlered bucks harvested** per county could be related to population size. Ideally, this measure would be standardized by hunter effort, but the DNR only has access to county of harvest for reported deer and does not know the total number of hunters per county. We also do not know how hunter goals/motivations may have changed through time, which could affect buck harvest (e.g., holding out for larger bucks). The **number of deer/animal vehicle collisions** (standardized by billions of miles driven) is likely related to the deer population size. Trends over time and among counties may also be influenced by changes in whether crashes are reported or roadkills are observed. Changes in roads, adjacent habitat, vehicles, and driver conditions may also influence trends in these data.

In summary, there is inherent variation in each of these indices that makes it difficult to use any one of them individually to track changes in Iowa's deer population. However, when used together, they increase the reliability of the estimated population trend and lead to more informed management decisions.

Methods

Given this background, we evaluated four components of the DNR spotlight survey and deer ecology to build a population model that would produce the least biased estimates of deer density by Iowa county. Those four components were:

1) **Accounting for viewshed.** We accounted for variation in viewshed (i.e., area visible to observers along the survey route) structure among counties. Observers can sample more area in flat counties with little forest cover because there are not many barriers to visibility compared to counties with more topographic change and forest cover. We used a Digital Elevation Model and National Landcover Data to derive viewsheds for each county using ArcGIS. We then incorporated the spatial distribution of each county's viewshed into our distance sampling model structure so that detection probability (i.e., the estimated probability that any given deer that exists in the sampling area would be

detected) and deer abundance were accurately estimated over the areas DNR staff sampled.

2) **Deer distribution relative to Iowa roads**. We assessed deer spatial distribution from gravel roadways in Iowa to confirm this was random and did not violate model assumptions. Either attraction or avoidance of deer to gravel roads could bias the estimate of detection probability and abundance within the sampling area. We conducted a drone study of deer landscape use in spring 2024. Preliminary analysis suggests deer are randomly distributed from roadways in rural Iowa. This indicates no analytic correction is needed and deer density within 400 m of roadways (where DNR staff sample) can be extrapolated to farther distances from roadways with little to no bias.
3) **Are deer counts repeatable within a year?** We tested the degree to which deer counts were subject to unexplained variation in deer landscape use on the sample night. For three years, up to 18 counties were repeatedly sampled up to three times each to test the repeatability of counts. Observers recorded very similar counts (repeatability = 86%) during subsequent nights, suggesting survey counts provide a reliable and consistent index of the population. Detection probability decreased throughout the season, which probably was the result of a greater portion of the population remaining within forested areas after vegetative green-up begins.
4) **Is survey route habitat representative of the county?** We tested the degree to which habitat quality along survey routes was representative of the habitat quality of the respective county. We found that the deer habitat suitability (from Kaminski et al. 2019) of each transect is highly correlated with the habitat suitability of the counties they represent ($r = 0.97$). In other words, transects are good samples of the county they represent and therefore should provide a representative sample of the deer population in each county.

We built a model that included distance sampling to estimate the abundance of deer within the viewshed of each transect each year. To estimate density, we extrapolated abundance to similar habitats (open landcovers) within a 400 m buffer of transect routes. We then divided that extrapolated abundance over the entire area of the route buffer, which is representative of the habitat quality for each county (following component 4 above).

We displayed estimates as three-year moving averages to account for variation in estimates that result from sampling error and to best represent population trends. We also plot data from the three other indices that the DNR uses to estimate annual population trends for additional inference over a longer range in time.

Results and Discussion

During the most recent time period (2022–2024), deer density was highest in counties in south-central and northeastern Iowa and lowest in a broad area across western to north-central Iowa (Figure 1). In particular, counties with higher deer habitat suitability tended to have higher deer densities (Figure 2; Kaminski et al. 2019). Stemming from Kaminski et al. (2019), the quality of deer habitat increases with greater landcover in grass and Conservation Reserve Program enrollment, and in areas with more rugged terrain. Habitat quality also increases closer to forest patches, streams and rivers. Forest cover has been posited as the main factor limiting deer population size in the Midwest (Murphy 1970), but other landcovers that exist through winter, such as woody wetlands, cattail marshes, and prairies, are also likely important in Iowa.

Population trends since 1996 are variable through time, among counties, and among Wildlife Management Units (Figure 3, Appendix A). In 44 counties, the estimated overall population trend declined since 1996. In forty-three counties the estimated overall population trend remained stable while in 12 counties the overall trend was increasing since 1996.

Current status of density estimation confidence

The density estimates produced by our distance sampling analysis represent the least biased measures of deer density in Iowa to date. We are confident that this sampling framework characterizes two components of deer population size well: (1) the magnitude of differences in population sizes among counties, and (2) county-level population trends through time. However, areas of study remain that are likely to resolve additional variation in the data. Below we list three sources of variation that would be fruitful to resolve:

1) Deer that occur in forested habitat during the spotlight survey cannot be observed. The portion of the population that remains in forest during spotlight surveys increases as spring progresses (in concert with spring plant leaf-out), meaning that surveys relatively late in the spring likely undercount the population. We are in the process of estimating and correcting for this source of bias.
2) The data collection process switched from paper records to logging via a smartphone app in 2018-2019. This resulted in more efficient data logging, but has consistently recorded deer closer to the road than historic methods. Our on-going research suggests that with the historic method, deer would detect observers prior to being detected and move farther from the roadway. Another possibility is that observers estimate shorter distances with the new methodology than historic methods. Regardless, this needs to be resolved and may influence the model's estimation of detection probability and density.
3) It takes many different observers to run the spotlight survey in 99 counties every year, and observers differ in their ability to detect deer. This is incredibly difficult to address analytically but a better understanding of observer skill levels might help resolve discrepancies in some counties.

Finally, incorporation of density estimates with other sources of data are likely to yield fruitful insights that will inform DNR management of deer. For example, what is the relationship between deer density, habitat, and conflicts (deer-vehicle collisions; crop depredation)? How do habitat, deer sex ratios, and harvest interact to influence population growth (or decline)? Estimates produced in this report are now poised to be used to address these and other relevant deer management questions.

Figure 1. County-level white-tailed deer density estimates for Iowa. The number below each county indicates the estimated number of deer per square mile from 2022–2024. Darker orange indicates counties with higher densities of deer. Note that summing these county-specific deer densities does not equate to a meaningful statewide population estimate because non-deer habitats (e.g., water, developed areas, etc.) are not excluded so a raw extrapolation is not valid.

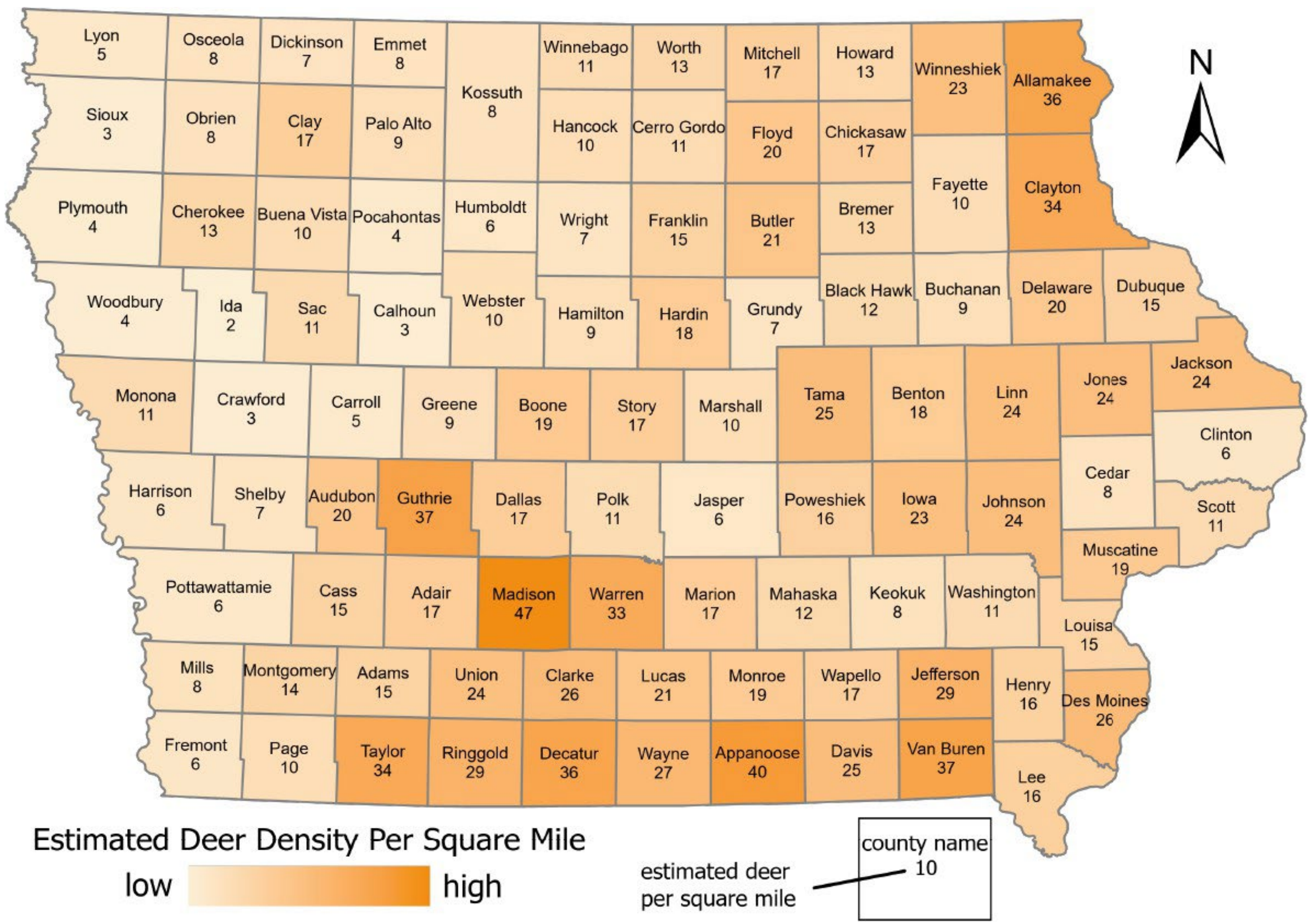


Figure 2. County-level white-tailed deer density estimates in relation to deer habitat quality in Iowa. The number below each county indicates the estimated number of deer per square mile from 2022–2024. Darker green indicates counties with higher suitability of habitat for deer (from Kaminski et al. 2019).

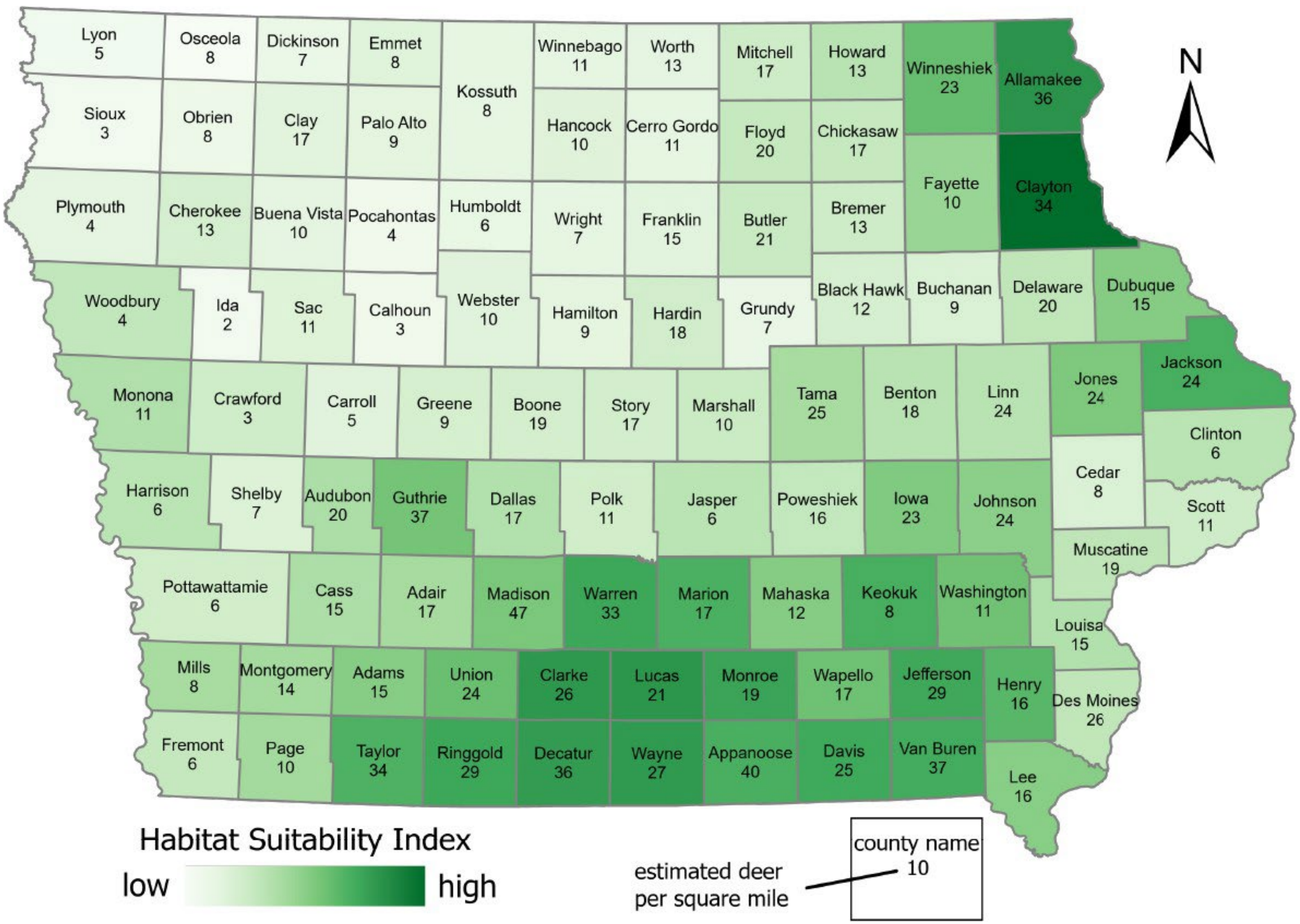
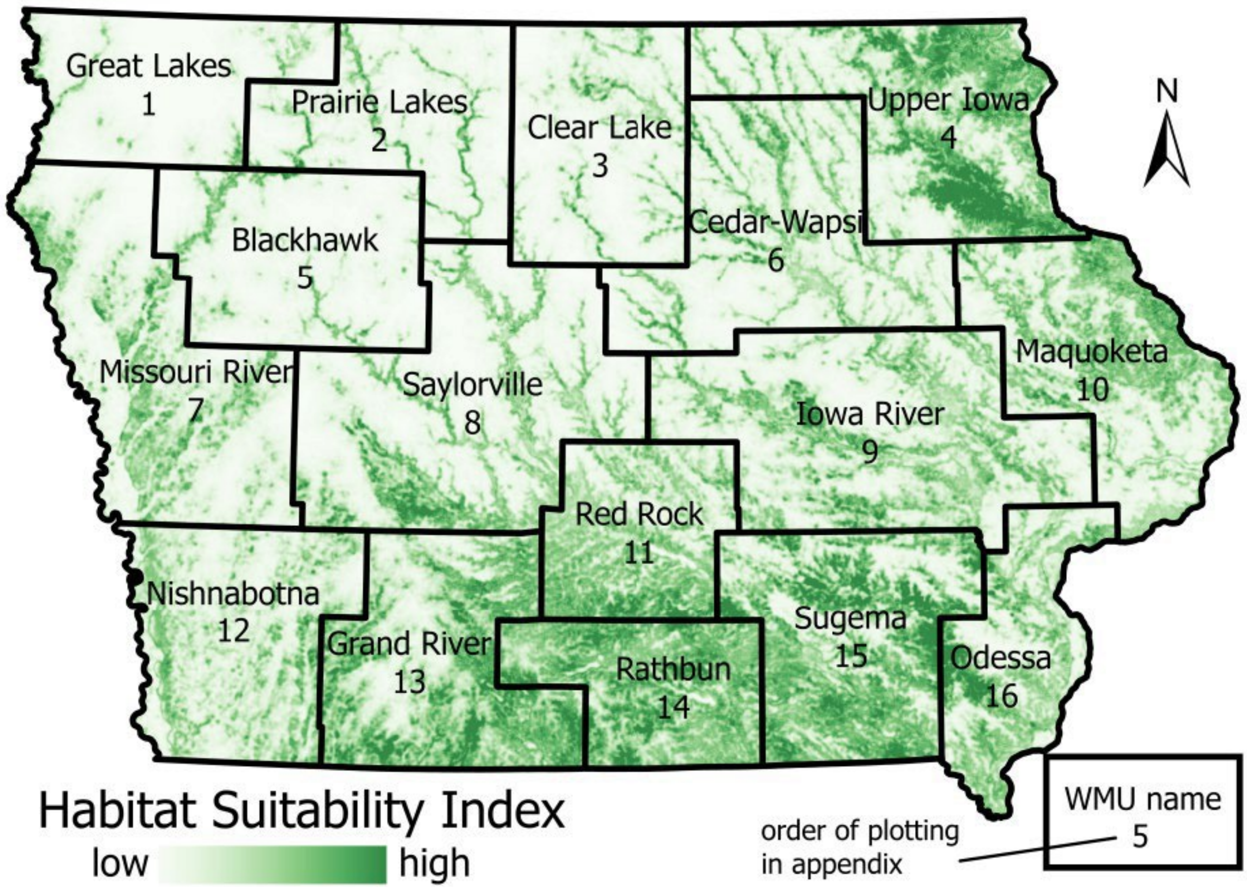


Figure 3. Iowa Wildlife Management Units overlayed on a map of deer habitat quality in Iowa. The number below the Unit name indicates the order of plotting for temporal trend figures (Appendix A). Background is a 30 m resolution map of Habitat Suitability for deer (Kaminski et al. 2019).



Charge 2: Review and provide scientific data relating to the environmental impact of deer populations, including the impact to crops and nut, fruit, Christmas, and lumber trees. Additionally, the report shall include information on property loss, medical costs, and fatalities due to deer-vehicle accidents and incidents of airport runway incursions by deer.

Work led by John C. Tyndall, Professor, ISU
Joseph McCartan, Student Researcher, ISU

For this analysis, we provide 1) a brief overview of some of the economic benefits attributed to deer in the state, and 2) an analysis of two distinct areas in which deer can negatively impact the Iowa economy: human property and health impacts with regard to vehicle accidents, and damage to field crop and specialty crop enterprises due to crop depredation and other damages.

Key to interpreting the findings of this report is a recognition that data are limited with respect to the economic value of deer in Iowa and so we focused heavily on relevant secondary data and made adjustments to these data as needed in accordance with economic research best practices (Bell et al. 2022). We did however collect primary data regarding deer damage to high-value specialty crop farms. Also, the financial assessments made represent only the lower bounds of both economic benefits and costs. We note relevant data-related or interpretive caveats throughout this analysis as needed.

We first overview some of the economic benefits that deer contribute to the Iowa economy and follow with our assessment of various types of damage cost.

(1) Analysis of economic benefits of deer to Iowa communities

Without question Iowa white-tailed deer are a source of significant tangible economic benefit whether associated with deer-centered (or related) recreational activities or various businesses involving deer products or services (e.g., equipment, outfitting, venison processing, taxidermy). These benefits variously contribute to local and regional economies in important ways that in turn can support jobs, generate income, and lead to broad positive economic outcomes (USDOI USFWS 2022).

From a recreational standpoint, deer are arguably the most important and economically valuable wildlife species in Iowa, and a key aspect of Iowa's tourism-oriented approach to economic development (IDNR 2019). There are a number of indirect ways to estimate the value of deer in Iowa and one way is to explore deer licensing fees and related markets. Here we explore deer hunting license revenue, the value of venison, revenue associated with processing venison, and revenue associated with taxidermy (Table 1).

The Iowa Department of Natural Resources (DNR) maintains a database that accounts for all hunting licenses purchased by residents and nonresidents for deer hunting in the state. For context, during the 2022-2023 hunting season, a total of 328,979 deer hunting licenses were issued (Elliott 2023). Using revenue data from the past four years (2020-2023), an average of $12.2 million has been generated per year in deer hunting licensure. To value venison, total annual harvested (reported) deer weight was conservatively estimated in pounds of venison yield per harvested deer based on sex-age category (fawns = 20 lbs, adult does = 40 lbs, adult bucks =

60 lbs) and then we used annual retail ground beef prices for the sales years 2020-2023 in Iowa as a reference price for venison (Elliott personal communication, 2024). Based on these assumptions, the inferred value of venison from deer harvested in Iowa averages $24.6 million per year.

In relation to the value of venison, there are a number of specialized meat processing lockers in Iowa that are licensed to process venison. Based on the 2023 Iowa Deer Hunter Survey, approximately 52% of deer hunters in Iowa take their harvested deer to a commercial venison processor (28.5% boned-out, 25.7% whole) (Elliott 2023b). Whole carcass processing is typically $125-150/deer and boned-out processing is typically $50-100/deer. The estimated average processing expense is $100 per deer (Elliott personal communication, 2024). As such, it is estimated that across 2020-2023 an average of $6.2 million per year was generated in venison processing.

Table 1. Summary of the economic value of deer hunting licenses, venison, and meat processing from 2020 to 2023. Dollar amounts in 2023$. Note: economic data include rounding.

Data year	Deer license [1]	Venison value [2]	Meat processing [3]	Total
2020	$12,472,000	$24,648,000	$6,779,000	$43,900,000
2021	$12,398,000	$23,444,000	$6,252,000	$42,095,000
2022	$11,861,000	$26,195,000	$6,213,000	$44,269,000
2023	$12,034,000	$23,919,000	$5,422,000	$41,375,000
4-yr Ave	$12,191,000	$24,552,000	$6,167,000	$42,910,000

1. Includes the purchase of deer preference points by nonresidents. 2. Estimated based on annual retail ground beef prices in Iowa; yield adjusted by sex-age categories. 3. ~ 52% of hunters utilize commercial venison processors; average processing expense = ~$100/ deer.

Taxidermists are self-employed and tend to use taxidermy as a supplemental business. Nevertheless, depending on total services provided (e.g., ranging from custom mounting, specialized trophy work, and offering training services) there can be a notable amount of income generated (Phillips 2018). The Iowa Taxidermy Association (ITA) currently lists 48 businesses as active members (ITA Members, undated) and the Manta online business directory lists 140 taxidermy businesses in Iowa. Based on reported 2023 prices for shoulder mounting deer (online pricing survey, n=7 Iowa-based taxidermists), it costs between $530 and $685 per shoulder mount. Assuming each business mounts 100 deer per year, this would equate to about $60,000 gross revenue per year per business. Assuming this estimate per business is accurate, there may be somewhere between ~ $2.9 million and ~ $8.4 million per year in gross revenue per year associated with deer-based taxidermy in the state. Taken as a whole, examining only these deer-related markets (hunting license expenditures, value of venison, venison processing, and taxidermy), an average of $48.6 million dollars of value is experienced in Iowa annually.

Additional values associated with deer can be explored using data from the 2011 USFWS National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (USIOD USFWS 2011). This periodic national-level survey collects and compiles comprehensive data regarding hunting and wildlife viewing activities and activity-specific annual expenditures (e.g., food and lodging, transportation, equipment, and other miscellaneous trip costs) that are relevant to deer hunting. The 2011 survey was the last time those data were presented on a state-by-state basis, so we will refer to and adjust 2011 data for this assessment. The 2011 USFWS survey estimated that 253,000 hunters (both resident and non-resident) spent about $405 million experiencing Iowa's hunting opportunities, largely for deer, turkey, upland birds and waterfowl ($563 million in 2023$; USIOD USFWS 2011).

Adjusting 2011 USFWS data to be specific to deer, it was estimated that 176,000 people (16 years and older, resident and non-resident) participated in deer hunting, or about 88% of all "big game" hunting participants accounted for in the survey (in Iowa, big game also includes wild turkey). These people collectively hunted deer for almost 2.6 million days in Iowa, and spent an estimated $136.2 million ($189.3 in 2023$), or about $575 per hunter per year (after adjusting for hunter type as per USFWS 2011, table 18) ($796 per hunter per year in 2023$). Assuming these expenditure rates hold today, there were about 166,000 deer hunters in Iowa in 2023 (Elliott 2024) who collectively spent an estimated $132.1 million to experience hunting in the state.

In summary, using only data that are specifically deer related, the lower bound value of tangible benefits that deer contribute each year in Iowa is about $180.7 million (in 2023$). Adding in the contribution of deer to other tangible values such as their role in wildlife viewing experiences, the USFWS data suggest that the tangible value of deer to the state of Iowa is upwards of several $100s of millions per year (Appendix B provides additional commentary).

(2) Cost of deer–vehicle collisions on human property and health in Iowa

One of the primary deer-related costs to society involves deer and vehicle collisions. A deer–vehicle collision (DVC) occurs when a human-operated road vehicle (automobile, truck, sports utility vehicle, recreational vehicle, or motorcycle) and one or more deer collide on a roadway (Huijser et al. 2017). According to State Farm Insurance estimates of deer collision likelihood (2022-23 data), drivers in Iowa have a 1 in 63 chance of experiencing a DVC; as of 2023, Iowa ranks sixth nationally in DVC likelihood (State Farm Insurance 2023). Nevertheless, it should be recognized that over the past 10 years DVCs represent only 14% of total car accidents, and involve 92% fewer cars than other car crashes in Iowa (ICAT, 2014-2023).

When a DVC does occur, it can lead to property damage (vehicle and non-vehicle), human injury or death, and deer fatality. The direct and indirect cost in both monetary and psychological terms (e.g., the mental and emotional outcomes) of these encounters can be significant at all scales, ranging from the individual who experiences a DVC, up to the total economic impact of all DVCs in a given region (Conover 2019). In any given state within the native range of white-tailed deer, the number of DVCs, injuries, and fatalities and concomitant cost varies spatially within the state and temporally (seasonal variation as well as year to year) due to changes in human populations and primary transportation routes, seasonal weather, deer mating season, hunting pressure, land cover, and fall crop harvest (Gkritza et al. 2010; Pagany 2020; Shaw et al. 2023). It is also important to recognize that the various costs of a DVC manifest in both short- and long-term impacts and therefore can be complex and emergent across time. Ultimately, it is not possible to calculate the true total cost of DVCs in their entirety or track over time. Nevertheless, there are accepted methods for assessing available data and calculating reasonable lower-bound estimates of the costs associated with DVCs at state levels (Drake et al. 2005; Huijser et al. 2009; Conover 2019).

Likewise, deer-aircraft collisions (DAC) during takeoff and landings occur about 30 times a year in the U.S. (based on Federal Aviation Administration Wildlife Strike Database reports from 2014-2023). While DACs represent only 0.002% of wildlife strikes in the U.S. during the past 10 years, they are regarded as the most hazardous wildlife encounter with 84% of deer strikes causing damage to aircraft (FAA 2018). One study noted that a DAC on average results in six times more economic damages to aircraft compared to other wildlife (Biondi et al. 2011). Injuries and fatalities associated with DACs have occurred in North America, yet are relatively rare.

Analysis results for cost of deer–vehicle collisions on human property and health

The following is a summary of the findings associated with the estimated total cost of Deer Vehicle Collisions (DVCs; private and commercial vehicles) in Iowa in 2023$ (USD). To calculate this, we used the Huijser-Ament approach (Huijser et al. 2009). Based on average Iowa Department of Transportation (IDOT) data regarding total DVCs and proportional outcomes of DVCs relative to injuries, fatalities, property damage (data years 2014-2023; Appendix C, tables C1, C2, and C3), and Iowa Local Technical Assistance Program (ILTAP) salvaged and unsalvaged roadkill data during the past 10 years, the average total cost per DVC is $17,012. The average number of IDOT reported DVCs in Iowa from 2014-2023 is 7,560 (IDOT 2023). Combining all findings, the estimated average lower-bound total annual cost of DVCs in Iowa is ~$128.6 million.

Costs associated with airport runway incursions by deer in Iowa have been negligible during the last 10 years. Based on the FAA Wildlife Strike Database (https://wildlife.faa.gov/home), the percent of wildlife collisions in Iowa that were deer aircraft collisions (DACs) during this time is 0.003% (2 reported incidents in 10 years, 2014-2023). One DAC resulted in minor damage to a small 2-passenger aircraft and the other caused significant fuselage damage to a small experimental craft (FlightAware: https://www.flightaware.com/). We estimate that the annual cost of a DAC is $9,536 (2023$).

Later in this report we provide additional details for this work including 1) methodology, data, caveats, and interpretation, 2) other important values of deer accounted for but not included, 3) comprehensive overview of component costs of a DVC and total average costs in Iowa (Appendix C).

(3) Estimated costs of crop damage related to corn and soybean production

Deer can negatively impact row crop production in various ways. The incidence of white-tailed deer browsing in agricultural crop fields has resulted in significant direct and indirect economic losses throughout the United States with other deer behaviors such as rubbing and inadvertent trampling also causing damage. Field crop losses caused by deer during the 2001 growing year in the United States were estimated by the USDA to cost ~$628 million (in 2023$;

USDA NASS 2002). In the U.S. Cornbelt region, corn and soybeans are considered a major component of the diet of white-tailed deer (MacGowan et al. 2006).

For this analysis we updated data from a study that included Iowa in a regional assessment of wildlife depredation on corn systems (Wywialowski 1996). The Wywialowski (1996) study utilized a representative sample of 3,000 corn fields in 10 corn-producing states in the U.S. Midwest. Analyzing observed damage to only ripening corn grain, it was estimated that deer caused the loss of an average of 0.57 bushels per hectare across the 10-state harvested corn production area. An average loss of 0.21 bushels corn per hectare was reported for Iowa. To provide a simple baseline estimate we updated various parts of the Wywialowski (1996) study, while holding certain assumptions constant across time. We provide a comprehensive overview of methods, data, and additional assumptions later in this report (Appendix D).

Assuming expected per hectare loss due to deer is the same today as it was in 1993 (0.21 bushels corn per hectare), that level of damage relative to 2023 harvested corn acreage, average yields, and price would be valued at $5.2 million (Appendix C, Table C1). Again, this relates only to lost grain and does not account for any other damage that deer may cause to corn systems and farms (e.g., due to vegetation browsing, trampling, bedding, etc.) or the cost of deer management. A primary caveat of this assessment is that the original data were collected in a cropping year when Iowa was experiencing historically significant spring flooding conditions, and it is not known how these conditions impacted deer populations and behavior relative to crop depredation. Additionally, cropping systems in Iowa have expanded and changed considerably during the past 30 years (with reference to 1993). Likewise, regional deer populations are dynamic and change in terms of numbers and patterns of movement as a function of a number of factors such as hunting pressure, changes in land cover, urban and rural development, disease, and weather (McShea 2012; Little et al. 2016; Laurent et al. 2021). As such, we have no basis to assume that depredation rates would be the same across time. Nevertheless, these data provide some general context for the potential lower bound range of lost value to corn systems because of deer depredation.

Unfortunately, we do not have additional information regarding other damage that deer can cause to row crops. Beyond consumption of grain (e.g., Wywialowski 1996), deer can cause other direct impacts to crops (e.g., defoliation, trampling, crushing, etc.) and they can also damage farm infrastructure, and induce farmers to implement any number of costly and time-consuming wildlife management actions. Likewise, we do not have similar data relative to soybean crops. One wildlife depredation study in Indiana noted that 61% of observed damage to soybean fields was caused by deer (MacGowan et al., 2006). As such, damage to soybeans in Iowa could be similar to and perhaps more costly than corn. Later in this report we provide a brief overview of different ways in which corn and soybean farmers can experience direct and indirect economic loss from deer and details on an additional analysis of 1) multiple years of federal crop insurance claims in Iowa relative to wildlife loss, and 2) 2023 data from the DNR Wildlife Depredation Program which records and investigates farmer reports of deer depredation and qualifying crop damage (Appendix D).

(4) Estimated costs of high-value specialty crop depredation (e.g., impacting fruit, vegetable, nut, and tree nursery farms)

The financial impact of white-tailed deer on high-value agricultural systems manifests in myriad ways similar to commodity crops (Paulin et al. 2022). High-value agricultural cropping systems (e.g., fruits, vegetables, nuts, plant stock, specialty crops, etc.) are often particularly vulnerable to negative financial impact due to deer damage because of their relative smaller scale (as compared to commodity-oriented agricultural systems), high marginal risk associated with yield and crop quality impacts, thinner markets (e.g., fewer buyers and sellers), and often limited or comparatively expensive (relative to commodities) risk mitigation tools such as specialty crop insurance (Decker and Brown 1982; Raszap Skorbiansky et al. 2022). In the 2001 growing year, the damage caused in the U.S. to vegetable, fruit and nut crops alone by deer was estimated by the USDA to be about $87.5 million (in 2023$; USDA NASS 2002).

The objective of this component of our work was to assess the types of damage, extent of damage, and the overall economic impact of white-tailed deer on Iowa producers of high-value specialty crops. We also characterize and monetize the various control methods utilized by these farmers and assess the general efficacy of control methods. For this assessment we surveyed Iowa producers of fruits, vegetables, nuts, tree nursery stock, and Christmas trees. According to the USDA NASS 2022 Agricultural Census, there were ~1,512 specialty crop farms in Iowa that produced these specific products. Iowa farms that were predominantly commodity crop growers or livestock producers were excluded from our survey. We drew a sample of identifiable specialty crop farms in the state (n=216), collecting data from August to September 2024 via an online Qualtrics survey (note identifiable means that we obtained names and addresses from various trade and university extension sources). Later in this report is a more detailed overview of survey methods (Appendix E).

Survey results in brief

A total of 49 surveys were completed. Based on follow-up correspondence from a number of people who received a solicitation letter, follow-up phone calls to several businesses associated with returned mail (e.g., "return to sender"), and further internet investigation we determined that at least 16 farms were ineligible for various reasons. As such we have an adjusted overall response rate of 25% (Wiseman 2003). While this is a relatively low response rate, nationally farmer surveys often have response rates around 10% (Jussaume et al. 2019).

Respondents operated the following type of farms (n=49): Community Supported Agriculture (CSA) farms (n=9), fruit orchards including vineyards (n=14), nut producers and nut tree growers (n=9), tree nurseries (n=3), Christmas tree farms (n=13), and flower farms (n=1). Tree farms and nut producers had the highest response rates by farm type. About 50% of the respondents have been in operation at their current production site for ≥10 years. The majority of respondents have just one production site, yet 12 had multiple sites. Just under half the respondents who provided business financial data (n=36) earn >25% of their household income from their farm system, with 48% earning >$50k per year.

Across all respondents who reported farm size (n=40), there was a total of at least 1,955 acres under cultivation in 2023 represented in the survey (or ~15% of total acres in Iowa for these specialty crops, USDA NASS 2022). The majority of farm sites are located in rural areas with a subset (n=10) being in urban or suburban areas. The vast majority of production sites were located adjacent to crop fields, forest, and grassed areas.

In 2023, 32 of 48 respondents (67%) indicated they experienced crop damage that they were reasonably sure was caused by deer, 10 of 48 respondents (20%) said they did not experience deer damage (but they did experience damage from other wildlife such as rabbits and raccoons), and 6 respondents were not sure.

Based on data from 22 farmers, and weighting data by farm type represented, the average percent area per farm impacted by deer in 2023 was 24%, impacting an average of 4.8 acres per farm, causing an average of ~$3,226 damage to their crops in 2023. Only one respondent indicated that they had insurance coverage for the damage incurred.

Most respondents stated that the damage experienced was slight to moderate. More than a third of the respondents (n=17) indicated that deer also caused damage to non-crop aspects of their farm (e.g., damage to fencing, irrigation equipment). Feeding, browsing and antler rubbing were the primary causes of deer damage. The majority of respondents found the damage to their farm sites to subjectively range between moderately acceptable and moderately unacceptable. Just under a third of the respondents indicated that they contacted the DNR Wildlife Depredation Program for assistance.

The vast majority of respondents (n=42) actively manage their farms to mitigate or prevent deer damage. On average (based on 20 respondents), specialty crop farmers spend about $1,400 per year on deer management. Twenty farmers use high deer fencing (41% of respondents), with 9 of these respondents indicating they have invested an average of ~$4,700 specifically on deer fencing (fences are on average 14.5 years old). Amortizing this sum over 14.5 years at an assumed interest rate of 6% comes to about a $490 per year investment for fencing.

Extrapolating the findings to represent all the specialty crop producers in Iowa is difficult because of data limitations. Nevertheless, it may be informative to assume general representativeness of the data. If this is the case, assuming 50% of Iowa's specialty high-value crop producers experienced similar degrees of deer damage, in 2023 there may have been around $3.4 million in crop damage experienced by Iowa's specialty crop producers, with an additional $832 thousand spent to manage deer damage at individual farms. Later in this report we provide a summary by farm type of average and total acres and average and total financial impact of deer (Appendix E).

Charge 3: The department shall also review the spread of disease in deer and other Cervidae wildlife populations.

Authored by Jace Elliott, State Deer Biologist

Chronic Wasting Disease

Chronic Wasting Disease (CWD) is an infectious disease of cervids that has been detected in captive or free-ranging populations of deer, elk, moose, and reindeer in the United States, Canada, Norway, Finland, Sweden, and South Korea. This disease was first identified in 1967 in a herd of captive mule deer maintained at a research facility in Fort Collins, Colorado. As of September 2024, CWD has been detected in free-ranging mule deer, white-tailed deer, elk, and moose in 34 states and four Canadian provinces in North America. Since 2016, it has also been detected in free-ranging reindeer, moose, and red deer in northern Europe. Although South Korea imported CWD-positive elk in the mid-1990s, spillover into wild populations of native cervids remains undocumented.

CWD is transmitted by proteinaceous infectious particles called prions. Prions are normal host proteins distributed throughout the cells of the body, however, following exposure to the aberrant (i.e., infectious) isoform, normal host proteins will misfold and propagate. The accumulation of misfolded prions in host tissues is what causes disease. Deer are most susceptible to infection following exposure across the oral and nasal mucosa (i.e., direct transmission). Once deer become infected with CWD, it typically takes between 18 months and three years to begin displaying physical signs of disease. This long incubation period makes disease management particularly challenging as both direct and indirect transmission (i.e., contact with contaminated surfaces in the environment) are possible. CWD is 100% fatal, meaning a deer is guaranteed to die from CWD infection or other proximate cause resulting from CWD infection.

CWD surveillance began in Iowa in 2002 in response to detections of the disease in neighboring states, namely Wisconsin. In 2013, Iowa's first positive case of CWD in wild white-tailed deer was detected and confirmed in Allamakee County in northeastern Iowa. Since 2013, a minimum of 4,000 individual deer have been sampled annually, including deer from every county. As of September 2024, CWD has been found in wild deer in Iowa 23 counties and in captive deer in six Iowa counties. To date, there is no direct evidence that CWD poses a health risk to non-deer species, including humans and livestock, through natural transmission pathways.

Due to the persistent nature of CWD and its potential to have long-term impacts on white-tailed deer populations, the DNR routinely implements Deer Management Zones (DMZs) in counties where CWD has been detected in wild white-tailed deer. These DMZs allow hunters additional antlerless harvest opportunities to help slow the spread of CWD and increase CWD surveillance. The DNR relies heavily on hunters to effectively manage and monitor CWD spread in Iowa.

Hemorrhagic Disease

Hemorrhagic disease describes two closely related viruses: Bluetongue (BT) and Epizootic Hemorrhagic Disease (EHD). Although deer can contract BT, it is primarily a disease of small ruminants and cattle. In contrast, deer are the primary hosts of EHD. This disease is spread by midges (*Culicoides* spp.), often called “no-see-ums,” that consume a blood-meal from an infected deer and then transmit the virus to new hosts with each bite. Infected deer experience an incubation period of 7-10 days, during which they remain asymptomatic, followed by the rapid onset of clinical signs (often including death) within 8-36 hours. Deer are often found in or near bodies of water trying to cool themselves during end-stage disease. Infected livestock, such as cattle, rarely show clinical signs of hemorrhagic diseases, although they likely represent the primary reservoir of BT and EHD transmission to white-tailed deer in Iowa.

Hemorrhagic disease tends to affect deer in Iowa between late summer and early fall, although outbreak severity can vary from year to year. Hunters and landowners may discover multiple deer carcasses on a property, specifically near a water source, during these months as a result of hemorrhagic disease. There is no effective treatment or known prevention for wild deer. It is worth noting that these diseases typically don't impact county deer populations uniformly, meaning that deer on one property may experience a severe outbreak while deer on neighboring properties do not. Since Iowa's first major outbreak in 2012, the majority of counties that faced severe hemorrhagic disease activity saw deer populations return to near-normal levels within 2-3 years without management intervention (reduction of antlerless quotas, etc.). Counties with low or declining deer populations may be exceptions, in which case the DNR may explore options to help facilitate population recovery.

Future Needs

This study would not have been possible without the many sources of data about Iowa’s white-tailed deer population and related information on their economic impacts to agricultural crops and losses due to vehicle collisions. Despite this wealth of information we could have used additional data in some areas to better inform this report. Those data needs include:

1. Movement data of individual deer in Iowa. Such information could better inform our model with respect to deer availability during spotlight surveys, deer distribution along roadways, possible deer movements in response to surveyors, seasonal and spatial patterns of deer use in agricultural fields, and much more.
2. Further investigation of the relationship between crashes reported to DOT those reported to Iowa insurance companies. This will help refine cost estimates associated with deer-vehicle collisions in Iowa.
3. Additional data are needed on deer impacts to commodity crops in Iowa. We acknowledge that available data for this report were limited, so our estimate is probably close to a lower bound and could be improved by updated information.

Literature Cited

Acharya, S., Morgan, M., Xu, S., & Palmer, M. H. (2023). A descriptive analysis of deer-vehicle collisions along Missouri interstate highways. *Trees, Forests and People*, *13*, 100409.

Alliance for Automotive Innovation (AFAI). (2022). Autos drive Iowa Forward. Industry Impact Report Summary. Available at: https://www.autosinnovate.org/resources/insights/ia (Last viewed 120923).

Allen, R., Hanuschak, G. A., & Craig, M. E. (1997). *Forecasting crop acreages and yield in the face of and in spite of floods*.

Allen, T., Southwick, R., & Howlett, D. (2012). *Hunting in America: an economic force for conservation*. Southwick Associates.

Ament, R., Huijser, M., & May, D. (2022). *Animal Vehicle Collision Reduction and Habitat Connectivity Cost Effective Solutions-Final Report*. Nevada Department of Transportation.

Baker, L. A. (2010). *State survey of white-tailed deer (Odocoileus virginianus Zimmerman) impacts on residential landscapes and the green industry of Alabama and an evaluation of commercial deer repellents* (Doctoral dissertation, Auburn University).

Bell, E., Bryman, A., & Harley, B. (2022). *Business research methods*. Oxford university press.

Bergstrand, J. R. (2024). *Perceptions of Wildlife Damage, Tolerance, and Abatement Programs Among Agricultural Producers* (Master's thesis, University of Wisconsin-Stevens Point).

Betterton, R. (2023). Average cost of car maintenance. Bankrate. Auto and Personal Loan Report. June 5, 2023. Available at: https://www.bankrate.com/loans/auto-loans/average-car-maintenance-costs/ (last viewed 120923)

Biondi, K. M., Belant, J. L., Martin, J. A., DeVault, T. L., & Wang, G. (2011). White-tailed deer incidents with US civil aircraft. *Wildlife Society Bulletin*, *35*(3), 303-309.

Blincoe, L., Miller, T. R., Zaloshnja, E., & Lawrence, B. A. (2015). The economic and societal impact of motor vehicle crashes, 2010 (Revised) (No. DOT HS 812 013).

Blincoe, L., Miller, T., Wang, J.-S., Swedler, D., Coughlin, T., Lawrence, B., Guo, F., Klauer, S., & Dingus, T. (2023, February). The economic and societal impact of motor vehicle crashes, 2019 (Revised) (Report No. DOT HS 813 403). National Highway Traffic Safety Administration.

Boyer, C. N., Chen, L., Perez-Quesada, G., & Smith, S. A. (2024). Unwelcomed Guests: Impact of Deer Harvest on Corn and Soybean Wildlife Damage. *Crop Protection*, 106753.

Brown, T. L., Decker, D. J., & Curtis, P. D. (2004). Farmers' estimates of economic damage from white-tailed deer in New York State. HDRU Series No. 04-3. March 2004.

Buckley, N. (2018). The rules of the roadkill: Who is responsible for picking up deer carcasses? ABC 13 News. Traffic. Available at: https://www.wzzm13.com/article/traffic/the-rules-of-the-roadkill-whos-responsible-for-picking-up-deer-carcasses/69-619779701 (Last viewed 120923).

Conover, M. R. (2019). Numbers of human fatalities, injuries, and illnesses in the United States due to wildlife. *Human–Wildlife Interactions*. **13** (2): 12.

Conover, M. R., & Conover, D. O. (2022). *Human-wildlife interactions: from conflict to coexistence*. CRC Press.

Decker, D. J., & Brown, T. L. (1982). Fruit growers' vs. other farmers' attitudes toward deer in New York. *Wildlife Society Bulletin (1973-2006)*, *10*(2), 150-155.

Donnelle, E. (2024). Roaming cattle cause car accidents, ruin crops, NE Iowa neighbors say: Aggressive bulls bringing chaos to Howard County. Des Moines Register**;** Des Moines, Iowa. 12 Mar 2024: A.1.

Drake, D., & Grande, J. (2002). Assessment of wildlife depredation to agricultural crops in New Jersey. *The Journal of Extension*, *40*(1), 13.

ERI Economic Research Institute (undated). Online salary database: https://www.erieri.com/salary/job/taxidermist/united-states (Last accessed Sept 18, 2024).

Elliott, J. (2023a). 2022-2023 White-tailed Deer Program Report. Available at: https://www.iowadnr.gov/Portals/idnr/uploads/Hunting/trends/2022-23%20White-tailed%20Deer%20Program%20Report.pdf (Last accessed Sept 18, 2024).

Elliott, J. (2023b). 2023 Iowa Deer Hunter Survey Report. Available at: https://www.iowadnr.gov/Portals/idnr/uploads/Hunting/hunting-files/2023-Iowa-Deer-Hunter-Survey-Report.pdf (Last accessed Sept 18, 2024).

Edmonds, E. (2018). New vehicle technologies double repair bills for minor collisions. AAA NewsRoom. October 25, 2018. Available at: https://newsroom.aaa.com/2018/10/new-vehicle-technologies-double-repair-bills-minor-collisions/ (Last accessed Sept 18, 2024).

Federal Aviation Administration. (2018). Advisory Circular (RE: minimum acceptable standards for the conduct and preparation of Wildlife Hazard Site Visits (Site Visit), Wildlife Hazard Assessments (Assessments) and Wildlife Hazard Management Plans (Plans). AC No.: 150/5200-38. Date: 8/20/2018.

Feldhamer, G. A., & McShea, W. J. (2012). *Deer: the animal answer guide*. JHU Press.

FlightAware (Undated). Aircraft Registration database. Available at: https://www.flightaware.com/ (Last accessed 120923)

Gkritza, K., Baird, M., & Hans, Z. N. (2010). Deer-vehicle collisions, deer density, and land use in Iowa's urban deer herd management zones. *Accident Analysis & Prevention*, *42*(6), 1916-1925.

Grupa, T. (2023). How Much Does a Tow Truck Service Cost? Home Guide. Cost Guides: Towing. Available at: https://homeguide.com/costs/towing-service-cost (last viewed 120923).

Harmon, T., Bahar, G. B., & Gross, F. B. (2018). *Crash costs for highway safety analysis* (No. FHWA-SA-17-071). United States. Federal Highway Administration. Office of Safety.

Harms, T.M., J.M. Coffey, J.R. Elliott, V.D. Evelsizer, D.J. Kaminski. (2022). Iowa bow hunter observation survey: 2022 summary. 1–24.

Hawley, 2023. Most popular vehicles sold by state. JD Power Consumer newsletter. (May 11, 2023). Available at: https://www.jdpower.com/cars/shopping-guides/most-popular-vehicles-sold-by-state (Last accessed Sept 18, 2024).

Hinton, G. C., Strickland, B. K., Demarais, S., Eubank, T. W., & Jones, P. D. (2017). Estimation of deer damage to soybean production in eastern Mississippi: Perception versus reality. *Wildlife Society Bulletin*, *41*(1), 80-87.

Huijser, M. P., Begley, J. S., & Canmore, A. (2016). *Wildlife Mitigation Opportunities along US Hwy 2*, Northwestern Montana.

Huijser, M. P., Duffield, J. W., Clevenger, A. P., Ament, R. J., & McGowen, P. T. (2009). Cost–benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada: a decision support tool. *Ecology and Society*, 14(2).

Huijser, M. P., McGowan, P., Hardy, A., Kociolek, A., Clevenger, A. P., Smith, D., & Ament, R. (2017). *Wildlife-vehicle collision reduction study: Report to congress.*

Huijser, M., McGowen, P. T., Fuller, J., Hardy, A., & Kocjolek, A. (2008). *Wildlife-vehicle collision reduction study: report to congress* (No. FHWA-HRT-08-034). Washington, DC: US Department of Transportation.

Hupp, C. (2019). Price Determinants of Recreational Land in Illinois. Southern Illinois University. MS Thesis. Available at: https://opensiuc.lib.siu.edu/gs_rp/897/ (Last accessed Sept 18, 2024).

Iowa Department of Natural Resources. (Undated). Iowa's White-tailed Deer. Available at: https://www.iowadnr.gov/Portals/idnr/uploads/Hunting/deer_information.pdf (Last accessed Sept 18, 2024).

Iowa Department of Natural Resources. (IDNR). (2019). *2018-2023 Outdoor Recreation in Iowa Plan.* Iowa Department of National Resources. Retrieved on July 30, 2023, from https://www.iowadnr.gov/About-DNR/Grants-Other-Funding/State-Conservation-and-Outdoor-Recreation-Plan (Last accessed Sept 18, 2024).

Iowa. Department of Natural Resources. Fish & Wildlife Division. (1994). *Trends in Iowa Wildlife Populations and Harvest*. Iowa Department of Natural Resources.

Iowa Department of Natural Resources (IDNR). (2023). Hunters harvest nearly 110,000 deer during 2022-23 season. DNR News Releases. Feb. 7, 2023. Available at: https://www.iowadnr.gov/About-DNR/DNR-News-Releases/ArticleID/4380/Hunters-harvest-nearly-110-000-deer-during-2022-23-season (Last accessed Sept 18, 2024).

Iowa Department of Transportation (IADOT). (2023). Investigating Officer's Crash Reporting Guide. IA DOT Motor Vehicle Division. Revised: August 2023. p123.

Iowa Local Technical Assistance Program. (IALTAP). Undated. Animal-vehicle crash fatality database. Deer-vehicle Crash Information Clearinghouse. Iowa State University Institute for Transportation. Iowa Report. Available at: https://iowaltap.iastate.edu/deer-vehicle-crash-information-clearinghouse/ (Last accessed Sept 18, 2024).

Iowa State University Extension and Outreach. (2021). Crop insurance coverage-frequently asked questions. Ag Decision Maker Newsletter. Vol. 25, No. 10. August 2021.

Iowa State University Extension and Outreach. (Undated). Corn and Soybeans: Harvested Acreage and Yield Per Acre NASS Chartbook. Available at: https://www2.econ.iastate.edu/outreach/agriculture/periodicals/chartbook/Chartbook2/Tables/Table10.pdf (Last accessed Sept 18, 2024).

Iowa Taxidermy Association Membership list: https://iowataxidermyassociation.com/Main/Members (Last accessed Sept 18, 2024).

Janke, A. (2022). Iowa's White-tailed Deer and CWD. Small Farm Sustainability. Iowa State University, Extension and Outreach. Acreage Living Newsletter. November, 2022. Available at: https://www.extension.iastate.edu/smallfarms/iowas-white-tailed-deer-and-cwd (Last viewed 120923).

Johanns, A., (2024a). Historical corn yields by county in Iowa. Ag Decision Maker. Iowa State University, Extension and Outreach. File A1-12. Revised March 2024.

Johanns, A., (2024b). Iowa cash corn prices (USDA NASS). Ag Decision Maker. Iowa State University, Extension and Outreach. File A2-11. Revised September 2024.

Johanns, A., (2024c). Historical soybean yields by county in Iowa. Ag Decision Maker. Iowa State University, Extension and Outreach. File A1-13. Revised March 2024.

Jussaume, R. A., Dentzman, K., & Owen, M. D. (2019). Producers, weeds, and society. *Journal of Integrated Pest Management*, *10*(1), 6.

Kaminski, D.J., T.M. Harms, J.M. Coffey. (2019). Using spotlight observations to predict resource selection and abundance for white-tailed deer. *Journal of Wildlife Management 83*:1565–1580.

Kaminski, D.J., T.M. Harms, V.D. Evelsizer, J.R. Elliott. (2024). Iowa Spring Spotlight Survey: 2023 Summary. Iowa Department of Natural Resources 1–44. (chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.iowadnr.gov/Portals/idnr/uploads/Hunting/spring_spotlight/Spotlight%20Survey%20Report_2024.pdf)

LaChance, D. (2022). Collisions with animals rose 7.2% during the pandemic, State Farm analysis says. Repairer Driven News. Society of Collision Repair Specialists (SCRS). Available at: https://www.repairerdrivennews.com/2022/05/17/collisions-with-animals-rose-7-2-during-the-pandemic-state-farm-analysis-says/ (Last accessed Sept 18, 2024).

Laurent, M., Dickie, M., Becker, M., Serrouya, R., & Boutin, S. (2021). Evaluating the mechanisms of landscape change on white-tailed deer populations. *The Journal of Wildlife Management*, *85*(2), 340-353.

Lemieux, N., Maynard, B. K., & Johnson, W. A. (2000). A regional survey of deer damage throughout Northeast nurseries and orchards. *Journal of Environmental Horticulture*, *18*(1), 1-4.

Little, A. R., Webb, S. L., Demarais, S., Gee, K. L., Riffell, S. K., & Gaskamp, J. A. (2016). Hunting intensity alters movement behaviour of white-tailed deer. *Basic and Applied Ecology*, *17*(4), 360-369.

MacGowan, B. J., Humberg, L. A., Beasley, J. C., DeVault, T. L., Retamosa, M. I., & Rhodes Jr, O. E. (2006). Corn and soybean crop depredation by wildlife. *Purdue Extension FNR-265-W, Purdue University, West Lafayette, IN*.

McKee, S. C., Shwiff, S. A., & Anderson, A. M. (2021). Estimation of wildlife damage from federal crop insurance data. *Pest Management Science*, *77*(1), 406-416.

McShea, W. J. (2012). Ecology and management of white-tailed deer in a changing world. *Annals of the New york Academy of Sciences*, *1249*(1), 45-56.

Miller, D.L., E. Rexstad, L. Thomas, L. Marshall, and J.L. Laake. (2019). Distance sampling in R. *Journal of Statistical Software 89*:1–28.

Mishra, B., Joshi, O., Chapagain, B. P., Lambert, L. H., & Will, R. E. (2023). Intentions of Landowners towards Active Management of Ecosystem for Deer Habitat. *Environmental Management*, 1-11.

Moore, A. (2021, January 27). *Decline in hunting threatens conservation funding.* North Carolina University: College of Natural Resource News. Retrieved on August 4, 2021 from https://cnr.ncsu.edu/news/2021/01/decline-in-hunting-threatens-conservation-funding/ (Last accessed Sept 18, 2024).

Murphy, D.A. (1970). Deer range appraisal in the Midwest. In White-tailed Deer in the Midwest: A Symposium. *USDA Forest Service Research Paper NC-39*:2–10.

Nezval, V., & Bíl, M. (2020). Spatial analysis of wildlife-train collisions on the Czech rail network. *Applied Geography*, *125*, 102304.

Normandeau Associates, Inc. (2012). *Deer-Vehicle Crash, Ecological, and Economic Impacts of Reduced Roadside Mowing – Final Report.* Federal Highway Administration, Washington, D.C., May 2012. Available at: https://intrans.iastate.edu/app/uploads/sites/10/2018/11/DVC-Mowing.pdf (Last accessed Sept 18, 2024).

Otto, D., Monchuk, D., Jintanakul, K., & Kling, C. (2007). The economic value of Iowa's natural resources. *Iowa State University*. https://www.card.iastate.edu/research/resource-and-environmental/items/dnr-amenity.pdf (Last accessed Sept 18, 2024).

Pagany, R. (2020). Wildlife-vehicle collisions-Influencing factors, data collection and research methods. *Biological conservation*, *251*, 108758.

Papandrea, R. (2022). The Average Age of a Used Car at Purchase Is 6.47, With Wide Variation Among States and Metros. Available at: https://www.valuepenguin.com/used-car-ages-study (Last viewed Sept 18, 2024).

Paulin, J.B., Arbab, N.N., and B.J. Schilling. NJAES/RCE. (2022). White-Tailed Deer and the Hidden Costs to Farmers' Livelihoods: A Case Study of New Jersey Stories. Rutgers University, School of Environmental and Biological Sciences, New Jersey Agricultural Experiment Station, Rutgers Cooperative Extension.

Phillips, J.E. (2018). How to Make Money with Taxidermy: 70 Tips for Hunters and Small Businesses. CreateSpace Independent Publishing Platform (September 5, 2018)

Rastandeh, A., Carnes, M., & Jarchow, M. (2022). Non-monetary landscape features most desirable across the Upper Missouri River Basin. *Land Use Policy*, 115. https://doi.org/10.1016/j.landusepol.2022.105980.

Raszap Skorbiansky, S., Astill, G., Rosch, S., Higgins, E., Ifft, J., & Rickard, B. (2022). Specialty Crop Participation in Federal Risk Management Programs. Economic Research Service Economic Information Bulletin Number 241 September 2022.

Riginos, C., Copeland, H., Smith, C., Sawyer, H., Krasnow, K., Hart, T., & Cooperative, N. R. C. (2016). *Planning-support for mitigation of wildlife-vehicle collisions and highway* *impacts on migration routes in Wyoming* (No. FHWA-WY-16/10F). Wyoming. Dept. of Transportation.

Riley, S. J., & Marcoux, A. (2006). *Deer-vehicle collisions: an understanding of accident characteristics and drivers' attitudes, awareness and involvement* (No. RC-1475). Michigan. Dept. of Transportation. Construction and Technology Division.

Savolainen, P., & Ghosh, I. (2008). Examination of factors affecting driver injury severity in Michigan's single-vehicle–deer crashes. *Transportation Research Record*, *2078*(1), 17-25.

Shaw, J. (2019). Unreported deer crashes on Iowa highways. Tech Transfer Summary. Iowa State University Institute for Transportation. Iowa Department of Transportation (InTrans Project 19-727).

Shaw, J.W., Nlenanya, I., and Allen, M. (2023). Unreported deer crashes on Iowa Highways. Iowa State University Institute for Transportation. Iowa Department of Transportation. (InTrans Project 19-727).

SKYbrary. (Undated). Non-avian Wildlife Hazards to Aircraft. Available at: https://skybrary.aero/articles/non-avian-wildlife-hazards-aircraft (Last accessed Sept 18, 2024).

State Farm Insurance. (2023). How likely are you to have an animal collision? Available at: https://www.statefarm.com/simple-insights/auto-and-vehicles/how-likely-are-you-to-have-an-animal-collision. (Last accessed Sept 18, 2024).

St. Clair, C. R., & Gassmann, A. J. (2021). Linking land use patterns and pest outbreaks in Bt maize. *Ecological Applications*, *31*(4), e02295.

Tzilkowski, W. M., Brittingham, M. C., & Lovallo, M. J. (2002). Wildlife damage to corn in Pennsylvania: farmer and on-the-ground estimates. *The Journal of wildlife management*, 678-682.

U.S. Department of Agriculture. Risk Management Agency Data: https://www.rma.usda.gov/Information-Tools/Summary-of-Business/Cause-of-Loss (Last accessed Sept 18, 2024).

U.S. Department of Agriculture, National Statistical Service. (2002). U.S. Wildlife Damage. Summary Report. Available at: https://usda.library.cornell.edu/concern/publications/gt54kn01b (Last accessed Sept 18, 2024).

U.S. Department of the Interior, U.S. Fish, & Wildlife Service (USFWS) (Eds.). (2011). *2011 National survey of fishing, hunting and wildlife-associated recreation – Summary for State of Iowa*. Fish & Wildlife Service.

U.S. Department of the Interior, U.S. Fish and Wildlife Service, (2024). 2022 Economic Contributions of Wildlife Watching in the United States: Addendum to the 2022 National Survey of Fishing, Hunting, and Wildlife- Associated Recreation.

U.S. Department of Transportation (USDOT) (2021). *Valuation of a Statistical Life Update 2021- Transmittal Memorandum*. Available at: https://www.transportation.gov/resources/2021-revised-value-of-a-statistical-life-transmittal-memo (Last accessed Sept 18, 2024).

U.S. Department of Transportation (USDOT) (2024). *Departmental Guidance on Valuation of a Statistical Life in Economic Analysis*. Effective Date: Monday, May 7, 2024. Available at: https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis (Last accessed Sept 18, 2024).

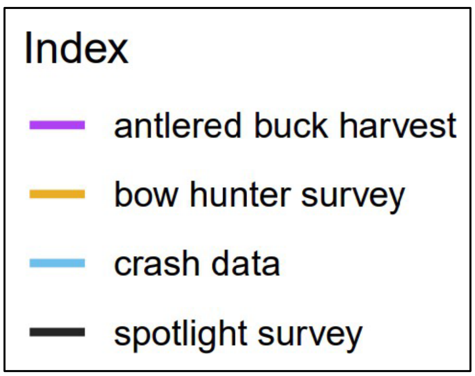
VerCauteren, K. C., & Hygnstrom, S. E. (2011). Managing white-tailed deer: midwest North America. In *Biology and management of white-tailed deer* (pp. 514-549). CRC Press.

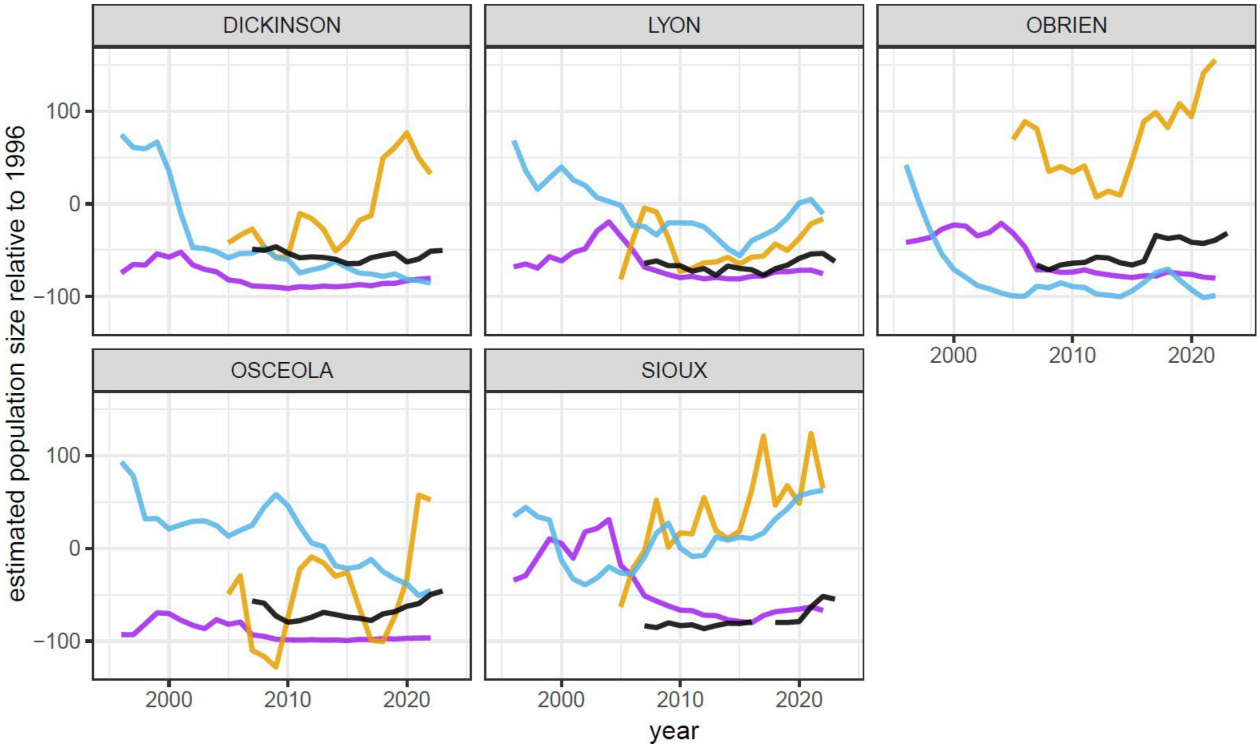
Wiseman, F. (2003). On the reporting of response rates in extension research. *Journal of Extension, 41*(3), 1–5.

Wywialowski, A. P. (1996). Wildlife damage to field corn in 1993. *Wildlife Society Bulletin*, 264-271.

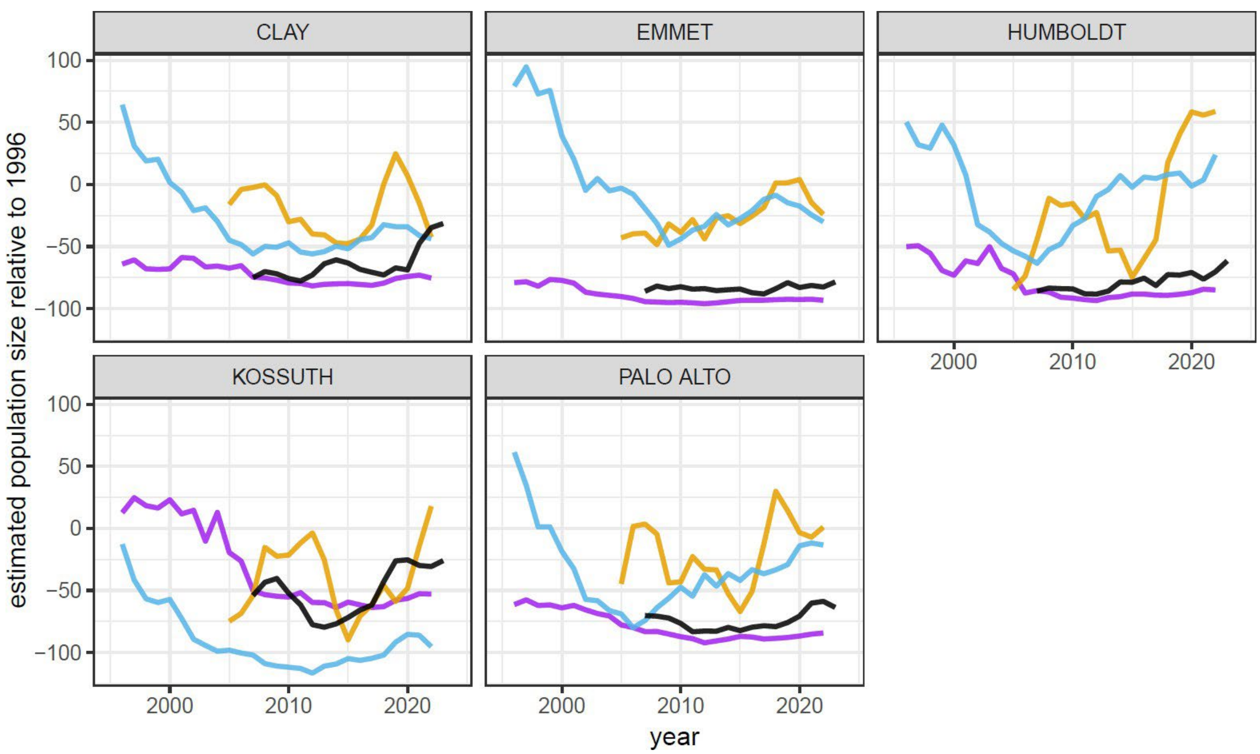
Appendices

Appendix A: County-level white-tailed deer density trends by Iowa Wildlife Management Unit, 1996–2023. The following legend denotes the data source in the subsequent 16 Wildlife Management Unit figures. We focused our effort on analyzing data from the spotlight survey to estimate deer density. We standardized density estimates with measures from three other indices so all measures occurred on the same scale. We then anchored population size on the estimated population size at the start of this time period, 1996, and display estimates as the percent difference to the starting estimate. We estimated the 1996 population size for each county as the mean of the two indices recorded at that time (antlered buck harvest and crash data). Thus, a population size of zero means that the population is estimated to be the same as in 1996.

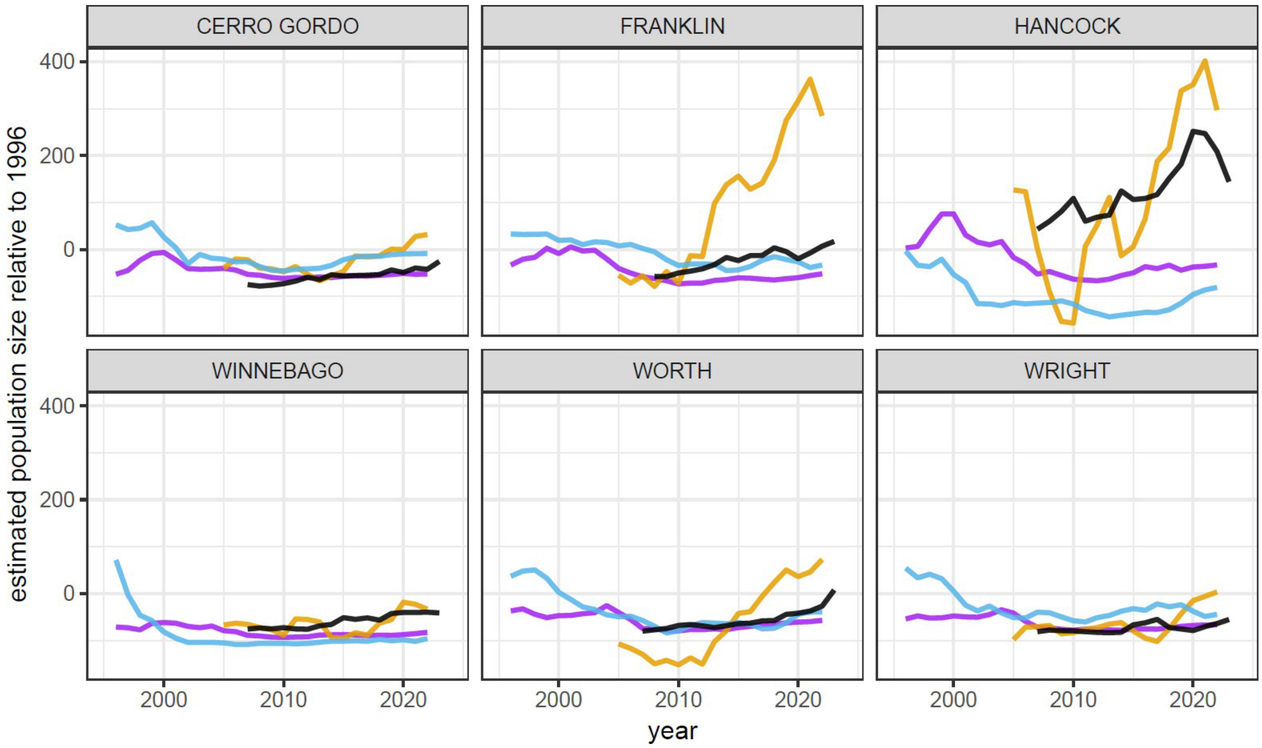




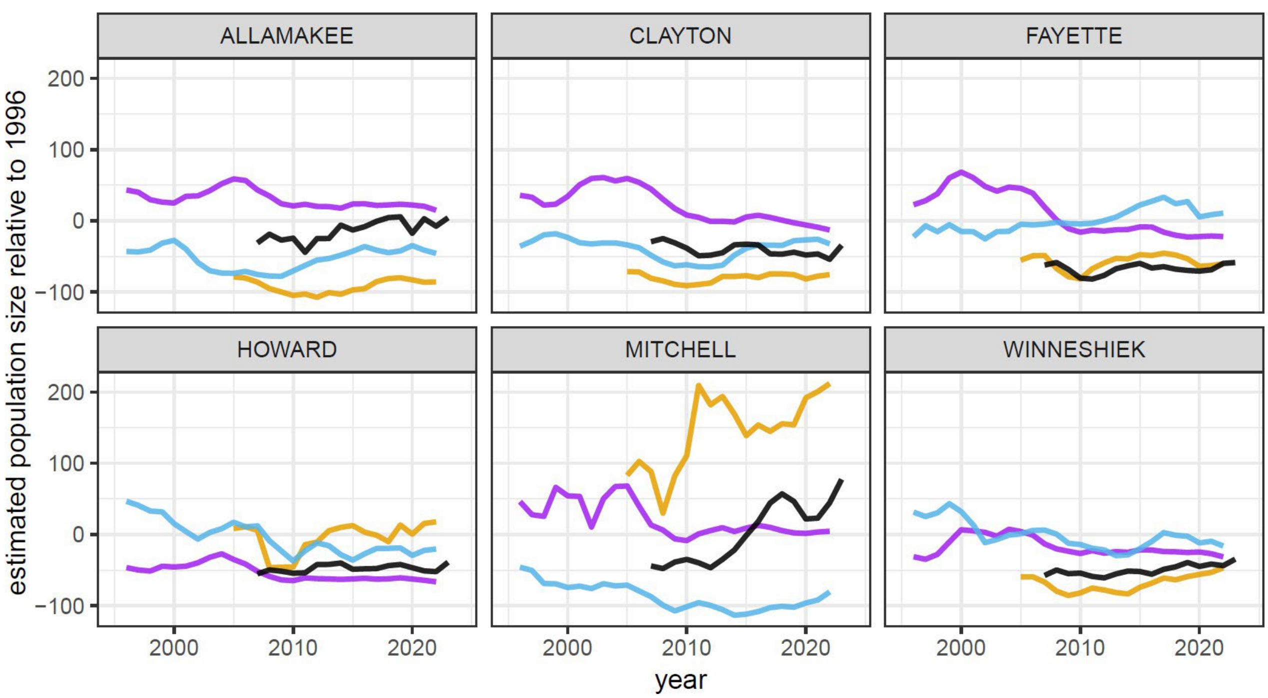
Wildlife Management Unit Figure A1: Great Lakes



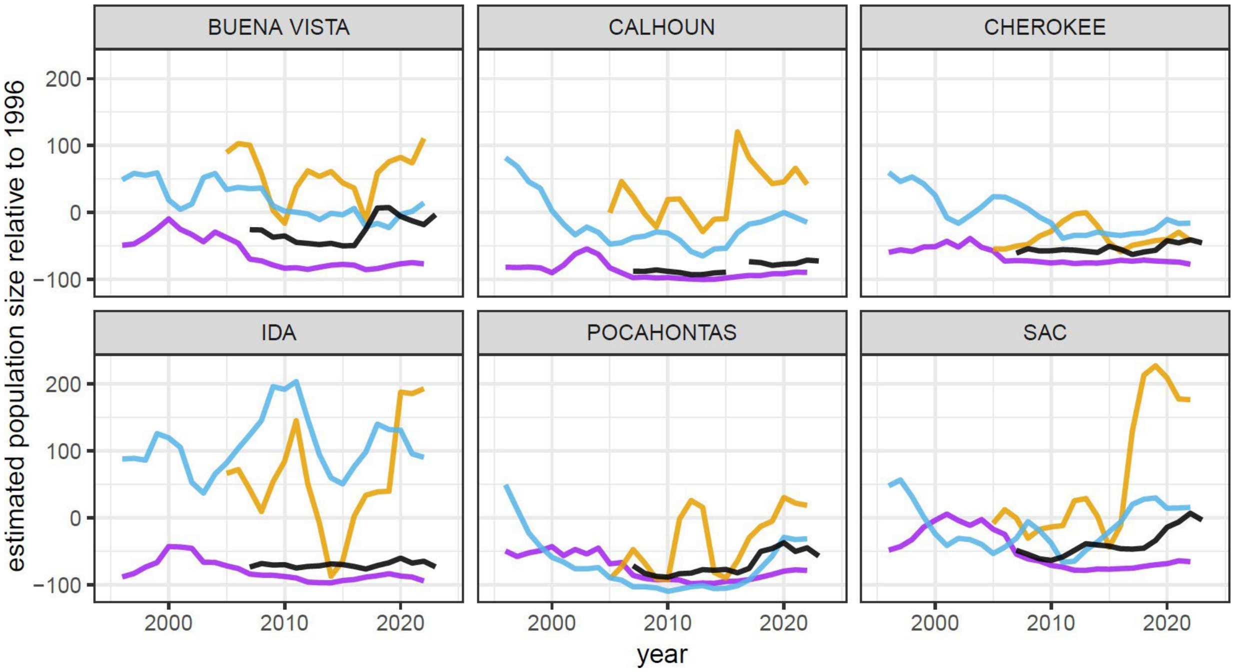
Wildlife Management Unit Figure A2: Prairie Lakes



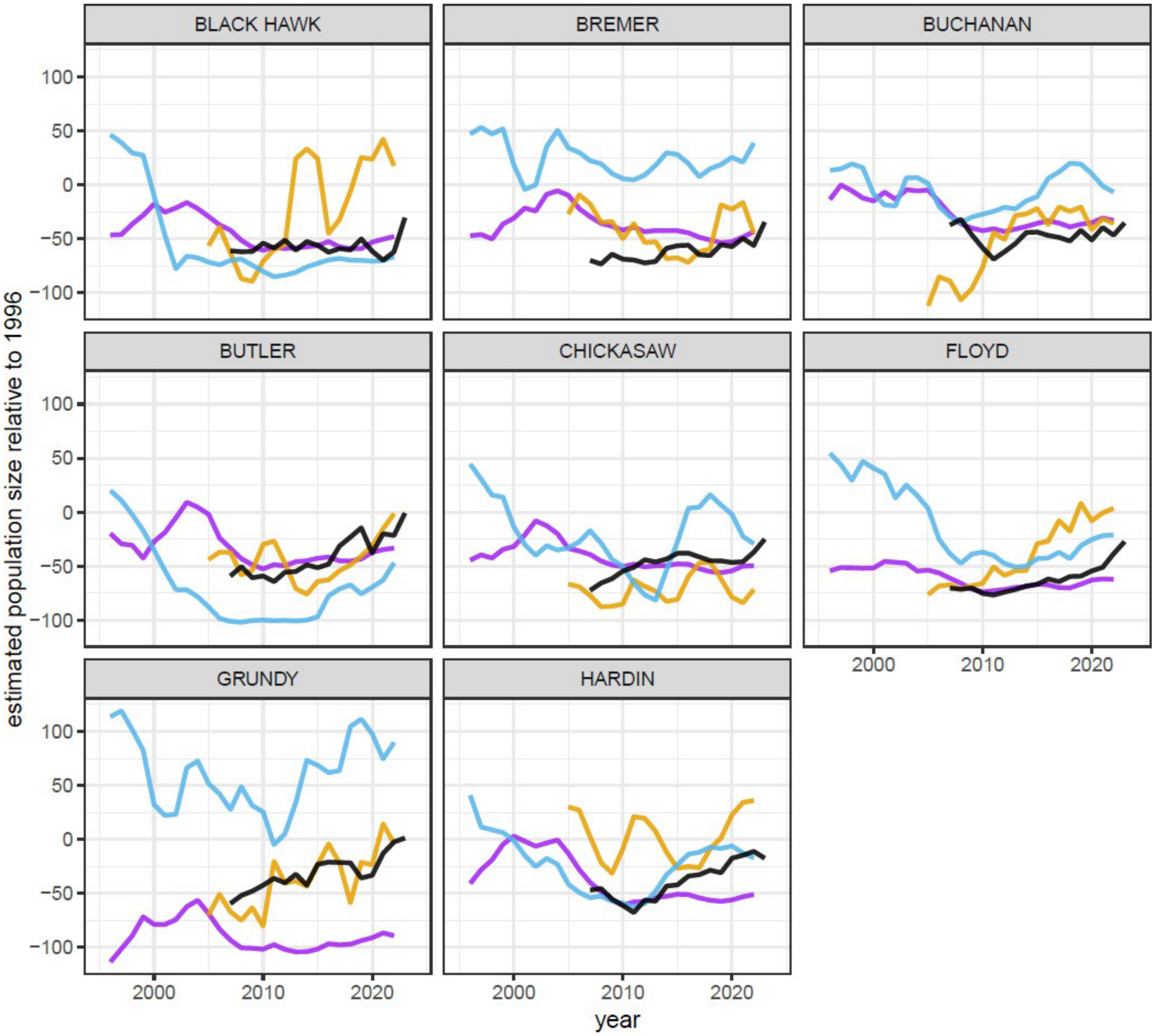
Wildlife Management Unit Figure A3: Clear Lake



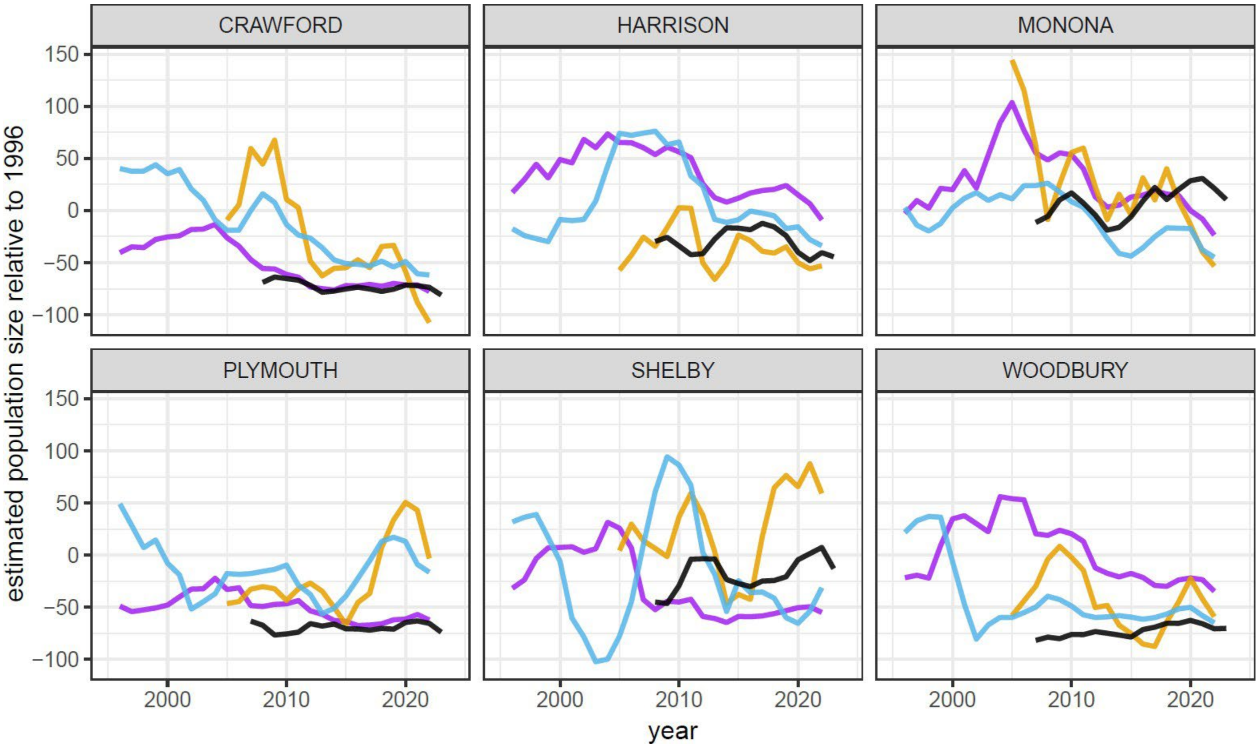
Wildlife Management Unit Figure A4: Upper Iowa



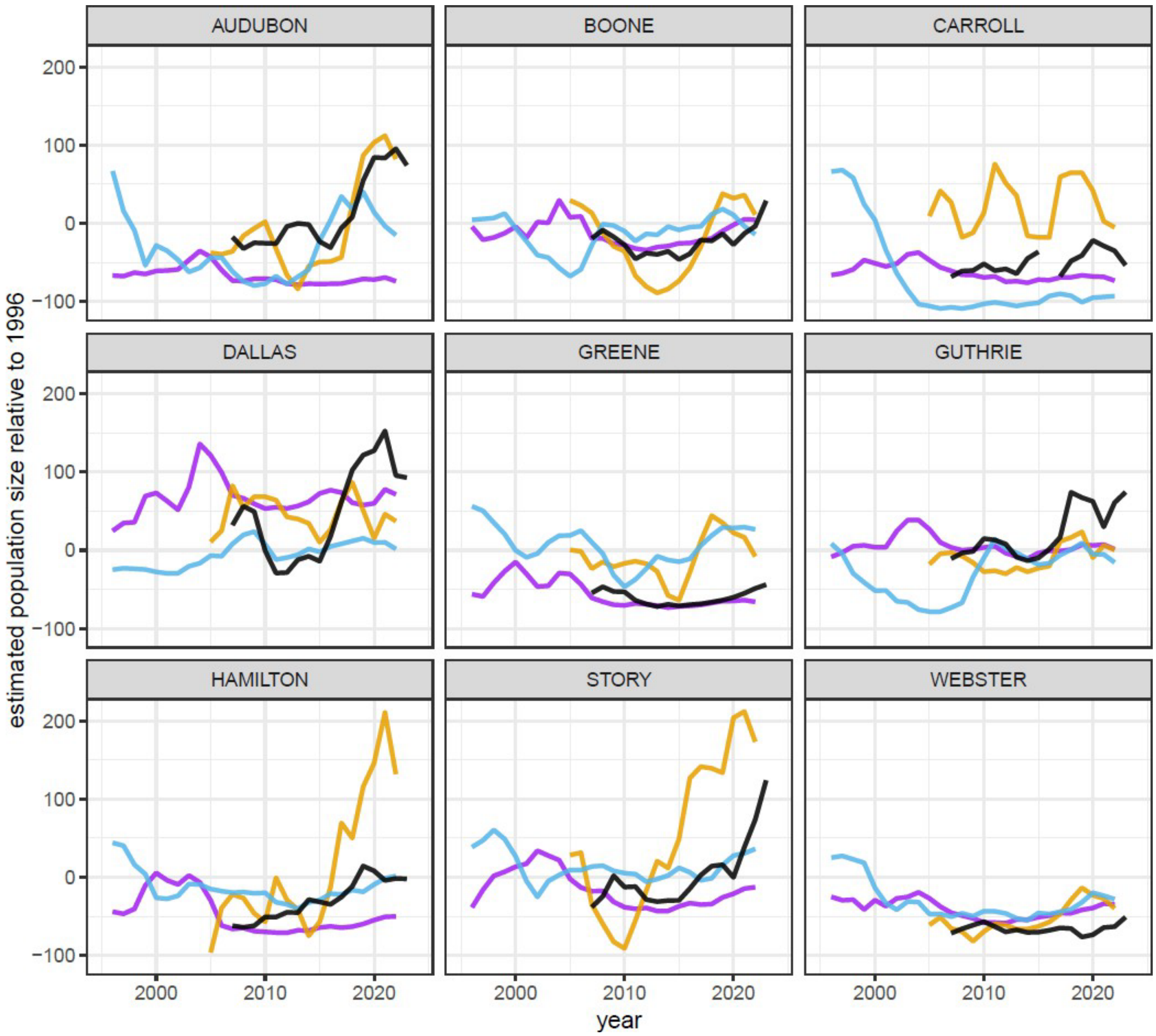
Wildlife Management Unit Figure A5: Blackhawk



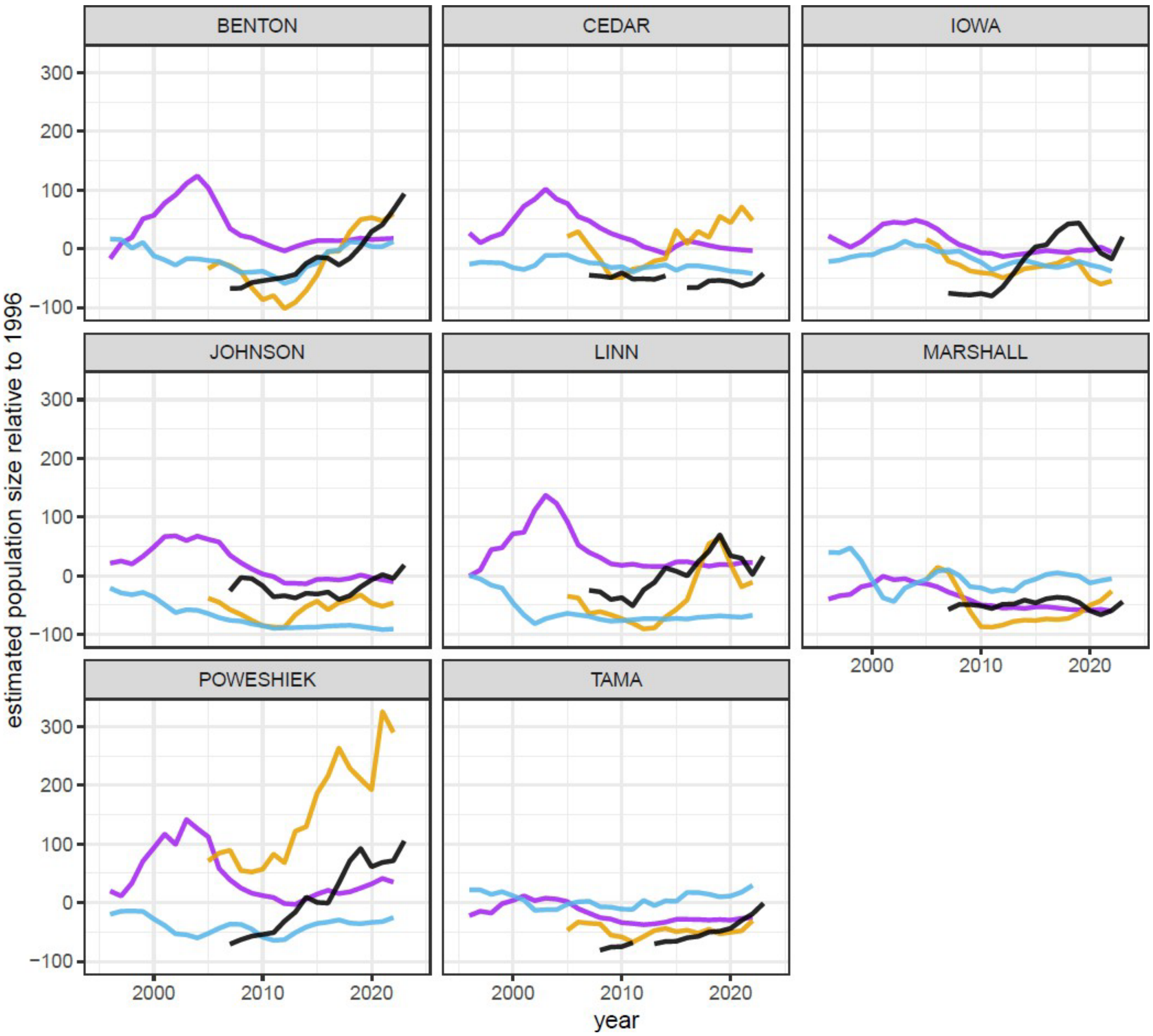
Wildlife Management Unit Figure A6: Cedar-Wapsi



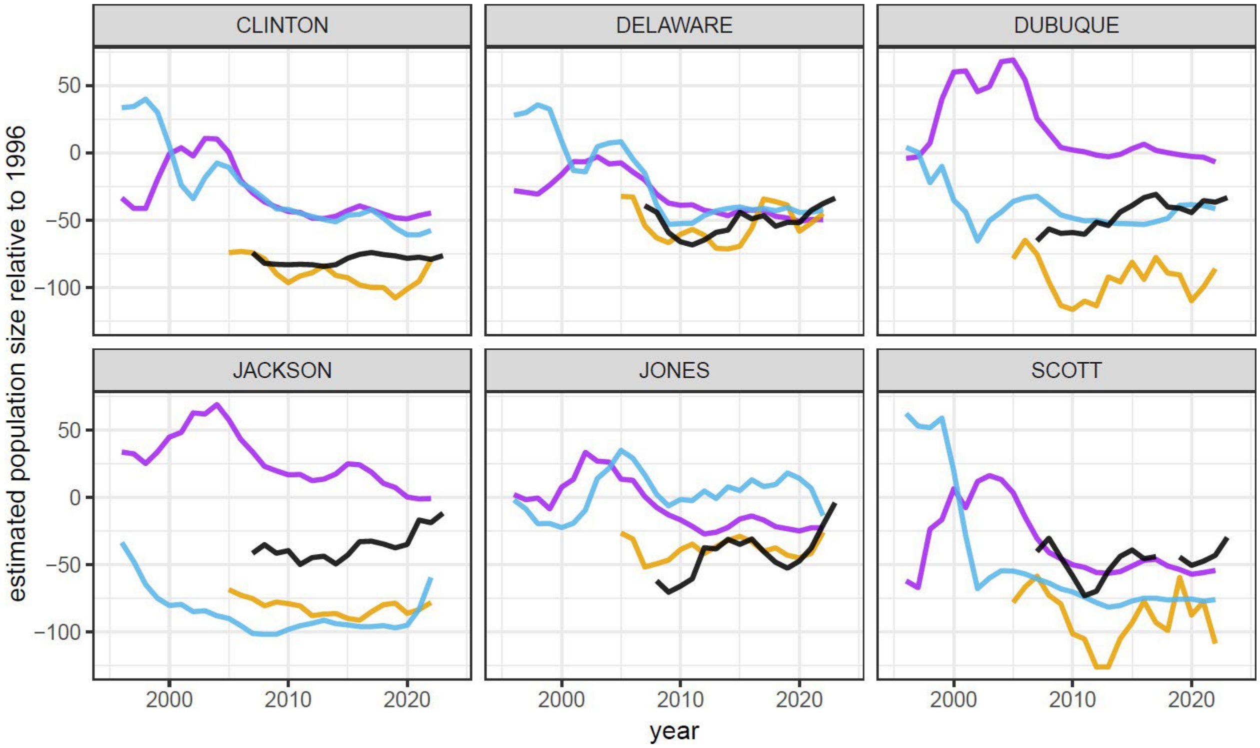
Wildlife Management Unit Figure A7: Missouri River



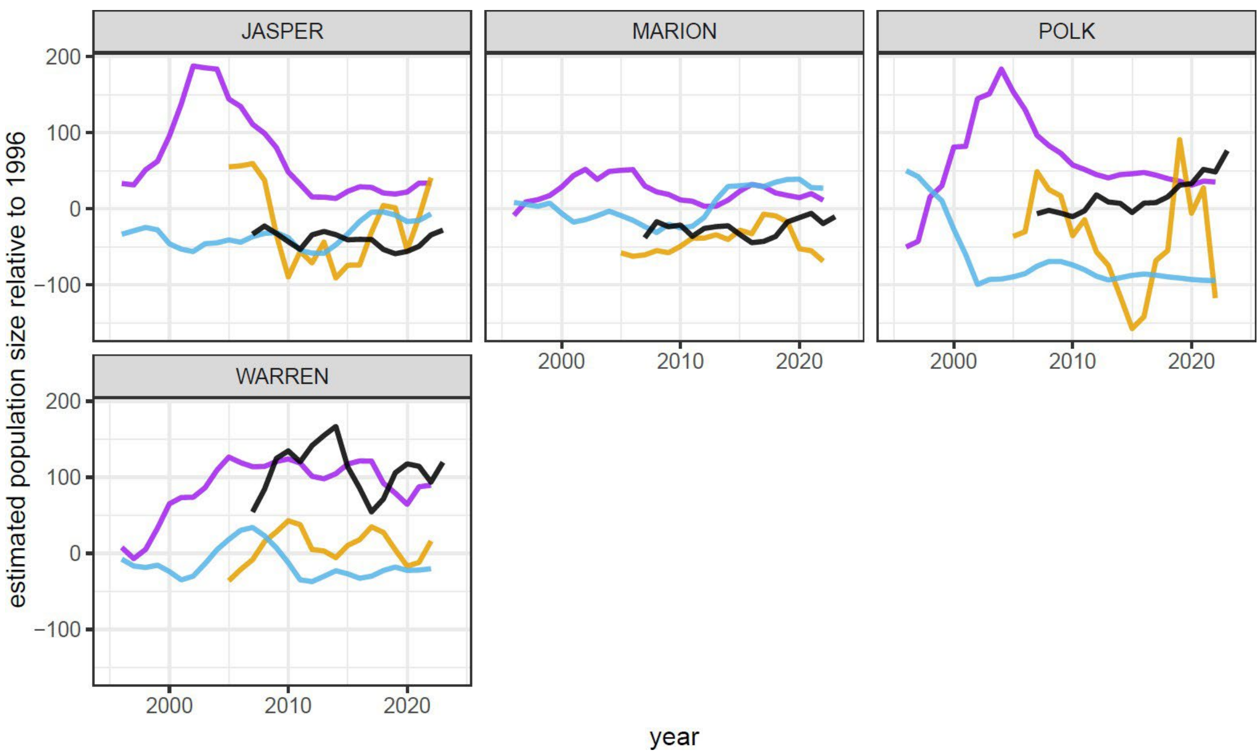
Wildlife Management Unit Figure A8: Saylorville



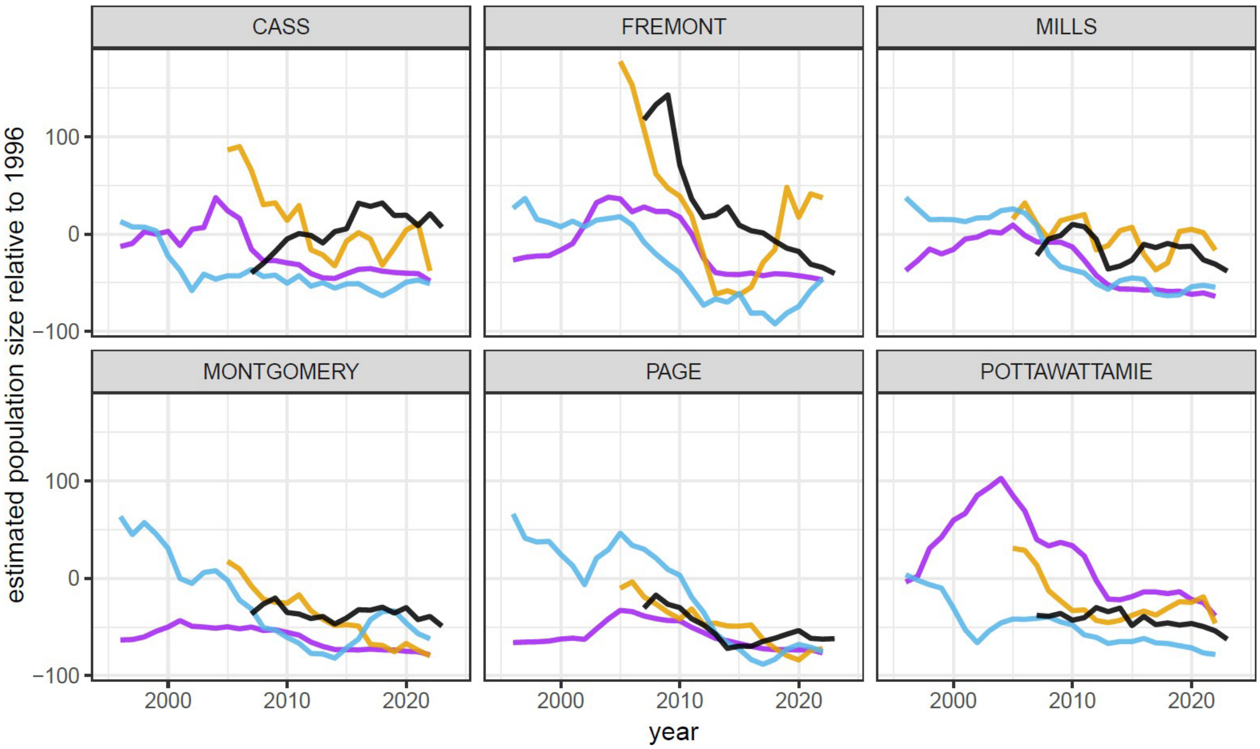
Wildlife Management Unit Figure A9: Iowa River



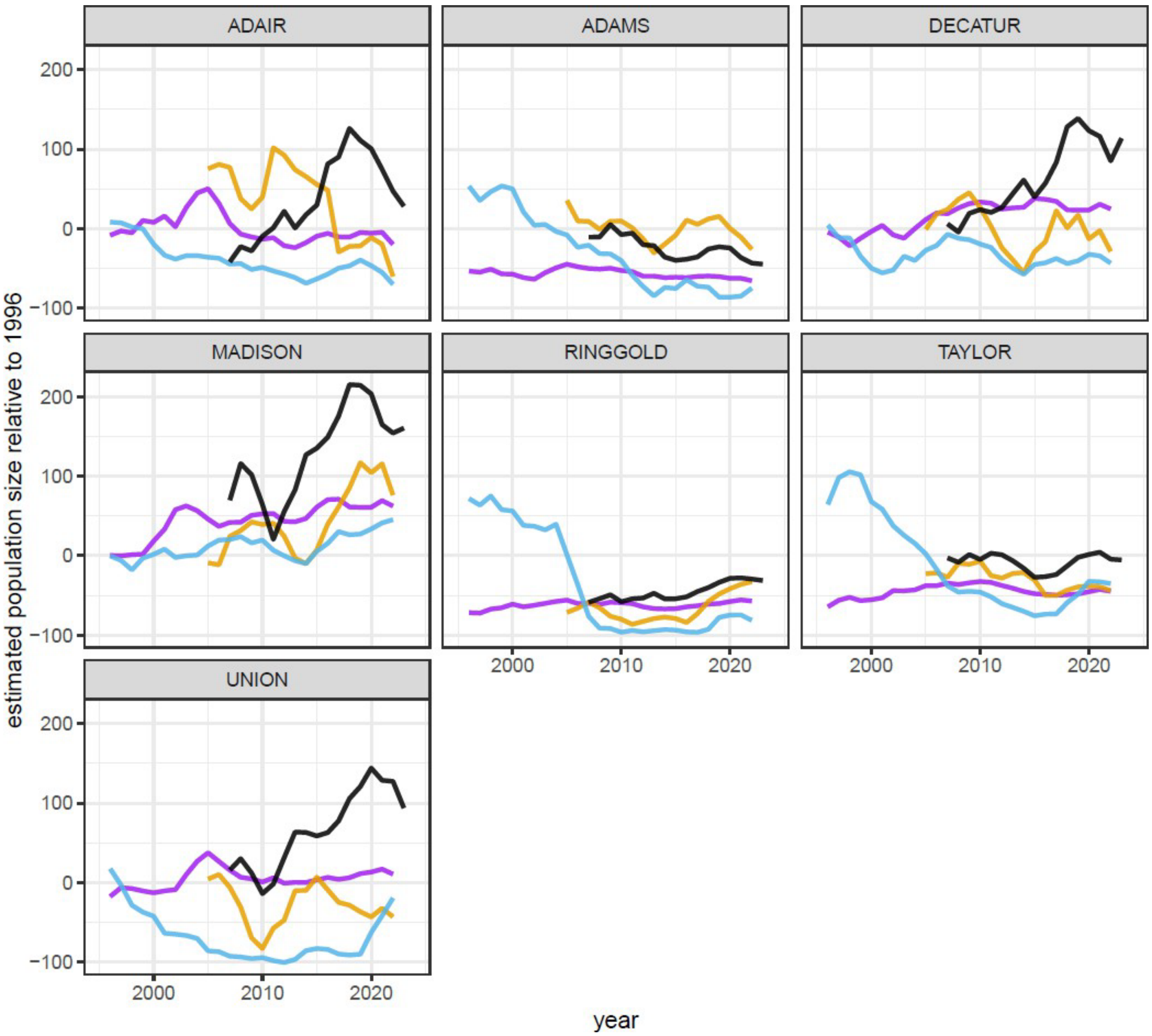
Wildlife Management Unit Figure A10: Maquoketa



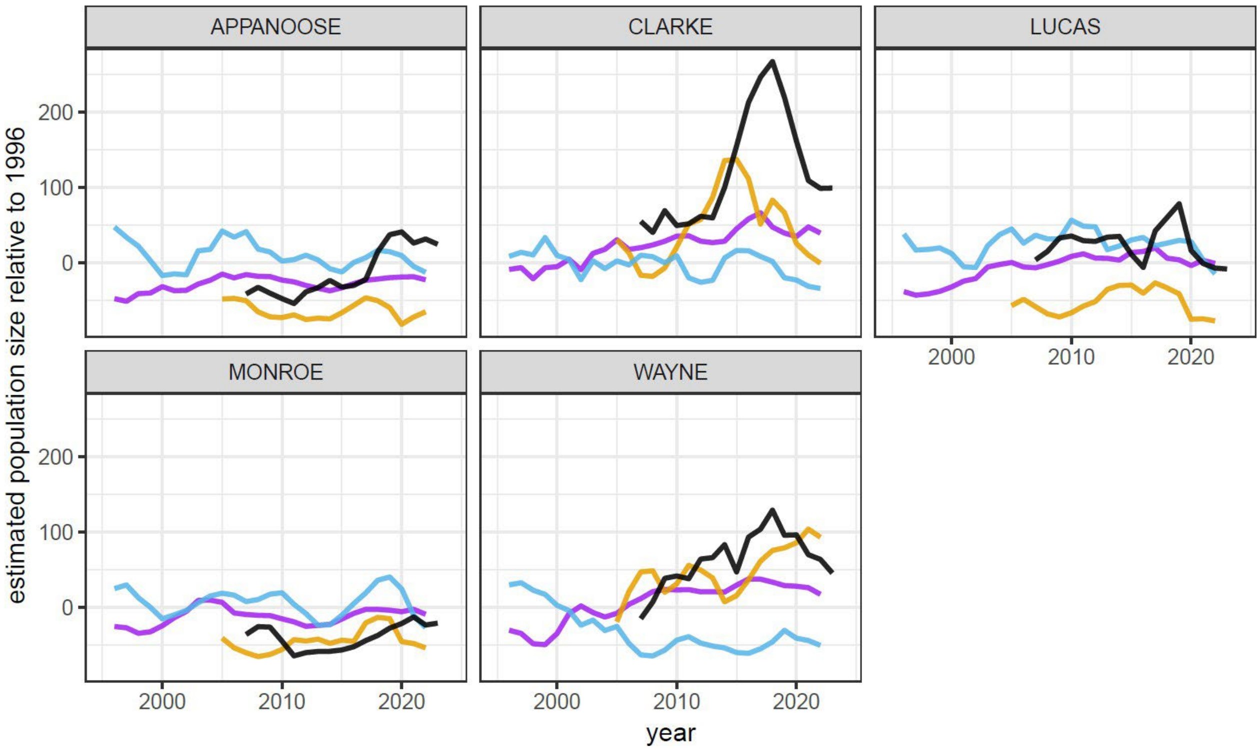
Wildlife Management Unit Figure A11: Red Rock



Wildlife Management Unit Figure A12: Nishnabotna

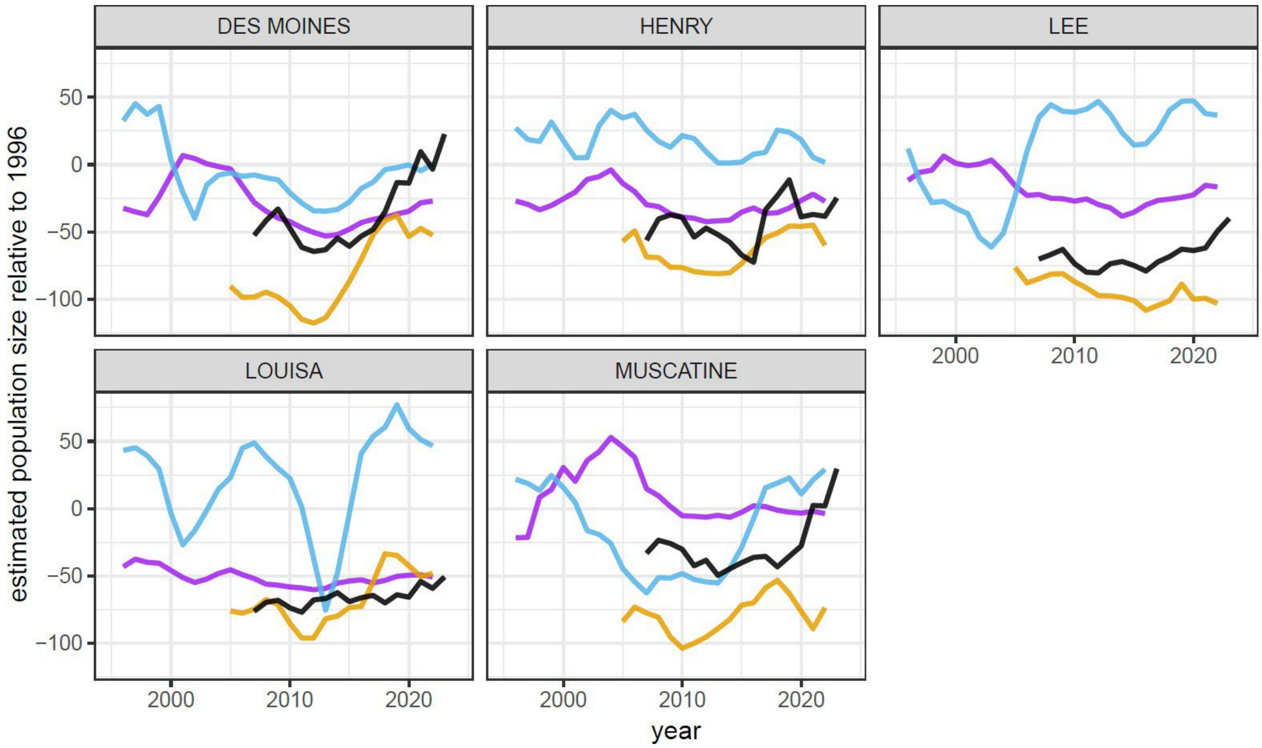


Wildlife Management Unit Figure A13: Grand River



Wildlife Management Unit Figure A14: Rathbun

Wildlife Management Unit Figure A15: Sugema



Wildlife Management Unit Figure A16: Odessa

Appendix B

Deer hunting and other deer/wildlife-based recreation in the state of Iowa have long provided economic development opportunities such as jobs and personal income for residents and contribute to human welfare in the region (Otto et al. 2007). An economic impact analysis estimated that deer hunting alone generates over $400 million annually in direct, indirect, and induced (e.g., wages and income) economic effects, and an additional ~$60 million in federal, state, and local taxes (Allen et al. 2012; note that dollar values have been inflated to reflect 2023$). Interestingly, deer hunting has influenced the value of non-agricultural land throughout the U.S. Cornbelt region and elsewhere in important ways turning woodlands into recreational investment opportunities and incentivizing critical habitat management activities including timber stand improvement and invasive species mitigation (Hupp 2019; Holzemeuller, Forest Real Estate Professional, personal communication, 2023; Mishra et al. 2023).

Additionally, about 837,000 people also spent about $711 million in 2011 to observe wildlife within the state. Unfortunately, the USFWS data are not species specific and so it is not possible to adjust data to represent only deer. Nevertheless, there is no doubt that deer play a significant role in these experiences. The available data note that 287,000 people identified big game as the primary wildlife experienced relative to wildlife watching activities around the home (within 1 mile of residence). The economic contribution of deer to the total expenditures for wildlife viewing is likely significant.

Appendix C

Table C1. Iowa Department of Transportation Iowa crash analysis data related to wildlife collisions. Data reflect crash years 2014-2023.

Crash Year	Fatal crash	Suspected Serious Injury Crash	Suspected Minor Injury Crash	Possible/ Unknown Injury Crash	total Injuries	Property Damage only	Total
2014	3	23	110	156	289	6,097	6,446
2015	0	40	129	153	322	7,068	7,470
2016	3	24	118	144	286	6,932	7,288
2017	3	33	129	157	319	7,416	7,827
2018	5	26	130	172	328	7,823	8,246
2019	1	30	123	157	310	7,587	7,979
2020	5	22	121	152	295	6,977	7,353
2021	5	32	122	173	327	7,385	7,791
2022	5	35	137	146	318	7,275	7,683
2023	5	26	129	170	325	7,752	8,131
10-yr average	3.50	32.30	145.20	181.00	358.50	7231.20	7621.40
Average with "DEER" adjustment [1]	3.47	32.04	144.04	179.55	355.63	7,173.35	7,560.43

[1]. Deer adjustment refers to 99.2% of wildlife collisions are related to deer collisions, and are deer-vehicle collisions (DVC), Huijser et al. (2007b).

In this next section, we provide a comprehensive overview of 1) methodology and data used in the deer-vehicle collision assessment, 2) the results, and 3) caveats.

Methodology - The Huijser-Ament approach

While accounting for all the dynamic costs of Deer Vehicle Collisions and Deer Aircraft Collisions (DVCs and DACs) is not possible there are methodologies that allow for snapshot accounting of certain outcomes, thus allowing analysts to establish lower bound cost estimates of DVCs and DACs for a given time period. To characterize and estimate costs of direct and indirect deer related vehicular and aircraft (e.g., runway) accidents in Iowa, we used the methodology developed by Huijser et al. (2009).

The Huijser-Ament approach uses relevant empirical data such as state Department of Transportation DVC reports, various damage cost estimates using state-level insurance data and other transaction evidence, and determines data weighting factors based on percentage or probabilities of certain DVC outcomes to calculate the costs of the average DVC. As noted in Huijser et al. (2009): “The advantage of using the costs of an average collision is that no assumptions have to be made whether a particular accident (past or future) did or will result in human injuries or fatalities; this is averaged out” (page 11). Furthermore, as described in Harmon et al. (2018), estimated and actual crash costs will differ in every crash due to the unique circumstances of every DVC. Because of this it is likely not possible to consistently qualify and quantify the finite costs of each individual past, present, or future DVC. As such, estimating average crash unit costs for average DVC circumstances provides a more consistent, and pragmatic way to estimate the impact of past and future DVCs. The Huijser-Ament method has been used extensively in national and state level DVC mitigation assessments (e.g., Normandeau Associates, Inc. 2012; Huijser et al. 2016; Riginos et al., 2016; Ament et al., 2022). The method was first featured in a national wildlife vehicle collision (WVC) reduction study presented to Congress in 2008 (Huijser et al., 2008).

The Huijser-Ament approach first calculates the average total cost per DVC which is a summed composite of the following average individual cost components per DVC based on proportion of these impacts across total DVCs in the state of Iowa: 1) human injuries, 2) human fatalities, 3) vehicle damage (repair or replacement), 4) towing, 5) emergency services (police, ambulance, fire services), 6) deer carcass removal and disposal, and 7) the salvage kill value of a lost deer (see an overview of DVC cost components listed in table B2). These component costs are then summed to calculate average total cost per DVC. The average total cost per DVC is then multiplied by the total annual known DVCs in the state. For our purposes, a comprehensive overview of all data used and computational assumptions is presented below.

Table C2. Overview of component costs associated with a Deer Vehicle Collision (DVC) and Deer Aircraft Collisions (DAC) in the state of Iowa. Includes type and general description of cost, and a brief overview of the primary data used in the cost assessment. Adapted from Huijser et al., (2009).

Cost component	Description of Cost	Primary Data
Human injuries per collision/accident	Average monetary costs to injuries of different severity (excluding fatalities) experienced during DVCs.	Iowa Department of Transportation (IADOT) ABCO (injury severity index excluding fatalities) data. IADOT Crash Analysis data utilizing a 10-yr average (table A1). Also: Harmon et al., 2018 and Blincoe et al., 2023.
Human fatalities per collision/accident	Probabilistic value of a DVC that results in a fatality based on the USDOT Value of a Statistical Life.	IADOT Crash Analysis data utilizing a 10-yr average (2014-2023 data; see table A1); USDOT Value of a Statistical Life (USDOT 2024).
Vehicle repair costs per collision/accident	Average repair or replacement cost of vehicles involved in a DVC. Range includes minor damages up to actual cash value (ACV) for vehicles declared a total loss.	Average 2023 DVC repair cost data based on media review of 8 states that have similar types of vehicles on the road as Iowa (based on data provided by J.D. Powers). IADOT Crash Analysis data utilizing a 10-yr average (2014-2023 data; see table B1).
Towing damaged vehicle	Cost is relative to percentage of vehicles that require towing from site of a DVC; these costs involve towing, temporary vehicle storage, and temporary replacement vehicle.	Cost data based on 2022-2023 towing transaction evidence from J.D. Power, & a 2023 review of car rental economy rates across range of national vehicle rental companies.
Accident attendance and investigation costs per collision/accident	These costs are relative to public emergency services (e.g., fire and emergency medical services) present at the crash scene, incident management services, police services, coroner or medical examiner services for fatalities.	Updated data from Blincoe et al. (2023) using U.S. Department of Labor's Consumer Price Index calculator inflation factors. Iowa Department of Transportation (DOT) KABCO (injury severity classification scale including fatalities) data.
Carcass removal/ disposal cost	This is the cost of removing the deer carcass after a DVC (e.g., roadkill) and appropriate disposal.	Based on 1) reported contractor costs for carcass removal and disposal, and 2) estimates provided by Shaw et al. (2023). Iowa Local Technical Assistance Program (ILTAP) Deer-Vehicle Crash

		Information Clearinghouse data on annual Salvaged and Unsalvaged Deer Carcasses.
Salvage kill value of lost deer	This is a proxy value of a deer killed in a DVC. It is based on the restitution value of deer in the state of Iowa.	Iowa Code 481A.130 Damages in addition to penalty — animals — ginseng. Cost based on antlerless deer.
Costs due to airport runway incursions by deer	Average repair cost of vehicles involved in a DAC.	Federal Aviation Administration Wildlife Strike Database; data 2014-2023. Also: FlightAware aircraft registration database to verify type of aircraft involved in reported DAC.

Cost of deer-vehicle collisions in Iowa – Results overview

Table C3. Valuation of key component costs of deer–vehicle collisions (DVC) on human property and health in Iowa. All monetary values presented in 2023$ (USD). See comprehensive methods below. Methods adapted from Huijser et al. (2009).

Cost Category	Cost (2023$)	Total Annual Costs	Unit Costs	Unit	Key Calculations	Assumptions
Human injuries per crash	$4,343	$32,838,693	$93,064	Human injury	SUM [(cost per injury type * % injury type) * % of DVCs that result in human injury] = ave. total annual human injury cost of DVCs	10-year DVC ABCO (injury only) averages for the state of Iowa (Iowa DOT data range: 2014-2023). Cost per injury data: Harmon et al., 2018; Blincoe et al., 2023. Dollar values inflated to 2023$ (U.S. Department of Labor's Consumer Price Index calculator inflation factors).
Human fatality per collision	$6,732	$50,896,807	$13,200,000	Human fatality	Weighted cost per fatality = ($13.2 million * 0.00051) * (average total DVCs) = total cost of DVC fatality	Each DVC results in an average of 0.00051% human fatalities in Iowa (IADOT Crash Analysis data utilizing a 10-yr average). The 2023$ USDOT VSL estimate is $13.2 million per person (US DOT 2024). Average 10-yr annual reported DVCs in Iowa (data: 2014-2023) = 7,560.
Vehicle damage costs per collision (repair or replacement)	$5,342	$37,159,846	$5,807	Per DVC	Cost per DVC * average total DVCs = total annual DVC repair cost	Average 2023$ repair costs in DVCs = $5,807 per car per DVC (based on 2023 media review of reported DVC repair costs in 8 states). Huijser et al., 2009: 92% of DVCs results in vehicle damage. Average 10-yr annual reported DVCs in Iowa (data: 2014-2023) = 7,560.
Towing and temporary car rental	$298	$2,256,334	$829	Per towed car	Cost per towed car * (percent of DVCs that need towing* average total DVCs) = average total cost of towing	Iowa-specific weighing factor = 35.8% of DVCs in Iowa require towing services. Average IA insurance claims for towing services and car rental following a DVC. Data were compiled using IA insurance claims covering the dates between Jan 1, 2021 and Dec 31, 2023. Data averaged from a total of 12,828 individual DVC claims for towing and subsequent temporary car rental.

Emergency service costs	$109	$821,205	$109	Per DVC	Emergency service cost = Weighted response cost per DVC * average # of DVC	Blincoe et al. (2023) emergency response cost data adjusted to 2023$ and weighed by IADOT Crash Analysis data utilizing a 10-yr average KABCO data relative to % of IA DVCs classified across injury categories (Data range 2014-2023).
Deer carcass removal & disposal per DVC	$187	$2,271,115	$187	per DVC	Cost of carcass removal = cost per carcass * average # of deer carcasses	Cost per carcass removal and disposal is the average of reported contractor costs, and DOT estimates provided by Shaw et al. (2023). Iowa Local Technical Assistance Program (ILTAP) Deer-Vehicle Crash Information Clearinghouse data on annual Salvaged and Unsalvaged Deer Carcasses (12,145 carcasses per year).
Value of deer involved in DVC [1]	$750	$9,109,000	$750	Per DVC	Value of deer = restitution value * average # of DVC	The current restitution value of an antlerless deer in Iowa is $750. Iowa Local Technical Assistance Program (ILTAP) Deer-Vehicle Crash Information Clearinghouse data on annual Salvaged and Unsalvaged Deer Carcasses. (12,145 carcasses per year).
Total average cost	$17,012 / DVC [2]	$128,617,976/ year [2]				

[1.] The value of a lost deer is not included in our final overall cost per DVC, or in estimated average total costs of DVCs per year. Data are presented for reference only. [2.] Data presented includes rounding.

Human injuries per collision/accident

The direct medical cost of a human injury incurred during a DVC can be categorically estimated based on injury severity. Iowa police crash reports use what is called the KABCO injury classification scale to report crash and injury severity (the Iowa scale translates to K = fatal, A = suspected serious/incapacitating injury, B = suspected minor/non-incapacitating injury, C = possible injury - complaint of pain/injury, O = uninjured; IADOT 2023). The Iowa DOT ICAT (Iowa Crash Analysis Tool) classifies accidents by KABCO designation. Huijser et al. 2009 utilized a different scale of injury severity called the Abbreviated Injury Scale (AIS). We adapted the Huijser approach to allocating average monetary costs to injuries of different severity experienced during DVCs using the Iowa DOT KABCO data as guided by Blincoe et al. (2023). We summarized 10-year DVC KABCO averages for the state of Iowa (IADOT data range: 2014-2023). We then use and updated data provided by the U.S. DOT Federal Highway Administration's Crash Costs for Highway Safety Analysis (Harmon et al. 2018) and additional data from Blincoe et al. (2023). Harmon et al. (2018) and Blincoe et al. (2023) present state-by-state crash unit costs for use with the FHWA Highway Safety Benefit-Cost Analysis Guide. All financial data were inflated to 2023$ (using U.S. Department of Labor's Consumer Price Index inflation calculator). We then apply the Huijser equation to data: Formula = SUM [(cost per injury type * % injury type) * % of reported wildlife caused accidents that result in human injury that are attributable to deer] to calculate the average weighted human injury cost per DVC in Iowa. Huijser et al. (2007b) estimate that 99.2% of all reported wildlife– vehicle collisions in the United States relate to deer. The costs accounted for relative to a DVC incurred injury variously include lost earnings, lost household production, direct medical costs (e.g., emergency room and extended hospitalization as needed), roadway travel delays, vocational rehabilitation, workplace costs, administrative, legal, and pain and lost quality of life (see Harmon et al. 2018 for comprehensive overview of methods and data).

It should be noted that accidents caused due to avoidance actions (e.g., swerving to avoid contact with deer) are not necessarily reported as a DVC and likewise may not be part of the IADOT dataset. This is notable because some studies suggest that accidents caused by avoidance driving have a higher chance of experiencing significant damage to vehicle, or leading to injuries and fatalities because when vehicles swerve in an attempt to avoid hitting deer there is a higher chance of hitting other vehicles or roadside features such as trees, guardrails, retaining walls, or rolling over (Savolainen and Ghosh 2008).

Human fatalities per collision/accident

To calculate the probabilistic value of a DVC that results in a fatality, following Huijser et al. (2009) we start with the USDOT's estimate of the "value of statistical life" (VSL). The VSL is technically defined as, "the additional cost that individuals would be willing to bear for improvements in safety (e.g., reductions in risk) that, in the aggregate, reduce the expected number of fatalities by one. This conventional terminology has often provoked misunderstanding on the part of both the public and decision-makers. What is involved is not the valuation of life as such, but the valuation of reductions in risks (USDOT 2021, page 1). This value is used as a proxy for estimating risk-associated fatalities. We then calculate the percent of reported DVCs in Iowa that result in a fatality. Each DVC results in an average of 0.00051% human fatalities in Iowa (IADOT Crash Analysis data utilizing a 10-yr average; 2014-2023). The USDOT VSL estimate is $13.2 million per person for analyses using a base year of 2023 (US DOT 2024).

Vehicle repair costs per accident

Vehicle repair costs will vary considerably by accident and are a function of damage sustained, vehicle type, vehicle age, and general condition of the vehicle prior to accident. We followed Huijser et al. (2009) assumption that 92% of DVCs result in vehicle damage. We updated Huijser et al. (2009) average repair cost data to represent 2023 repair costs based on a literature review of online news media for 8 states that have similar types of trucks and cars on the road as Iowa (based on top 10 vehicle lists for given states; Hawley 2023). Average 2023$ repair costs in DVCs = $5,897 per car per "wildlife" collision (includes all wildlife); as per Huijser et al. (2009) it is assumed that 99.2% of all reported wildlife– vehicle collisions are related to deer.

For context regarding the nature of vehicle damage costs of a DVC, it is recognized that deer are the largest mammal encountered in direct impact accidents in the U.S. Midwest excluding stray livestock, yet encounters with livestock are comparatively uncommon (Donnelle 2024). Additionally, average DVC repair costs have been trending upwards over the years due to a number of factors including changes in consumer preferences for more expensive vehicles. Sport Utility Vehicles (SUV) and trucks represent 85% of new car purchases in Iowa (AFAI 2022) and on average trucks and SUVs are more expensive to maintain and repair than sedans and smaller passenger cars (Betterton 2023). Likewise, technological automotive advancements resulting in more complex engines and drivetrains (e.g., hybrid systems), as well as increased use of aluminum and composite materials per vehicle tend to drive up the cost associated with vehicle damage repair or vehicle replacement (Edmonds 2018). On the other hand, there are a few trends that tend to temper the cost of DVC repairs in the state of Iowa. The average age of Iowa vehicles is slightly higher than the national average (13.7 compared to 12.2; AFAI 2022), likewise the average age of cars purchased in the used car market in Iowa is greater than the national average (7.67 years compared to 6.47 years; Papandrea 2022).

There may be a number of additional costs that are not accounted for in this current assessment yet are relevant in DVC cases where there is property damage. These costs relate to absence from work or school due to transportation challenges, emotional or psychological stress, increased insurance premiums, and transaction costs associated with repair and insurance logistics and paperwork. Interestingly, vehicle collisions with wildlife increased 7.2% during the COVID-19 Pandemic (July 2020 and June 2021) (LaChance 2022). Based on State Farm Insurance data, this increase was attributed to generally higher speeds on highways and rural roads due to fewer cars on the roads (LaChance 2022). As such, it should be acknowledged that year-to-year variability in DVC occurrence can be notable.

Towing required due to DVC

Not all DVCs require having a car towed from the accident site. Prior analysis (Huijser et al. 2009) assumed that 25% of DVCs result in the need of towing services, an assumption based on a referenced national level assessment conducted in 1989. Because speed limits have increased nationally since 1989 on highways and rural interstates (in 2005, for example, the speed limit on rural interstate highways in Iowa increased from 65 mph to 70 mph), an Iowa-specific weighing factor was derived by examining percent of DVCs by accident type (IADOT Crash Analysis data utilizing a 10-yr average. Data range 2014-2023). As such, 35.8% is the weighing factor of DVCs that we assume result in the need of towing services in Iowa. This calculation is based upon an assumption that 100% of all DVCs that result in human injury and 33% of "damage only" DVCs require towing services. For costs in Iowa, we assume the following cost components of the need for towing services (involving direct cost of towing and related ancillary costs): a one-time $75 dollar hook-up fee, plus $4.00 per mile (assume an average of 30-mile tow truck distance per accident) (Grupa 2023) = $75 + $120 = $195 for towing. Beyond the direct costs of towing, assume 1-day storage lot fee = $25/ day (after storage, car would then be towed to collision repair shop). Assume 1-day rental car = $70/ day (based on 2023 national car rental data for small vehicle economy rates). Finally, there would be an accident report fee of $4.00 in Iowa (this is a required service fee charge as of July 2023 in the state of Iowa). Accident reports are needed for car owners to file for insurance.

Ultimately, the cost of towing as associated with a DVC is quite variable situation-to-situation and is a function of: the time-of-day an accident occurs, whether it occurred on a weekday vs. weekend or holiday, the surrounding terrain, vehicle type, and severity of damage. Related costs that are additional to towing and temporary car rental per DVC are also quite variable and relate to relevant vehicle storage needs, timeline for repairs, prolonged car rental if required, and transaction costs beyond accident reporting for insurance purposes. These costs are not accounted for.

Accident attendance and investigation costs per DVC

Emergency services include fire and emergency medical services (EMS) traveling to and attending a crash scene, various incident management services, police services, and coroner or medical examiner services for fatalities. Blincoe et al. (2023) analyzed police and fire response to car accidents in the U.S. They estimated the percent response by police only or police and fire including paramedic/ambulance services so as to estimate public response cost per accident. Estimated total costs per accident are a function of which emergency service entity responds to an accident, severity of accident, time spent at accident site, salary and fringe benefits for police, fire, and EMS personnel typically involved, urban versus rural factors such as travel time and available resources). Fire department response is on average 113% more expensive than police only response. Further, it is assumed that all accidents where fire services respond, police also responds so all fire response accidents also account for the additional cost of police presence. There are different costs of response and incident management per type of accident based on the Maximum Abbreviated Injury Scale (MAIS). Because the IADOT uses the KABCO scale to classify accidents within their ICAT - Iowa Crash Analysis Tool and not the Abbreviated Injury Scale (AIS) as used in Blincoe et al. (2023), we recategorized the Iowa KABCO data to correspond to the AIS scale. Blincoe et al. (2023) public response cost data were then adjusted to 2023$ and weighed by IADOT data relative to percent of Iowa DVCs classified across KABCO (MAIS equivalent) categories.

Carcass removal/ disposal cost

When a deer is killed and present during a reported DVC or is otherwise found as roadkill on the side of a road or highway, for safety and human and animal health concerns, the carcass must be removed and disposed of in a legally appropriate way. The cost of removal and disposal involves: labor to pick up the carcass (an adult male deer can weight over 200 lbs), a vehicle to transport the carcass, and any direct costs of the disposal process including possible tipping fees for municipal waste facilities or animal compost site. The responsibility of paying these costs often falls on local and state government, who maintain staff to conduct these and other activities. For this analysis the cost of deer carcass removal and disposal is the average cost per deer from reported private contractor costs, and DOT estimates provided by Shaw et al. (2023). Private contract rates are assumed to average $232 per deer using updated interview data (Buckley 2018). Shaw et al. (2023) report costs of $181 per deer in Iowa. It is assumed that every DVC leads to 1 deer carcass. Iowa Local Technical Assistance Program (ILTAP) Deer-Vehicle Crash Information Clearinghouse data were used to estimate annual Salvaged and Unsalvaged Deer Carcasses (an average of 12,145 carcasses per year across the years 2004-2013).

Deer salvage/kill value

The value of a deer lost in a DVC can take on many forms. Huijser et al. (2009) calculate the value of a deer relative to the value of a harvested deer in a hunting context, factoring a USFWS value of a deer divided by a calculated hunter success rate. The USFWS value for a deer is based on research values available for hunter willingness to pay for a season of hunting (e.g., USFWS 2003). Lacking more up-to-date data, a simply proxy approach is to use a replacement value. DVCs are accidental and therefore they are exempt from any legal context for restitution payments (e.g., legally enforceable penalty payments relative to the illegal taking of wildlife, such as hunting out of season). Nevertheless, restitution value can serve as a replacement value for the animal in question. The current restitution value of an antlerless deer in Iowa is $750 per deer. The restitution value of antlered bucks ranges from a minimum of $2,000 for 150 gross inches or less to a minimum of $5,000 for a buck more than 150 gross inches. There is no available data regarding the nature of deer carcasses, so this analysis simply uses the restitution value of an antlerless deer to serve as the lower bound cost. As with carcass removal estimates, we used Iowa Local Technical Assistance Program (ILTAP) Deer-Vehicle Crash Information Clearinghouse data to estimate annual lost deer due to DVCs (12,145 carcasses per year across the years 2004-2013).

Deer-aircraft Collisions (DAC)

DACs are costs associated with airport runway incursions. The FAA maintains a wildlife strike database and categorizes all wildlife-based collisions by species. Along with log data regarding place, time, and overall nature of a DAC, the FAA Wildlife Strike database also provides a detailed overview of each DAC in terms whether human injury was sustained, the severity of injury, the type of damage incurred, and an estimate of repair costs. Iowa has eight commercial airports and 96 general aviation airports. As noted above, there have only been two reported DAC over the past 10 years (2014-2023), and both occurred at general aviation airports. In Iowa likelihood of a DAC at a commercial airport tend to be much lower compared to general airports due to their size, urban location, high area traffic, and often multiple layers of fencing. General aviation airports are typically located in more open areas adjacent to small or midsized towns or in semi-rural areas with fewer impediments (such as traffic and fencing). Therefore, smaller aircraft are probably the most likely to experience a DAC. This is notable because smaller aircraft are more vulnerable to any kind of damage relative to compromising the safety of flight (SKYbrary undated).

The Iowa DNR provides deer shooting permits for free to airports to address deer in runway/safety areas at a request from airports. An average of 13 deer are harvested on airports across the state each year with these shooting permits (Kellner personal communication, 2024). Airports also contract with USDA Wildlife Services to address wildlife issues, including deer, at airports. In Iowa, most of this time is focused on avian issues.

Three important notes. One, with regard to our DVC cost analysis, we used wildlife related collision data relative to total collisions per year and the nature of these collisions (e.g., reported injuries and vehicle damage) as recorded by the Iowa DOT. We adjusted these data by 99.2% to eliminate non-deer wildlife as per Huijser et al. (2007b). As discussed in Shaw (2023), the IA DOT maintains detailed animal crash records based on law enforcement reports, but not all such collisions are reported. Drivers in Iowa are not obligated to report a crash if total property damage is estimated (by the driver) to be less than $1500 and there were no discernable human injuries. Shaw (2023) estimates that about 40% of DVCs are not reported to law enforcement and therefore not recorded by the IA DOT. It should also be recognized that there may be a significant number of DVCs that go unreported due to lack of insurance (Acharya et al. 2023).

The second note, is that there is another important cost associated with a DVC and this is the concomitant lost value of a deer killed relative to its potential contribution to hunting and other wildlife related recreation. This value however is somewhat more abstract in nature and is often based on contingent valuation surveys that estimate the foregone expected hunting value per deer based on average hunter "willingness to pay" to harvest a deer times the probability that a given deer would have been harvested (Huijser et al. 2009; Conover and Conover 2022). To our knowledge there are no recent studies relevant to Iowa or the U.S. Midwest exploring this willingness to pay (the Huijser et al. 2009 study utilized data from 1992). As such we chose to exclude this type of estimate from our current study. Nevertheless, to provide a simple baseline proxy value estimate for reference, using the current restitution value of an antlerless deer in Iowa associated with an illegal taking of a deer of $750 per deer (as per Iowa Code 481A.130), there may be an additional average cost per year of ~$9,109,000 in lost deer value (again, this is not included in our primary analysis).

The final note, while trains do have collisions with wildlife including deer, we could not determine if deer have ever caused any reportable damage to a train, train related infrastructure, or caused any human injury in the state of Iowa. Studies have reported that the impact of large ungulates on a train have led to disruptions in train scheduling and some direct costs to trains (Bhardwaj et al. 2022). Nevertheless, most studies suggest that a train hitting a single deer or group of deer results in minimal damage to the locomotive and generally present minimal risk of injury to train personnel or passengers (Nezval and Bil 2020).

Appendix D

In Iowa, corn and soybeans are the primary crops, typically grown in rotation, although continuous corn systems are somewhat common in the northern and central counties in the state (St. Clair and Gassman 2021). In some cases, deer can cause direct economic damage to planted acreage from grazing, browsing, trampling, bedding, or knocking over crops (which singularly or in combination can negatively impact crop yield and or quality). There can also be significant costs associated with destruction of farm infrastructure (e.g., damage to fencing, irrigation, drainage, etc.) leading to increased repair or replacement costs. Additionally, there can be indirect costs incurred such as cost of any deer mitigation or prevention management or deterrent infrastructure (e.g., fencing, repellants, scare devices, landscaping). Overall risk management costs can also increase in response to wildlife management as associated with crop insurance premiums (when available) and transaction costs related to acquiring desired coverage and filing claims. It should be recognized that there can also be significant non-monetary costs associated with negative deer and other wildlife interactions that are of a more emotional nature and often associated with uncertainty and stress (Bergstrand 2024), nevertheless this type of cost is beyond the scope of the work presented here, yet worthy of recognition.

The following are the different ways in which corn and soybean farmers can experience direct and indirect economic loss from deer. The financial loss is characterized by direct impacts to crops, damage to farm infrastructure, as well as wildlife management actions taken (MacGowan et al. 2006; Paulin et al. 2022; Boyer et al. 2024):

Variously reducing crop yields:

- Consumption of corn grain and soybeans (lowers total salable yield).
- Damage caused to planted acreage from browsing and grazing with defoliation limiting plant growth and increasing potential weed pressure.
- Damage caused by trampling, bedding, knocking over crops (which can negatively impact yield).
- Depending on season (e.g., grain filling period), deer grazing can increase likelihood of disease infection such as from common smut (*Ustilago maydis*) spores, which in turn can negatively impact yield.

Non-crop damage:

- Destruction of infrastructure (fencing, irrigation, drainage) leads to repair or replacement cost.
- Direct costs of mitigation/ preventative management (e.g., scare devices, repellents, edge of field vegetation/habitat management).

Indirect costs:

- Crop Insurance premiums, transaction costs associated with claims.
- Forced changes to cropping system (e.g., change in rotation, crops, inputs, available time/ labor).
- Emotional toll and impact on quality of life.

Various regional or state-specific studies have occurred that have estimated wildlife depredation damage on commodity crops (e.g., Wywialowski 1996; Tzilkowski et al. 2002; Drake et al. 2002: Hinton et al. 2017; Paulin et al. 2022). Many studies combined farmer survey data and on-the-ground assessment. Other studies have used federal crop insurance data to estimate lower bound damage costs of wildlife to crops (McKee et al. 2021). Because numerous wildlife can cause damage to crops, it is often difficult to decern the specific animal in a given situation. Still a number of studies have been able to estimate damage caused specifically by deer in corn and bean systems. Below, we provide an overview of the data used in updating the Wywialowski (1996) study (Table D1).

Table D1. Field corn produced for grain and corn lost to wildlife in Iowa, 1993 and 2023.

Corn for grain produced					
Data	Area harvested corn (1,000s)	Corn Yield (bu/ha)	Production (Total bu) (1,000s)	Corn price[4] ($/bu)	Total value ($) (1,000s)
1993[1]	4,452	198[3]	881,496	2.50	2,203,740
2023[2]	5,101	496[3]	2,532,493	4.85	12,282,593
Corn lost to deer					
	Estimated yield loss due to deer (bu/ha)[5]	SE[5]	CV[5] (%)	Total production loss due to deer (bu) (1,000s)	Value of loss attributed to deer (1,000s) (2023$)[6]
1993[1]	0.21	±0.17	27.3	935	5,025
2023[2]	0.21	±0.17	27.3	1,071	5,196

1. Data source: Wywialowski (1996); 2. Data source: Iowa State University Extension and Outreach NASS Chartbook (undated); 3. Iowa corn yield in the 1993 cropping season was considerably lower than expected due to excessive precipitation and wide spread spring flooding (Allen et al., 1997); 4. Price is the weighted marketing year average released by USDA NASS; Johanns 2024b; 5. Scaling data and standard error as calculated by Wywialowski (1996) held constant; 6. Note that this loss is only relative to grain consumed or damaged. It does not include any other damage potentially incurred due to deer. This was calculated by multiplying the estimated production loss due to deer (total bushels) by the price per bushel; 1.071 million bushels * $4.85 per bushel = $5.196 M.

Federal Crop Insurance Analysis

Using crop insurance records to estimate wildlife losses is a way to set lower bounds on economic loss due to wildlife damage. Because there are many reasons why an insured farmer may not file a claim due to wildlife loss (e.g., missed relevant insurance period, appraisal not conducted, transaction costs) or why a farmer may choose not to have coverage, wildlife claims tend to be a very small percentage of total claims (McKee et al. 2020; ISU E&O 2021). Therefore, it is likely that a significant amount of wildlife damage is not accounted for in insurance records.

Nevertheless, we reviewed five years of federal crop insurance claims for the state of Iowa. Mckee et al. (2020) reviewed 2017 USDA Risk Management Agency (RMA) data regarding both crop insurance policies as well as cause of loss indemnity records to estimate the lower bounds for dollar and percent losses attributable to wildlife in the United States with a focus on four primary commodity crops including corn and soybeans. Their assessment estimated that losses to wildlife were incurred by soybeans (costing a total of $408.1 million in 2023$) and corn (costing $244.4 million in 2023$) with estimated percentage for soybeans (0.87%) and corn (0.40%). Guided by McKee et al. (2020) we reviewed USDA RMA crop insurance records for

Iowa in the years 2019-2023 (https://www.rma.usda.gov/tools-reports/summary-business/cause-loss). We filtered the claims attributed to “wildlife” and examined only corn and soybean claims; note that the data make no distinction on wildlife species causing the damage. Across these years there was an average of 79 claims made for wildlife damage (2019 had a high of 115 claims; 2023 had a low of 52). From 2019-2023, 54% of total wildlife loss claims were associated with corn and 46% associated with soybeans. We determined the 5-year average wildlife indemnity payouts to both corn and soybean crops and then further scaled the data by literature values on percentage of damage to corn and soybean crops attributable to deer (e.g., deer account for 33% of damage to corn crops and 61% damage to soybean crops; Wywialowski 1996 and MacGowen et al. 2006, respectively). Our data show a 5-year average annual lower bound financial loss to crops due to deer of just $153,507 ($47.7K for corn; $105.8K for soybeans).

DNR Wildlife Depredation Program Data Analysis

Additionally, we examined multiple years of data from the DNR Wildlife Depredation Program which records and investigates farmer reports of deer depredation and qualifying crop damage. Farmers in Iowa can voluntarily report suspected deer damage to their crops or farm. A field assessment is then conducted to determine if a minimum threshold of $1,000 of damage was incurred. While we have multiple years of depredation records, we focused our analysis on the 2023 data set because it was the most complete including estimated total acres impacted. A total of 318 incident reports that met the $1,000 threshold were analyzed; 236 were used in our final analysis based on completeness of data. We calculated the area weighted corn and bean yields of impacted crop fields using county-specific average crop yields for the 2023 growing season (Johanns 2024a, 2024c) and average marketing year commodity prices (Johanns 2024b) to estimate the potential crop loss for commodity farmers. Based on these data, the total economic loss in 2023 was estimated to be $301,409 (see Table D2 for summary data). Note that because it is possible that farmers who reported depredation to the DNR may have also filed a wildlife loss insurance claim, as such, the DNR depredation program data and the crop insurance-based loss estimates are not summative.

Table D2. Summary of eligible cases in the DNR Wildlife Depredation Program registered for the 2023 growing season and total acres impacted, estimated total corn and soybean yield impacted, and estimated lost value.

Data	Corn	Soybean
Total yield impacted (bu)	52,920	3,551
Total damage value (2023$)	$256,662	$44,747
Total reported incidences of =>$1,000 damage [1]	191	45
Total acres used in analysis	608.5	267.5
Area-weighted average yield of impacted fields (bu/acre) [2]	196	56
Average market commodity price per bu (2023) [3]	$4.85	$12.60

1. Based on unpublished DNR data provided by Andy Kellner, Iowa DNR Depredation Biologist; 2. Area weighting was based on relevant county specific average crop yields for the 2023 growing season (Johanns 2024a; 2024c); 3. Price is the weighted marketing year average released by USDA NASS (Johanns 2024b).

Appendix E

List of farm systems included in specialty crop survey:

List of Iowa Community Supported Agriculture (CSA) farms:
https://www.extension.iastate.edu/ffed/iowa-csa-directory/

List of Iowa fruit orchards: https://www.orangepippin.com/orchards/united-states/iowa ; from ISU - https://www.visitiowafarms.org/directory/2

List of Iowa nut tree growers: https://iowanutgrowers.com/

List of Iowa tree nurseries and garden centers:
https://www.nurserytrees.com/States/state%20Iowa.htm

List of Christmas tree growers: https://www.iowachristmastrees.com/

Overview of specialty crop producer survey context and methodology

Survey Information collected includes:

- White-tailed deer sighting frequency and timing
- Characteristics of surrounding landscape (e.g., is property near or adjacent to wooded areas, row crops, etc.)
- Frequency and severity of browse damage
- Damage experienced – crop, type of damage, damage metrics (e.g., estimated yield loss, total plants lost, quality changes), size of impact area, estimated damage cost, insurance claims, etc.)
- Plant or landscaping replacement activities (frequency, type, number, estimated cost)
- Preventative management activities utilized (preventative actions and estimated cost)
- Other damage noted (e.g., to fencing, built environment)

The sampling frame for this survey was developed by combining and verifying (to the degree possible) various lists of specific high-value agricultural producer types in the state of Iowa. These lists are maintained by Iowa State University Extension and Outreach and by industry associations (see appendix C for these listings). Included in our sample of relevant high-value Iowa operations (n=216) are: 1) Community Supported Agriculture (CSA) farms (n=82), 2) fruit orchards including vineyards (n=73), 3) nut producers and nut tree growers (n=31), 4) tree nurseries (n=5), 5) Christmas tree farms (n=16), and 6) flower farms (n=9). Iowa State University's Institutional Review Board approved our research approach and data management protocols prior to data collection (IRB approval # 24-233-00).

Our survey tool was developed by reviewing similar prior surveys, particularly those utilized by Lemieux et al. (2000), Brown et al. (2004), Baker (2010), and USDA "wildlife damage and attitude toward deer and other wildlife survey" (USDA 2019). In addition to the primary data collected, key secondary data include USDA NASS 2022 Agricultural Census data regarding high value crop production in the state, and current and past prices received for various crops.

Tables E1 and E2 provide a summary of select survey findings and analysis:

Table E1. Summary of average and total acres, average and total financial impact of deer by farm type as represented by 22 survey respondents. Data: collected 2023. Data reflect rounding.

Farm Type (n=22) [1]	Average acres under cultivation[2]	Total acres represented in survey	Average percent of farm impacted by deer	Average acres impacted by deer	Average financial loss due to deer per farm	Total reported financial loss by farm type
Community Supported Agriculture (n=8)	3.5	28	11%	0.4	$1,931	$15,450
Orchard or vineyard (n=5)	77	385	22%	18	$7,255	$32,020
Nut and tree nurseries (n=4)	108	433	23%	35	$2,438	$9,750
Christmas tree producers (n=5)	22	112	37%	8	$1,900	$9,500
Average or Total	53	958	24%[4]	3.1[4]	$3,226[4]	$60,720

1. 22 respondents had complete data across all informational categories presented in this table; for summary purposes, we excluded all other respondents from this compilation. 2. Respondents were on average larger than average farms of similar type. According to 2022 Agricultural Census data for Iowa the average production area for vegetable producers is 7 acres, fruit producers (orchards/ vineyards) 3.1 acres, nut producers 3.7 acres, tree nurseries 3.79 acres, and Christmas tree producers 8.1 acres; 3. Note there are two comparatively large-scale operations that self-defined as a CSA/ diversified vegetable farms that experienced significant deer damage in 2023. Because their data skewed averages considerably, we removed these operations from this summary data set. 4. Averages calculated by weighing data by farm type represented.

Table E2. Summary of average and potential total financial loss due to deer by farm type in 2023.

	Average financial loss due to deer per farm (survey; n=22)	SD	Number of farms by type in Iowa (USDA NASS 2022; ISU E&O)	Total potential costs of deer damage by farm type[1]	Total potential expenditures for deer management by farm type [2]
Community Supported Agriculture	$1,931	$2,269	82	$79,171	$55,000
Orchard or vineyard	$7,255	$10,423	810	$2,938,275	$544,000
Nut and tree nurseries	$2,438	--	156	$190,164	$105,000
Christmas tree producers	$1,900	--	188	$178,600	$126,000
			Totals	$3,386,210	$832,000

1. Conservatively assumes 50% of all farms experience deer damage and that average costs per farm type apply to all farms. 2. Assumes 47% of all farms actively manage for deer each year and spend an average of $1,400 per year.