# EVALUATION OF BLACKBIRD DAMAGE TO SUNFLOWER AND THE RELATIONSHIP TO PRODUCER DAMAGE ESTIMATES

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## ABSTRACT

Sunflower producers face profit losses due to crop depredation by migrating blackbirds (Icteridae). Blackbird damage to sunflower in North Dakota is highly localized, where economic loss to some sunflower fields is severe (loss >20%), others face negligible loss (<5%). To mitigate conflict between producers and blackbirds, an understanding of severity and distribution of bird damage is essential. We investigated blackbird damage to sunflower using estimates collected in the field and estimates gathered from producers through a written survey and direct contact. Damage estimates indicate a state-wide loss of US$10.3-33.5 million. Our comparison of estimates from 2020 indicate that blackbird damage is higher when reported by producers (i.e., survey and direct contact) when compared to infield estimates. The disparity of estimates and unpredictability of bird damage warrants investigation into estimation practices by both biologists (i.e., improved field and survey methods) and farmers (e.g., yield monitors) to achieve accurate estimates of damage.

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APHIS ..........................................................Animal and Plant Health Inspection Service

CWT.............................................................Cental Weight

EPA .............................................................Environmental Protection Agency

FSA .............................................................Farm Service Agency

GIS ..............................................................Geographical Information Systems

GPS .............................................................Global Positioning System

NASS ...........................................................National Agricultural Statistical Service

NDSU...........................................................North Dakota State University

OLR..............................................................Ordinal Logistic Regression

OR ................................................................Odds Ratio

URL..............................................................Uniform Resource Locator

QR ................................................................Quick Response

SD ................................................................Standard Deviation

SE.................................................................Standard Error

USDA...........................................................United States Department of Agriculture

USA..............................................................United States of America

US ................................................................United States

USGS ...........................................................United States Geological Survey

# CHAPTER 1: BACKGROUND LITERATURE REVIEW

## Landscape Changes and Human-wildlife Conflict

Humans across the globe have altered natural habitats and ecosystems through the introduction of exotic species, habitat fragmentation, and habitat loss (Messmer, 2009). Changes in landscapes and subsequent increases in species able to adapt to those changes have resulted in human-wildlife conflict, defined as negative interactions between humans and wildlife (Messmer, 2009). These conflicts take the form of economic losses, health hazards, and natural resource degradation. One issue is the economic loss faced by agricultural producers from wildlife damage to crops. As agricultural systems mesh with natural habitats, it is likely that livestock predation, crop damage, and zoonotic diseases involving wildlife will occur. Around the world, common crops like legumes (soybeans [*Glycine max*]), cereals, corn [*Zea mays*], wheat [*Triticum* spp.], grapes [*Vitis* spp.], tree nuts, and rice (*Oryza sativa*), are damaged by variety of species including mammals, birds, reptiles, and invertebrate pests. Sunflower (*Helianthus annuus* L.) depredation by birds occurs globally, including the United States, Israel, Argentina, Uruguay, Russia, Turkey, France, Hungary, Poland, Romania, and others (Pinowski, 1973; Besser, 1978; Canavelli et al., 2014; Schäckermann et al., 2014; Sausse et al., 2017). Due to the reduction of habitat and lack of alternative natural food, crops, like sunflower, replace native seeds in the avian diet (Besser, 1978). Understanding and mitigating conflict with humans is essential to the conservation of wildlife in agroecosystems as well as the preservation of human economic and agricultural interests (Messmer, 2009; Conover et al., 2018).

The Great Plains has been altered by human activities including agriculture, human development, tree plantings, and introduction of exotic pests causing the once great expanse of wetlands and grasslands to be reduced, altered, or fragmented (Igl and Johnson, 1997). In North

Dakota alone, 99.9% of the historic prairie (tallgrass, mixed grass, and short grass) has been lost (Samson and Knopf, 1994). In particular, intensive agriculture in the region has altered natural ecosystems through habitat conversion, tillage practices, planting of shelterbelts, altered hydrology, and altered grazing regimes (Stewart and Kantrud, 1972). Agriculture is one of the greatest sources of wetland loss and degradation in the Prairie Pothole Region and influences subsequent changes in the distribution and abundance of native wildlife. Although the majority of agricultural conversion occurred in the 1940s, row crop agriculture is still expanding in North Dakota as the demand for crops new to the region increase (e.g., corn ethanol; Johnston, 2013).

One implication of the increase in agriculture is the subsequent changes in vegetative communities, for example, the dominance of cattail (*Typha* spp.; Bansal et al. 2019). Prior to the 1930s, cattail in North Dakota's expansive wetlands was limited. Narrow-leaf cattail (*Typha angustifolia*), an invasive plant hybrid, was introduced in the 1940s in North Dakota, where it rapidly spread and began to 'choke-out' emergent native wetland vegetation (Kantrud, 1986; Linz et al., 1992). The wetlands of North Dakota were vulnerable to invasion because agricultural practices like row cropping, sloping (drainage), and tillage practices have altered the vegetative species composition and density. In particular, tillage has created disturbed habitat in the shallow areas and the lack of grazing no longer regulates vegetative growth and competition allowing non-native species to succeed (Kantrud, 1986; Linz et al., 1992). The dominance of cattail has negative effects on some waterfowl (Anatidae) species, but potentially positive effects for white-tailed deer (*Odocoileus virginianus*), ring-necked pheasants (*Phasianus colchicus*), and other migrating birds that use this habitat for roosting (Linz et al., 1992; Linz et al., 1995). Blackbirds (Icteridae) also benefit from the expansion and increase in the density of cattail because of the vegetative structure provided for roosting and nesting (Burger, 1985; Linz et al., 1995).

In the northern Great Plains, the crop most susceptible to bird damage is sunflower. Sunflower is a hybridized form of native sunflower that is used commercially for human consumption (sunflower oil and seed), animal feed (bird seed), and numerous industrial purposes (lubricants and paints; Bangsund and Leistritz, 1995). Sunflower production in North Dakota increased 18-fold from an average of 65,444 acres planted in 1962–1970 to 1,176,000 acres in 1971–1980 (USDA-NASS, 2017). Most production in these years (1960–1980) was confined to the Red River Valley (Kandel et al. 2020). In 1982, sunflower production peaked at 3,400,000 acres planted (USDA NASS, 2017). Sunflower production in North Dakota has shifted out of the Lake Agassiz Plain and Glaciated Plains ecoregions and into other parts of North Dakota in the last 20 years, particularly the drier ecoregion of the Northwestern Great Plains (USDA NASS, 2017). A decrease in the annual number of sunflower acres planted within the last 10 years has occurred, with an average of 646,750 (± 45,571) acres planted each year (USDA NASS, 2017). A decline in sunflower acres may be partly due to recent changes in the climate and new crop hybrids allowing for the expansion of corn and soybeans into the northern Great Plains (Reilly et al., 2003), with ethanol production further increasing the demand and providing a strong incentive to grow these crops (Johnston, 2013). In addition, blackbird damage is cited as the main reason producers remove sunflower from their rotation (Kleingartner, 2003). Changes in the natural habitats and the availability of other high-energy crops (e.g., corn), will likely further influence blackbird populations and distribution, and ultimately bird damage.

## Blackbirds: Conservation and Human-wildlife Conflict

Nearly all of North American avifauna is in decline, and blackbirds have experienced a roughly 40% population decline since 1970 (Rosenberg et al., 2019). Nelms et al. (1994) reported a decline in red-winged blackbirds (*Agelaius phoeniceus*) in North Dakota from 1967 to 1990. However, based on the USGS Breeding Bird Survey data from 1966–2015, red-winged blackbirds, yellow-headed blackbirds (*Xanthocephalus xanthocephalus*), and common grackles (*Quiscalus quiscula*) are steady and increasing in the Prairie Pothole Region (Sauer, 2017), most likely due to the presence of high-quality nesting habitat (i.e., cattails) and abundant food (i.e., sunflower). Landscape changes in North Dakota have an effect on breeding bird populations, and increased manmade structures and woody vegetation result in increased bird species that use these habitats, while wetland and grassland species decline (Igl and Johnson 1997). Blackwell and Dolbeer (2001) found that red-winged blackbirds in Ohio where negatively affected by the decline in hay production, earlier mowing of hay, and the increase in row crops. Changing agricultural practices causing declines in pest species seemingly should alleviate damage issues in corn and sunflower, but previous reports indicate that increased damage could be the result of increased use of the crop and not simply an increase in blackbird numbers (Hothem et al., 1988). Thus, changing landscapes can impact overall blackbird population numbers, but even at decreased numbers, birds can impact crops due to foraging decisions made in response to what resources are available on the landscape.

Conservation of blackbirds is important because of the potential ecosystem services they provide (e.g., consumers of insect and plant pests), maintenance of overall biodiversity of North American avifauna, and their intrinsic value and protected status under the US Migratory Bird Treaty Act of 1918 (Dolbeer, 1980; Bendell et al., 1981; Whelan et al., 2015). Species in the

Icteridae family are some of the most abundant avian species in North America. More blackbirds are found in central North America than anywhere on the continent, with a total of 31 million blackbirds estimated in late summer in North Dakota in 2003 (Homan et al., 2004). Most notable in this family are the red-winged blackbird, common grackle, and yellow-headed blackbird. Of these species, the red-winged blackbird comprises the majority of blackbird flocks in the Great Plains (Besser, 1978; Nelms et al., 1994; Homan et al., 2004). The preferred breeding habitat of red-winged blackbirds is emergent marshes, where the size and shape of the wetland affects their reproductive and nesting decisions (Beletsky and Orians, 1996). Additionally, they will use other habitats including upland grasslands, fallow fields, and sedge meadows (Yasukawa et al., 1995; Beletsky, 1996). Yellow-headed blackbirds predominately nest in deep water, emergent wetlands, typically cattails (Twedt, 2017). Common grackles prefer nesting in shelterbelts (particularly with the presence of blue spruce [*Picea pungens*]) and near farmsteads (Homan et al., 1996). Roosting habitats of all three species are similar, preferring cattail-dominated wetlands for shelter as they migrate in both seasons (Linz et al., 2003). The selection of wetlands for fall roosting sites is dominated by water-depth and thus cattail presence (Lutman et al., 2000). Climatic variation, particularly the previous year's precipitation, can alter the availability of roost sites, and in drier years shallow wetlands may be less dependable roost locations compared to deeper wetlands (Linz et al., 2003; Forcey et al., 2015). This variation in nesting and roosting habitat effects bird population numbers and distribution, and their potential to damage crops (Forcey et al., 2015; Forcey and Thogmartin, 2017).

Sunflower seeds are an excellent source of forage for birds because of the essential proteins and fats required for molting, growth, fat storage, and weight maintenance; and sunflower fields are readily available surrounding wetland roosting habitat in North Dakota

(Besser, 1978; Otis and Kilburn, 1988). Sunflower maturity coincides with the post-breeding period of blackbirds as they molt and prepare for fall migration and energy demands are high. In July to October mixed-species flocks, adults and young, begin to form congregations of 10,000 to >100,000 birds (Besser, 1978). Blackbirds begin consuming the sunflower seed during the "soft stage" within the first 18 days of anthesis (Cummings et al. 1989). Blackbirds will feed on both confectionary and oilseed sunflower, but will select for seeds with the highest oil content (Mason et al., 1991). Linz et al. (1984) determined red-winged blackbirds preferred sunflower over corn, reflecting the preference of food with greater energy content. Linz et al. (1984) also noted variation between the sexes, with female red-winged blackbirds and yellow-headed blackbirds consuming fewer sunflower seeds and more weed seeds than males, most likely a function of their smaller beak size, while common grackles of both sexes consumed sunflower seeds equally (Linz and Fox, 1983; Linz et al., 1984; Homan et al., 1994).

## Producer Estimates of Crop Damage

Crop damage estimates are typically assessed by producers or infield surveys by trained professionals, but the true extent of wildlife damage to crops is often unknown and uncertain (Elser et al., 2019). Infield estimates can be time consuming and labor intensive but are often assumed to have greater accuracy than producer-reported estimates. Producer surveys can encompass larger areas and involve greater detail, but in order to use these estimates to evaluate economic damage or tool efficacy, unknowns about bias and inaccuracy need to be investigated (Elser et al., 2019). A limited number of studies have been conducted to compare producer to infield estimates of wildlife damage (Tzilkowski et al., 2002; Johnson-Nistler et al., 2005; Humberg et al., 2007; Shwiff et al., 2012) with few evaluations in broad-scale, row-crop agriculture (e.g., sunflower).

Most recently, Elser et al. (2019) reported that for wine grapes (*Vitis vinifera*), sweet cherries (*Prunus avium*), and apples (*Malus domestica* 'Honeycrisp') damage estimates from producers were higher than infield estimates. However, this was only significantly different for 'Honeycrisp' apples indicating producer surveys are a useful estimate of damage for wine grapes and sweet cherries. Tzilkowski et al. (2002) compared producer and infield wildlife damage estimates to corn in Pennsylvania and reported no difference between producer reported and infield estimates. However, they concluded that individual farmer estimates are not reliable, and producer estimates should only be used for broad scale evaluations with a large sample of fields (Tzilkowski et al., 2002). Johnson-Nistler et al. (2005) investigated damage to alfalfa by ground squirrels (*Spermophilus richardsonii*) and determined that producer estimates of damage (22%) may underestimate actual damage (31%). Humberg et al. (2007) investigated producer estimates of wildlife damage to corn and soybean in north central Indiana and found grower estimates corresponded with the infield damage estimates, however producers could not reliably identify the species causing the damage.

Other studies investigating wildlife damage to corn indicate that the conspicuous nature of some bird species may cause producers to overestimate the damage contributed to those species. Producers may superficially overestimate wildlife damage to crops, particularly blackbird damage to sunflower because of the high visibility of blackbirds in flocks of >10,000 compared to other sources of yield loss: wind, insects, or other pests (Linz and Hanzel, 1997; Kandel and Linz, 2015). For example, Humberg et al. (2007) concluded that wild turkey (*Meleagris gallopavo*) damage to corn was trivial or nonexistent, however their visibility caused them to be considered a crop pest. Similarly, producers indicated sandhill cranes (*Grus canadensis*), large conspicuous birds, were a major source of loss in barley where actual damage was <3% (McIvor and Conover, 1994). Additionally, humans likely notice bird-damaged plants when observing fields from the edges where damage may be higher (Dolbeer, 1980; Cummings et al., 1989). Damage due to other sources (i.e., raccoon [*Procyon lotor*], deer [*Odocoileus* spp.]) can be mistaken for bird damage because birds are diurnal and highly visible (Dolbeer, 1980; Wakeley and Mitchell, 1981; Linz and Hanzel, 1997). Additionally, bird damage occurs at the conclusion of the growing season when anticipation of success is high (Klosterman et al., 2013).

A survey conducted by Conover (1998) reported that farmers implicate blackbirds as the main source of damage to agriculture in the Great Plains. In a pest and sunflower questionnaire conducted in North Dakota (surveys sent = 4,288; respondents = 652) 14% claimed that bird damage caused the greatest loss in sunflower production: 66% of respondents indicated 0–5% bird damage, 19% claimed losses of 5–10%, and 14% estimated losses >10%, which was similar to losses determined by infield surveys conducted in previous years (Lamey and Luecke, 1993). It is important that producers are accurately assessing wildlife damage because their tolerance of the perceived pest species will continue to decline, and farmer perception influences their attitude about wildlife (Conover, 1998). Sunflower producers commonly promote population reduction to solve their wildlife damage issues, however lethal approaches have marginal success in reducing bird damage due to the large number of birds, cost-effectiveness of implementing control, and the time lag associated with lethal approaches (Linz et al., 2015).

**Economic and Yield Loss in Sunflower due to Bird Damage**

Blackbird damage to sunflower in North Dakota is highly localized, in that the economic damage to some sunflower fields is significant, while others face marginal or negligible damage (industry standard of ≤5%; Linz and Hanzel 1997). Previous damage estimates by Hennel et al. (1979) report an average of 1.09% with the highest damage estimate at 7.54% in Benson County, North Dakota. An extensive study conducted by Hothem *et al.* (1988) in Minnesota, North Dakota, and South Dakota reported an average damage of 0.81%, 1.96%, and 2.40% in years 1979–1981, respectively. Only 1.60% of the fields surveyed had >10% damage, but of these, damage was estimated between 21–89% (Hothem et al., 1988).

Klosterman et al. (2013) conducted bird damage surveys in sunflower from 2008–2010 and found an average of 2.70% damage; additionally, they reported 11% of the fields had >10% damage, an increase from the surveys in 1979–1981. Damage of >5% is when it is economically feasible to implement blackbird management techniques (Linz et al. 2011). Blackbird damage is not uniformly distributed across sunflower fields and overall regional estimates of damage does not portray the magnitude of the effects on sunflower production. Klosterman et al. (2013). Ernst et al. 2019, reported an annual damage of 8.70% in North Dakota from 2009–2013, resulting in a direct loss of US$10.7 million and found that North Dakota ranked first in blackbird damage to sunflower compared to any other state. It is important to note that regional estimates of bird damage may neglect to show the localized damage (Peer et al., 2003).

## Research Objectives

To better understand blackbird damage to sunflower crops, an evaluation of different variables at several scales that may predict damage is essential for mitigating conflict and encouraging revised cultural practices that producers can employ. Additionally, understanding how producers assess blackbird damage is valuable for promotion of accurate and precise estimation methods for use in broad-scale assessments of damage levels, testing of potential tools, and knowledge of severity and when to implement tools.

The aim of Chapter 2 is to gather state-wide estimates of blackbird damage to sunflower from surveys conducted by biologists in the field and from producer estimates. Gathering the current level of bird damage allows us to assess economic loss and distribution of damage. Additionally, our goal was to compare the bird damage estimates of producers and biologists in 2020 through direct contact with known producers (phone call) or through returned survey instruments (mail). We analyzed these estimates further by separating them into categories based on Level III Ecoregions designed to examine the variability of bird damage within the state. Comparing damage estimates informs us of producers' perceptions of bird damage, accuracy of infield survey techniques, and future management goals. Finally, in this chapter we determined what factors influenced the producer reported impact-to-profit and their opinion and acceptance of blackbirds. We addressed the human dimensions and biological variables necessary, in part, to address the blackbird damage to sunflower conflict in North Dakota. Gathering current damage levels informs efficacy of current and future management practices. It is imperative that we understand the producer estimates and perceptions of blackbirds to mitigate the conflict and decrease economic loss while conserving a native, yet pest, bird species.

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## CHAPTER 2: COMPARISON OF PRODUCER ESTIMATES TO INFIELD ESTIMATES OF BLACKBIRD DAMAGE TO SUNFLOWER[1]

### Abstract

Agricultural producers face substantial economic loss to wildlife across the globe. Sunflower producers in North Dakota are the most at-risk population for blackbird depredation. Damage is not uniform, and the true extent is often unknown. To determine the current state of blackbird damage and profits lost in North Dakota, we gathered estimates from biologists in the field and sunflower producers through a written survey and direct contact. State-wide estimates from infield damage surveys (3.6 ± 5.5%; US$10.3 million) were significantly less than producer estimates from a written survey (11.6 ± 17.2%; US$10.3 million). Producer estimates from the Northwestern Glaciated Plains (W = 381, p = 0.08) and Lake Agassiz Plain (W = 62, p = 0.31) ecoregions had estimates more similar to infield estimates, potentially due to the regions having a long history of sunflower production and a large amount of water on the landscape, indicating a history of blackbird damage. Estimates gathered directly from producers about a specific field were higher (13.1 ± 10.2%) than our infield estimates. How a producer estimates damage and number of acres planted were related to the likelihood of reporting damage >5% (Wald $\chi^2$ = 30.0, df = 8, $p \leq 0.01$). A producer's experience with sunflower, the generation of their farm, and their estimation technique were related to their reported impact to profit and opinion of blackbirds. Potential sources of bias among sampling techniques in the field must be identified to accurately

[1] The material in this chapter was co-authored by Morgan Donaldson and Dr. Page E. Klug. Morgan Donaldson had primary responsibility for collecting samples in the field and for interviewing users of the test system. Morgan Donaldson was the primary developer of the conclusions that are advanced here. Morgan Donaldson also drafted and revised all versions of this chapter. Dr. Page E. Klug served as proofreader and checked the math in the statistical analysis conducted by Morgan Donaldson.

evaluate damage. Educational resources and instructions on how to estimate bird damage is necessary to evaluate the cost-benefit of damage management and an understanding of actual damage will aid producers in identifying when bird damage is a problem, which may improve opinions of blackbirds.

## Introduction

Human-wildlife interactions occur globally and can develop into conflicts as humans face risks to their property, economic losses, and health/life. Conversely, the conservation of native, yet nuisance wildlife, can be adversely affected by humans (Conover and Conover, 2022; Huang et al., 2023). Human-wildlife conflicts are projected to increase with continued landscape change, increased resource use by humans, and as other technological developments enable more conflict opportunities (Nyhus, 2016; Conover and Conover, 2022). The significance of assessing and mitigating agriculture related human-wildlife conflict cannot be understated, especially in light of rising human populations and the subsequent increase in food requirements (Adeleke and Babalola, 2020; Araneda et al., 2022). Globally, agricultural producers face millions of dollars in yield losses due to bird depredation (Stone, 1973; Conover et al., 2018; Huang et al., 2023). Producers aim to make their operations efficient and profitable by limiting sources of yield losses, however, bird damage poses a complex management issue (Elser et al., 2016; Lindell et al., 2016; Pekarsky et al., 2021).

Most recent estimates by Ernst et al. (2019), report bird damage to sunflower in North Dakota to be 8.7%, which equates to $US 10.7 million annually. North Dakota and South Dakota consistently rank as the top producers of sunflower in the United States and unfortunately, bird damage (USDA NASS, 2017; Kandel et al., 2020). Economic loss is considered significant when losses surpass the cost of management, typically above 5% for blackbirds damaging sunflowers

(Kandel et al., 2020). Each fall, large mixed-species flocks of blackbirds, mainly composed of red-winged blackbirds (*Agelaius phoeniceus*), common grackles (*Quiscalus quiscula*), and yellow-headed blackbirds (*Xanthocephalus xanthocephalus*), congregate in preparation for molt and migration and exploit highly nutritious sunflowers (Besser et al., 1979; Linz, 2013). The high mobility of blackbirds during migration results in birds not being evenly dispersed across the landscape. Thus, average regional damage estimates do not reflect the significant losses faced by producers located near large blackbird aggregations (Peer et al., 2003; Klosterman et al., 2013; Linz and Klug, 2017). Despite relatively low regional averages, blackbird damage is the main reason producers remove sunflower from their rotation (Besser et al., 1979; Kandel and Linz, 2015). Sunflowers should be retained given its profitability, along with how the crop enhances soil health, increases agricultural diversity, and provides resources for wildlife and pollinators (Adeleke and Babalola, 2020).

The perception of wildlife species involved in human-wildlife conflict can directly impact the management, tolerance, and conservation of individual species and ecosystems (Conover and Conover, 2022). This is especially important for native species that have adapted to agroecosystems but show overall declines across North America (e.g., red-winged blackbirds declined by 40% since 1966 but are stable in North Dakota; Sauer, 2017; Rosenberg et al., 2019). Although it is generally assumed that sunflower producers have negative opinions of blackbirds, formal evaluations of the factors that influence those opinions are limited. Blackbird damage to sunflower may have different significance to producers depending on farm size (i.e., number of sunflower acres), how established the farm is (i.e., new or in the family for generations), among other farm practices. Previous surveys of farmers related to wildlife damage in agriculture indicate that negative opinions of the pest species were more strongly related to the selection of intensive management strategies compared to any other factors (Canavelli et al., 2013; Kross et al., 2018). In general, a producer's opinion on wildlife species is subject to their past experiences, education, and age. Older producers with less education have been documented preferring more intensive management techniques (Canavelli et al., 2013; Tomass et al., 2020). Inherently, producers who are older or have more experience producing sunflower will have an increased likelihood of experiencing one or more high damage years (Tomass et al., 2020). The total acres harvested by a producer can affect the estimated damage lost and subsequent opinion, with previous studies indicating farmers with more acres report less damage (Zhang et al., 2018; Tomass et al., 2020; Smith et al., 2021) In some instances, the economic loss is the most important factor in forming an opinion on a pest species (Kross et al., 2018) and in others it is the past experience (Canavelli et al., 2013). Producers tend to attribute damage to more conspicuous species (large flocks of birds) while neglecting other inconspicuous sources of loss (small rodents; van Velden et al., 2016; Tomass et al., 2020).

Using the intensity of the management tool selected, previous studies have shown the opinion of wildlife pests are based on economic losses faced or sociodemographic factors. Understanding what creates a producer's attitude of a native species will inform researchers of potential biases in interpreting producer estimates and how to mitigate opinions on management and estimation techniques with the intention of conserving the species (Eriksson et al., 2022). Wildlife pests are often cited as a significant loss in agriculture. The accuracy and precision of wildlife damage estimates from producers and researchers is essential in the formation of opinions about blackbirds and the effectiveness of management tools (White 2021).

Evaluating the severity of bird damage is essential in managing losses faced by producers and accurate assessments inform when it is cost-effective to deploy tools, while minimizing negative impacts on native birds. Blackbird damage surveys conducted by researchers in sunflower fields are not regularly completed due to cost and labor involved. Using producers' estimates of wildlife damage increases sample sizes, allows for estimates at various spatial scales, and provides damage estimates near harvest, but biases exist. Previous studies comparing producer-reported damage estimates to infield surveys found that the similarity of estimates varied based on geographic location, crop type, and wildlife pest species (Tzilkowski et al., 2002; Johnson-Nistler et al., 2005; Humberg et al., 2007; Elser et al., 2019). Farmer's negative emotions about bird losses may also intentionally or unintentionally inflate responses.

**Objectives**

To improve conflict mitigation, we gathered data on blackbird damage to sunflower through a state-wide survey distributed to sunflower producers in North Dakota. We inquired about their farming practices, sunflower growing experiences, opinions on birds, use of damage management tools, and demographics. We investigated the variables influencing bird damage estimates reported by sunflower producers in North Dakota and its relationship to infield survey conducted in the same year. Specifically, our objectives were to 1) compare infield damage estimates conducted by biologists to both anonymous state-wide producer estimates and field-specific producer estimates, 2) determine what demographic, regional, or farm practices influenced the reported amount of bird damage, and 3) examine factors influencing the reported impact of blackbirds on profit and the attitudes of farmers toward blackbirds. By understanding the factors influencing bird damage and farmers' perceptions, stakeholders can implement effective management practices that strike a balance between crop protection and conservation of native bird species.

## Methods

### Producer Surveys

In January 2021, we mailed a paper booklet containing a cover letter, four pages of survey questions and a return envelope with business reply, prepaid postage to North Dakota residents on the National Sunflower Association's mailing list (n = 7,350; Appendix 1). We made an identical online version available through an anonymous URL or QR code (Qualtrics, Provo, UT). We published reminders in the National Sunflower Association's monthly e-newsletter and issues of The Sunflower magazine from January to March 2021. Given a third party (Forum Publications, Fargo, ND USA) distributed the paper surveys, we did not have access to producer names, addresses, or personal information, and all responses were recorded in an anonymous data file. We did not test for a nonresponse bias due to the use of a blind third-party list. We also sent invitations to complete the survey to local online farming magazines, county extension agents, and agricultural email listservs.

The survey was divided into four sections: 1) your farm and farming experience, 2) your opinion on birds, 3) management tools used, and 4) demographics (Appendix 1). Institutional Review Board determined no approval was needed to administer the survey because our intent was to investigate operations and strategies (IRB0003378). Respondents were asked to report sunflower acres planted in 2020, and the county, zip code, yield (lbs./ac), yield lost to bird damage (%), impact to profit, management cost ($US), and if they reduced sunflower acres due to bird damage. We asked them how they arrived at their damage estimate for 2020, with techniques including an on-the-ground visual estimate, a combine equipped with a GPS yield monitor, actual yield versus expected based on seeding rate, or other. We created questions about sunflower growing practices and experience to increase participation by those not experiencing bird damage. We asked for the number of blackbirds observed in 2020 (1 = <1,000, 2 = 1,000–10,000, 3 = 10,000–100,000, 4 = >100,000) and inquired about their opinions of blackbirds and their impact on sunflower yield (Table 2.1). General demographic questions included the respondent's gender, age, and education (≤high school, college, and graduate school), along with how many generations the farm has been in the family ($1^{st}$–$4^{th}$). We also asked the number of years they have grown sunflower (Table 2.2).

In a limited number of fields, where we recorded infield damage estimates, we collected producer estimates of bird damage for the same field by contacting the producer by phone at the conclusion of the harvest season (2020–2021). Producers were identified through plat maps, or the North Dakota GIS information hub. We obtained contact information through a white pages application or word of mouth.

**Infield Bird Damage Estimates**

We conducted bird damage estimates in randomly-selected fields (n = 74) from August–September in 2020 and 2021. The distribution of fields by county was determined by the average acres of sunflower planted and the number of sunflower producers in each county from 2018–2020 (Figure 2.1). We used ArcGIS PRO v 3.5 (Create Random Points tool) to create points to initiate our search for a sunflower field. To limit overlap, each point was a minimum of 3.2 km apart and 3.2 km from the county border (Ralston et al., 2007). We sampled fields using a sampling scheme modified from Klosterman et al. (2013) to include two additional rows on the field edges and two rows in the interior. Thus, we divided each field into four strata: the two edge strata each contained three edge rows and the two interior strata divided the rest of the field into an equal number of rows. We used a random number generator to select the rows sampled for both the edge (always the three edge rows on two sides) and interior stratum (counted the number of rows for each field). In each randomly selected row, five consecutive sunflower heads were surveyed every 135 m with the first point being a randomly generated number from 1–135 (Figure 2.2). We measured total diameter (cm) of the sunflower head, diameter of undeveloped

**Table 2.1.** Explanatory variables that may have influenced producer-reported number of blackbirds (Icteridae), impact of blackbirds on profit, amount of bird damage, and attitudes of farmers toward blackbirds (n = 278). The survey instrument was sent to North Dakota sunflower producers in the winter of 2021 and inquired about the 2020 growing season.

| Variables | Definition |
|---|---|
| *Planting Practices* | |
| Sunflower experience | Experience growing sunflower (years) |
| Sunflower grown | Amount of sunflower planted in 2020 (acres) |
| Estimation technique | Method used to estimate damage (visual, combine yield monitor, expected vs. actual yield, other) |
| Level III Ecoregion[a] | Location of sunflower fields (Northwestern Great Plains, Northwestern Glaciated Plains, Northern Glaciated Plains, and Lake Agassiz Plain (www.epa.gov/eco-research/ecoregions-north-america) |
| *Demographics* | |
| Age | Age of respondent (years) |
| Education | Highest level of education (≤high school, ≥college) |
| Generation | Number of previous generations employed by farming in the Dakotas (1$^{st}$, 2$^{nd}$, 3$^{rd}$, ≥4$^{th}$) |
| *Bird Damage* | |
| Yield lost to birds[b] | Producer-reported yield (%) lost to bird damage in 2020 (≤5% and >5%) |
| Impact on profit | Producer-reported economic losses from bird damage (high, medium, low) |
| Blackbird opinion | Producer-reported feelings towards blackbirds (do not enjoy, no feelings, enjoy but worry) |
| Blackbird observation | Producer-reported count of blackbirds observed in 2020 |

[a] County and zip code identified Level III Ecoregions that possessed different land covers, climate, and terrain to dictate sunflower acreage and blackbird habitat (e.g., wetlands in Prairie Pothole Region; (EPA, 2013) on the landscape.
b Bird damage ≤5% is considered acceptable by the sunflower industry (Dolbeer, 1979).

**Table 2.2.** Categorical and continuous variables used to analyze characteristics of respondents in relation to their opinions and observations of blackbirds (Icteridae) and reported blackbird impact to profits. The survey instrument was sent to North Dakota sunflower (*Helianthus annuus*) producers in the winter of 2021 and inquired about the 2020 growing season.

| Categorical variables | n | |
|---|---|---|
| Estimate technique* | 278 | Visual (n = 107); Other (n = 138) |
| Blackbird observation | 232 | <1,000 (n = 49); 1,000–10,000 (n = 107); 10,000–100,00 (n = 56); >100,000 (n = 20) |
| Impact on profit | 275 | Bird damage has little or no influence (n = 58) |
| | | Bird damage is one of several significant factors (n = 135) |
| | | Bird damage is the most significant factor (n = 82) |
| Blackbird opinion† | 275 | I do not enjoy/regard as pest (n =47) |
| | | I have no feelings (n = 51) |
| | | I enjoy them, but worry about the problems (n = 97) |
| Opinion of other birds | 275 | I do not enjoy and regard as pest (n = 226) |
| | | I have no feelings (n = 23) |
| | | I enjoy them, but worry about the problems (n = 26) |
| | | I enjoy them and I do not worry about problems they cause (n = 80) |
| Level III Ecoregion | 278 | Northwestern Great Plains (n = 63) |
| | | Northwestern Glaciated Plains (n = 60) |
| | | Northern Glaciated Plains (n = 124) |
| | | Lake Agassiz Plain (n = 31) |
| Education‡ | 272 | ≤High school (n = 57); ≥College (n = 215) |
| Generation⸙ | 270 | ≤2$^{nd}$ (n =37), 3$^{rd}$ (n = 138), 4$^{th}$ (n = 95) |
| **Continuous variables** | **n** | **Range (mean ± SD)** |
| Sunflower grown (ac) | 247 | 0–3,700 (614 ± 591) |
| Yield lost to birds (%) ∂ | 254 | 0–100 (12 ± 17) |
| Sunflower experience (yrs.) | 264 | 1–51 (18 ± 11) |
| Age (yrs.) | 275 | 24–86 (55 ± 12) |

* Other was a combination of yield monitor, expected v. actual yields, and any other technique reported (Table 2.3)
† Combined 'I enjoy them, but worry about the problems they may cause" (n =23) and "I enjoy blackbirds and I do not worry about the problems" (n = 3)
‡ Combined college (n = 200) and graduate school (n = 15)
⸙ Combined 1$^{st}$ (n = 1) and 2$^{nd}$ (n = 36) generation farms
∂ Combined all seed types: oil (n = 216), confection (n = 27), conoil (n = 30)

center (cm), and area of bird damage for each sampled plant. We used a gridded plastic template with each square representing 5 $cm^2$ to estimate area damaged per head (Dolbeer, 1975). We only attributed the damage to birds by noting bird sign (e.g., bird droppings, empty seed hulls, or torn bracts).

**Economic Damage Estimates**

We estimated economic loss due to bird predation using the total acreage of sunflower harvested in 2020, our estimates of bird damage (i.e., infield and producer surveys), and the March 2021 market value price of US$21.6/CWT (Shwiff et al., 2017; USDA NASS, 2017). We used the United States Department of Agriculture, National Agricultural Statistics Service (USDA NASS, 2017) for estimates of the amount of sunflower harvested in the state (lbs), average yield state-wide, and market pricing for the 2020 growing season (USDA NASS, 2017).

**Statistical Analyses**

We compared the producer-reported yield lost to bird damage (%) to our infield estimates within the same year using Wilcoxon rank sum tests (Kassambara, 2019). We compared 1) infield and producer-reported estimates from the survey instrument (anonymous responses) and 2) infield and producer-reported estimates from the same fields (via direct contact). We conducted both tests on a state-wide basis and the comparison of estimates from infield and the survey instrument was further analyzed by Level III Ecoregions (Figure 2.1).

Due to the anonymous survey data containing a large number of responses indicating damage ≤5% (industry standard for acceptable damage), we used a hurdle model to first determine what factors were correlated with producers reporting negligible damage (≤5%; n = 127) or severe damage (>5%; n = 151; zero truncated model). If severe damage was reported (>5%), we determined the variables correlated with the intensity of damage reported (% damage) using a negative binomial distribution with logit-link (truncated count regression model; Table 2.4). The goodness-of-fit was evaluated using rootograms and Q-Q plots. All analyses were run using the 'pscl' package in R (Jackman, 2020).

We conducted two ordinal logistic regressions (OLR) using the 'MASS' package in R (Venables and Ripley, 2020) to understand which variables (i.e., sunflower acres, sunflower experience, damage estimate technique, farm generation, age, and education) influenced producer-reported impact to profit based on categories of increasing significance and impacted producers' opinions of blackbirds based on categories of dislike, neutrality, and enjoyment (Table 2.2 & 2.3).

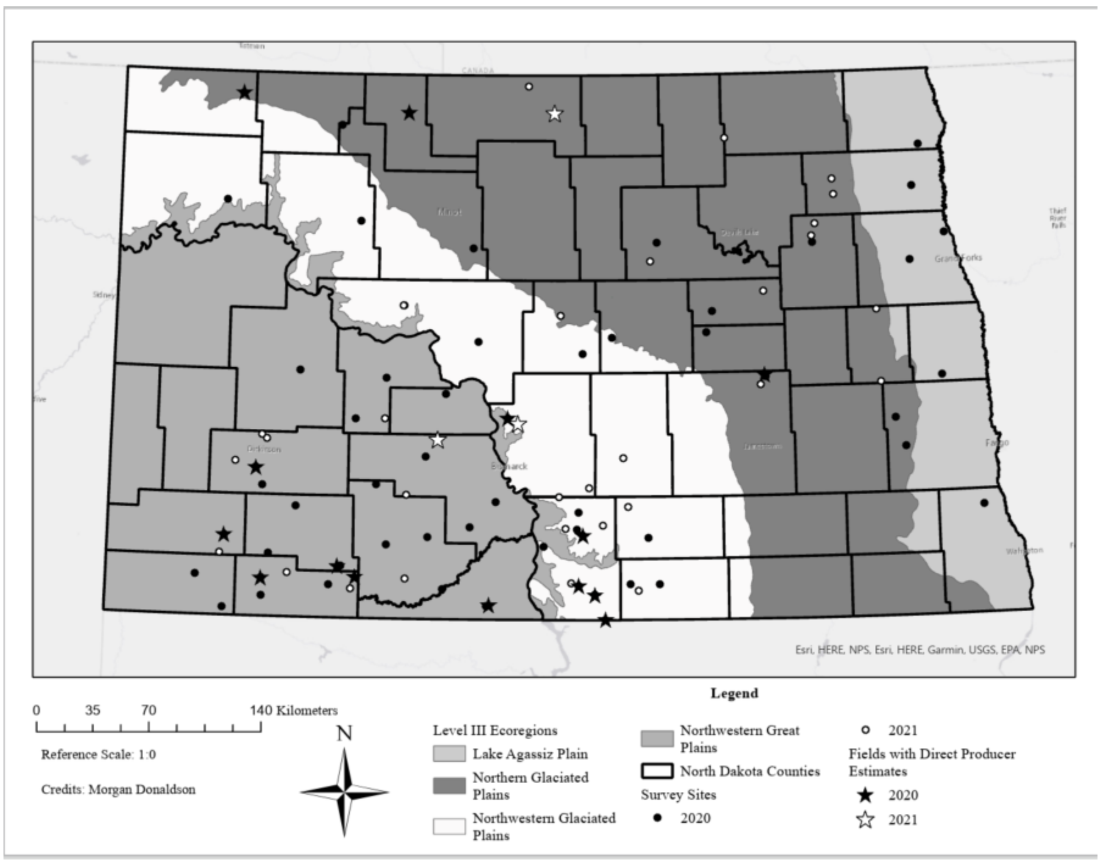


**Figure 2.1.** Sunflower (*Helianthus annuus*) fields surveyed for blackbird (Icteridae) damage across North Dakota in 2020 (white fill) and 2021 (black fill) by Level III Ecoregions. Fields identified by a star have both infield damage estimates and producer estimates specific to that field, whereas field identified with a circle only have infield damage estimates.

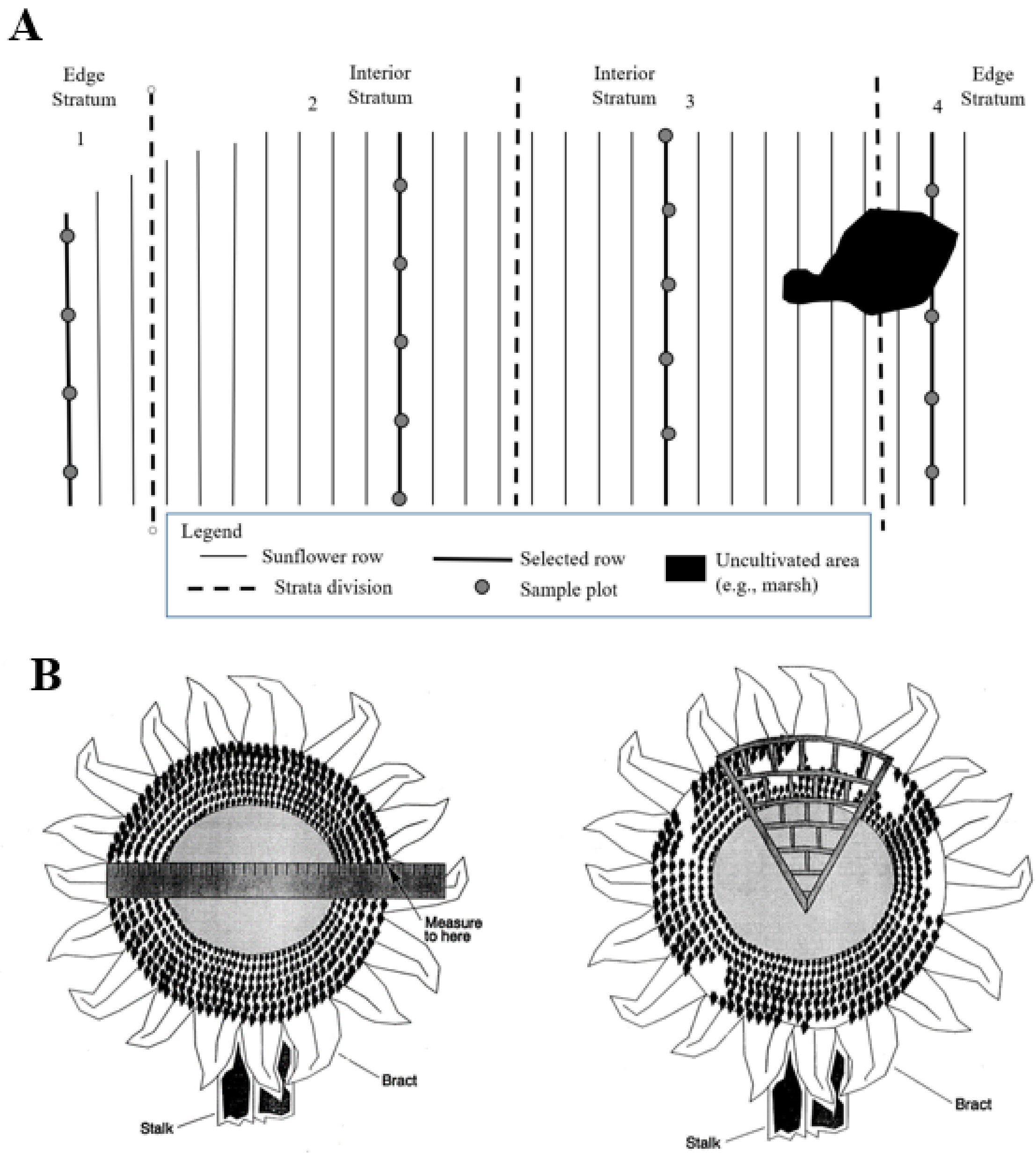


**Figure 2.2**. A) Sampling scheme for assessing blackbird (Icteridae) damage to sunflower (*Helianthus annuus*) fields modified from Klosterman et al. (2013). B) Measurement techniques for estimating the area of sunflower achenes lost to blackbirds on a single sunflower plant modified from Dolbeer (1975).

## Results

We received 1,065 surveys total and 278 from producers that grew a sunflower crop in North Dakota in 2020 and reported percent bird damage (mail = 243, online = 35). Four surveys from the mailing list could not be delivered, reducing the sample size to 7,346. Our overall response rate was 10.5% with a 3.8% response rate from producers with a sunflower crop in North Dakota in 2020. The USDA Farm Service Agency (North Dakota State Office, personal communication) reported that 1,862 farmers grew sunflower in North Dakota in 2020, indicating an amended response rate of 14.9%. The North Dakota producers who grew sunflower in 2020 and responded to our survey varied in geography, demographics, agronomic practices, and perspectives on bird damage (Table 2.2).

**Table 2.3.** Survey responses of producers who planted sunflower (*Helianthus annuus*) in 2020 when asked to select the technique used to estimate blackbird (Icteridae) damage. We included mean reported damage (% ± SD) and range for each technique or combination of techniques. Many respondents only used visual techniques (43.7%) and reported significantly less damage than for other techniques or combinations of techniques (20.2%; Kruskal-Wallis, $X^2 = 61.8$, p $\leq 0.01$). Therefore, we combined all techniques, besides visual only (n = 107), into one category (n = 138) for analyses (Table 2.2).

| Estimation technique | n | % Damage ± SD | Range |
|---|---|---|---|
| Visual only | 107 | 4.9 ± 4.7 | 0–20 |
| Combine only | 24 | 18.5 ± 22.2 | 1–100 |
| Expected v. actual yield only | 13 | 12.3 ± 10.6 | 2–40 |
| Visual and combine | 56 | 11.7 ± 7.9 | 0–30 |
| Visual and expected v. actual yield | 14 | 19.7 ± 25.5 | 2–99 |
| Combine and expected v. actual yield | 8 | 37.5 ± 42.9 | 7.5–100 |
| All three techniques | 23 | 21.7 ± 26.4 | 0–100 |

In 2020 there was 715,000 acres and 1.3 million pounds of sunflower harvested in North Dakota with a value of $283,572,000 based on the average market price in March 2021 of US$0.48/kg or US$0.216/lb. ($21.6/CWT; USDA NASS, 2017). Economic impact of crop damage was US$10.3 million (48,177,000 lbs.) when estimated by infield surveys (n = 93) and US$33.5 million (155,237,000 lbs.) when estimated from producer responses in the state-wide mailed survey (n = 278).

For the entire state of North Dakota, our 2020 estimates of damage (and resulting economic loss) due to birds was significantly less (W = 4737, p<0.01) when conducting infield surveys (3.6 ± 5.5%; approximately US$10.3 million) compared to estimates reported by farmers in the survey (11.6 ± 17.2%; approximately US$33.5 million). Additionally, the infield estimates of damage (6.5 ± 7.6%) were significantly different (W = 19, p<0.01) when compared to the producer estimates (13.1 ± 10.2%) referring to the same field. Infield surveys were conducted from 4 September to 25 October 2020 and encompassed a large area of the state (38 out of 53 counties; Figure 2.1). Sunflower fields ranged in size from 3.6–244.5 ha (mean = 42.03 ± 35.4) and in damage from 0–36.6% (mean =5.5 ± 7.1 for infield estimates). When evaluating by Level III Ecoregion, Northwestern Glaciated Plains (W = 381, p = 0.08) and Lake Agassiz Plain (W = 62, p = 0.31) had producer estimates similar to infield survey estimates, whereas the Northwestern Great Plains (W = 363.5, p<0.01) and the Northern Glaciated Plains (W = 364, p<0.01) had producer estimates that were significantly different from infield estimates (Figure 2.1, Table 2.4).

**Table 2.4.** Comparison of blackbird (Icteridae) damage estimates to sunflower (*Helianthus annuus*) from infield and producer survey by Level III Ecoregions in North Dakota, USA for the 2020 growing season.

| Ecoregion | Infield average % damage ± SD | Survey average % damage ± SD | W | *p* |
|---|---|---|---|---|
| Northwestern Great Plains | 1.9 ± 8.2 | 6.6 ± 14.8 | 363.5 | <0.001 |
| Northwestern Glaciated Plains | 6.6 ± 3.3 | 11.5 ± 14.8 | 381 | 0.08 |
| Northern Glaciated Plains | 3.0 ± 2.8 | 14.9 ± 18.4 | 364 | <0.001 |
| Lake Agassiz Plain | 4.9 ± 5.9 | 7.7 ± 18.8 | 62 | 0.31 |

From our survey data, 45.6% of the responses indicated damage ≤5%, whereas 54.3% of respondents indicated damage >5% (range = 6–100%, mean = 9.8 ± 17.1). The hurdle model was a good fit (Wald $\chi^2$ = 30.0, df = 8, $p \leq 0.01$; Table 2.5) for identifying the factors that influence producer-reported bird damage. The number of acres grown ($p = 0.04$) and estimation technique ($p \leq 0.001$) were both significant when predicting the presence or absence of substantial damage (>5%). As the number of sunflower acres decreases, producers were more likely to estimate damage to be >5%. The estimation technique (i.e., visual only and other) was a significant variable in the zero-truncated ($p \leq 0.001$) and count model ($p \leq 0.001$). In the second portion of the model, producers that only used other estimation methods, less visual only, were associated with higher reports of total yield losses >5%.

**Table 2.5.** Hurdle model showing factors correlated with whether North Dakota sunflower producers reported damage estimates ≤5% (i.e., damage accepted by industry) in the 2020 growing season. This binomial distribution (logit model) models the probability that a farmer will report severe damage (>5%). For the amount of damage reported, a negative-binomial distribution (truncated count regression model) examines the relationship between the reported damages (i.e., >5%) and selected covariates.

| | **Bird Damage ≤5%** | **Bird Damage >5%** |
|---|---|---|
| **Covariates** | **Coefficient ± S.E.** | **Coefficient ± S.E.** |
| Age (years) | 0.015 ± 0.015 | 0.008 ± 0.007 |
| Education | 0.604 ± 0.367 | -0.175 ± 0.175 |
| Sunflower experience (years) | -0.002 ± 0.017 | -0.007 ± 0.008 |
| Generation | -0.330 ± 0.228 | 0.189 ± 0.108 |
| Sunflower grown (ac) | -0.582 ± 0.289* | -0.018 ± 0.130 |
| Ecoregion | 0.118 ± 0.077 | 0.024 ± 0.037 |
| Estimation technique | 2.07 ± 0.339*** | 0.686 ± 0.182*** |
| Log pseudolikelihood | -562.5 (df = 17) | |
| n | 278 | |
| Wald $\chi^2$ (df = 8) | 30.0*** | |

***$p \leq 0.001$, **$p \leq 0.01$, *$p \leq 0.05$

The OLR model evaluating reported impact to profit of blackbirds was an overall good fit (LR $\chi^2 = 60.42$, $p \leq 0.01$, McFadden pseudo $R^2 = 0.12$; Table 2.6). Of our participants, 49.0% indicated that blackbird damage was one of several significant factors impacting their profit, followed by blackbirds were the most significant factor at 29.8%, and that blackbirds did not impact their profit at 21.1% of responses. Respondents who used damage estimation techniques other than visual alone reported higher impact of blackbird damage to profits ($p \leq 0.01$), and those who reported newer farms (1st and 2nd generation farms) also reported higher impact of blackbird damage to profit ($p = 0.04$). Our odds ratios (Table 2.6) indicates three variables did not affect odds of the outcome (OR=1), three variables are associated with lower odds of outcome (OR<1), and one variable (estimate type) has an odds ratio of 7.00, indicating that it is associated with higher odds. For producers that used other techniques or combinations of techniques, the odds of reporting more impact to profits from bird damage was 1.94 times greater than those who reported using visual only (i.e., utilizing other techniques reported negative impact over no impact).

**Table 2.6.** Ordinal logistic regression (OLR) model showing the coefficient (± SE) and odds ratios (OR) for variables that have a relationship with North Dakota sunflower (*Helianthus annuus*) producers report a greater impact of blackbird (Icteridae) damage on profits (see "Impact on profit" Table 2.2).

| Independent variables | Coefficient ± SE | OR |
|---|---|---|
| Age (years) | 0.023 ± 0.012 | 1.024 |
| Education | -0.129 ± 0.303 | 0.879 |
| Sunflower experience (years) | <0.001 ± 0.014 | 1.001 |
| Generation | -0.380 ± 0.191* | 0.684 |
| Sunflower grown (ac) | 0.150 ± 0.219 | 0.861 |
| Ecoregion | <0.001 ± 0.062 | 1.000 |
| Estimation technique | 1.946 ± 0.292*** | 7.002 |
| McFadden's Pseudo $R^2$ | 0.12 | |
| L.R.$\chi 2$ | 60.42*** | |
| *N* | 278 | |

***$p \leq 0.001$, **$p \leq 0.01$, *$p \leq 0.05$

The OLR model evaluating producer-reported opinions of blackbirds was an overall good fit (LR $\chi^2 = 22.97$, $p \leq 0.01$, McFadden pseudo $R^2 = 0.07$; Table 2.7). An overwhelming majority (82.1%) of participants selected the option "I do not enjoy blackbirds/regard as pest", followed by “I enjoy or enjoy blackbirds but worry about the problems” at 9.4% and finally “I have no feelings on blackbirds” at 8.3%. Opinions of blackbirds became more negative as sunflower growing experience increased ($p \leq 0.01$) and methods to estimate damage other than visual alone were used ($p \leq 0.01$). With each additional year of sunflower growing experience, the log odds of having a negative opinion of blackbirds (“I do not enjoy/regard as pest” versus “I enjoy or enjoy them but worry about the problems”). increases by 1.06, holding constant all other variables. For producers who reported they used techniques to estimate damage besides visual alone, the odds of having a more negative opinion is 2.56 times that of producers using visual alone. An additional survey question that asked about the participants’ overall feelings about birds (excluding blackbirds) in and around their farm revealed that 29.1% of the respondents indicated that they enjoy birds, 35.2% enjoy but worry about wild birds in general, 18.5% had no opinion, and 17.1% dislike or regard birds as pests.

**Table 2.7** Ordinal logistic regression (OLR) model showing the coefficient (± SE) and odds ratios (OR) for variables that have a relationship with North Dakota sunflower (*Helianthus annuus*) producers' negative opinions of blackbirds (Icteridae; see "Blackbird opinion" Table 2.2).

| Independent Variable | Coefficient ± SE | OR |
|---|---|---|
| Age (years) | -0.012 ± 0.017 | 0.987 |
| Education | -0.886 ± 0.572 | 0.412 |
| Sunflower experience (years) | 0.061 ± 0.021** | 1.063 |
| Generation | -0.186 ± 0.261 | 0.830 |
| Sunflower grown (ac) | -0.071 ± 0.270 | 0.924 |
| Ecoregion | 0.042 ± 0.085 | 1.047 |
| Estimate technique | 0.941 ± 0.350*** | 2.564 |
| McFadden's Pseudo $R^2$ | 0.07 | |
| L.R.$\chi2$ | 22.96*** | |
| *N* | 278 | |

***$p \leq 0.01$, **$p \leq 0.05$, *$p \leq 0.10$

## Discussion

Several characteristics of a sunflower crop, dynamics of avian foraging, and a grower's own experiences may influence their ability to accurately estimate bird damage. North Dakota is divided into four Level III Ecoregions, which possess different land covers, climate, and terrain that dictate the amount of sunflower acreage and blackbird habitat. Specifically, the Prairie Pothole Region consists of countless wetlands and grasslands that produce millions of birds a year (EPA, 2013; Forcey et al., 2015; Igl et al., 2017; Johnson et al., 2019). Farmers in the Prairie Pothole Region (i.e., Northern Glaciated Plains, Lake Agassiz Plain, and Northwestern Glaciated Plains) had estimates closer to our infield estimates, which could have been due to their familiarity with the problem given historically high sunflower acres along with blackbird numbers. These ecoregions inherently support more blackbirds (i.e., opportunity for damage) due to the amount of water on the landscape compared to drier, semi-arid western ecoregions. Although experience (geographic location, age, and farming experience) may improve estimates, farmer estimates were higher than infield estimates (3.6 ± 5.5%) when averaged at the state level (11.6 ±17.2%), and when producer and infield estimates were paired from the same field (13.1 ± 10.2%).

Elser et al. (2019) found that fruit crops of a shorter stature or with smaller fruit had similar estimates between producers and infield surveys. Although it is easier to observe damage in a relatively short-stature row crop, aspects of the damage scenario can make accurate assessments difficult for producers. Sunflowers are visible from the ground, but their heads face down (Kaiser et al., 2021), requiring effort to assess the damage on each head. Sunflower fields are large (441 ac on average; (USDA NASS, 2017) with topographic variation and limited accessibility, making interior and total estimates difficult. Aside from harvest, producers typically assess damage from field edges where instances of bird damage may be more visible, and damage is estimated to be significantly higher. Additionally, crops are rotated annually in the northern Great Plains (Putt, 1997), and the constantly changing landscapes, and bird responses to it, make it difficult to predict and estimate damage from year to year. Prior damage estimates (ranging from 0.87% in 1979 to 8.7% in 2013) do not indicate a clear pattern from one year to the next, and instead display the high variability of bird damage (Hothem et al., 1988; Klosterman et al., 2012; Ernst et al., 2019). Producers may also over or underestimate damage due to the detectability of the blackbirds compared to nocturnal or secretive pest species or other sources of crop loss (Peer et al., 2003; Johnson-Nistler et al., 2005; Lindell et al., 2016).

While it is generally assumed that infield surveys are more accurate than producer estimates (Elser et al. 2016), the true amount of bird damage is not known, and infield surveys have their own drawbacks. We contacted producers at the conclusion of the harvest season for their estimate (both paper surveys and direct contact), while infield surveys were conducted over two months (September–October) prior to harvest suggesting infield surveys would be biased to be lower. Infield surveys also use systematic linear transects that may not accurately record damage that is not uniformly distributed throughout the field. We asked producers to report a percent damage that was not collected systematically for comparison with our systematic infield surveys. When asked to speculate, a respondent may not consider 10% to be much different that 5% and tend to round up. In the mailed survey producers were reporting all of their sunflower fields as an aggregate, whereas we asked about a single, specific field when we spoke directly with the producers. Given sunflower damage across the landscape is not evenly distributed, providing an aggregate response may bias estimates to be lower, and thinking about a single field may bias estimates to be higher.

Although the face of the sunflower head is not visible from the combine during harvest, yield monitor technology displays real-time yield estimates in the combine. This technology may allow for better bird damage estimates when the foraging location of birds are known. However, it has the potential to inflate yield loss attributed to birds given producers vary in their ability to correctly correlate any decreases on the yield monitor with bird damage as opposed to other agronomic factors (i.e., soils, disease, weeds, or invertebrate pests). The use of onboard yield monitors should be further evaluated as a tool for assessing bird damage given the potential to accurately record damage and its distribution throughout an entire field. Especially, given our finding that producers who visually assessed damage reported lower estimates ($4.9 \pm 4.7\%$) compared to those using yield monitors ($15.9 \pm 20.6\%$).

Currently, we are not aware of any extension literature that offers guidance to producers in assessing bird damage percentages. In our analyses involving percent damage, impact to profit, and opinions of blackbirds, the estimation technique (visual v. other) is significant, and the more techniques used the higher the estimate. This highlights the significance of how wildlife damage is assessed. Inaccuracies may lead to underestimates, which undervalue the loss absorbed by farmers and opportunities for support. On the contrary, overestimates may lead to practices that negatively impact the conservation of native species.

Newer farms (1st or 2nd generations) may have less established production practices that exacerbate the actual or perceived impact to profit by blackbirds. Respondents using an estimation practice apart from visually assessing damage also reported a higher impact to profit. This in conjunction with the newer generations reporting greater impact to profit may indicate those producers may have less experience with and knowledge of bird damage. In a large survey of fruit producers 6% indicated that bird damage was the most significant factor affecting profits, which is less compared to the proportion of our participants at 30% (Anderson et al., 2013). Sunflower damage from blackbirds can be variable from one year to the next depending upon 1) the amount and distribution of sunflower fields on the landscape and 2) the amount of water on the landscape with regional reproductive success of blackbirds greater in wet years and the distribution of blackbirds a function of available roosting habitat with standing water.

The actual total cost of bird damage to producers in 2020 is unknown. An estimate of 3.6% sunflower yield lost to birds equates to a roughly US$10.3 million dollars in profit lost in the state of North Dakota. Superficially, a loss of 3.6% seems to be low and negligible based on our previous assumption that on average damage below 5% is acceptable. However, this average, regional estimate greatly underestimates substantial losses faced by some. The US$10.3 million represents yield lost and does not include the additional cost of bird damage management, nor the opportunities lost from removing sunflower from a rotation. The economic cost of potential profit lost to bird damage (0–46%) based on the average market value (US$0.216 lbs/ac) was estimated to be up to US$283,000 for an individual respondent (USDA NASS, 2017). However, these estimates are averaged across the state which does not represent the severe damage and loss faced by some, for example, one producer reported 10% yield lost from 200 ac, which equates to roughly US$8,087.04. The crop value and potential revenue of sunflower will affect a producer's cost-benefit analysis and decision making when it comes to determining if the profits offset the management costs. From the same survey, White (2021) determined producers were willing to spend on average a maximum of $1,628, however this ranges significantly ($0-20,000) highlighting the variation in the damage distribution in North Dakota. Additionally, blackbirds are not a species harvested for subsidence and do not provide sufficient ecosystems services in North Dakota to offset the disservices of crop damage (Naughton-Treves, 1998).

The losses faced by producers occur just prior to harvest and are difficult to mitigate leading to an understandable negative opinion of blackbirds. Respondents who indicated more years of sunflower growing experience were less tolerant of blackbirds. The annual variability in damage leads individuals with a longer history of planting sunflower to be more likely to have experienced higher levels of damage in the past contributing to their negative opinion. Again, using more than one estimate type, or an estimate besides visual, correlates to more negative opinions towards blackbirds. We also asked participants in this survey to indicate their opinion of wild birds in and around their farm, excluding blackbirds, and a majority (64.3%) reported "I enjoy birds" or "I enjoy birds but worry" and a smaller portion (17.1%) indicated "I regard birds in general as a pest". This is a stark contrast to our overwhelming majority of respondents (82.1%) indicating they disliked blackbirds and only 9.4% reported enjoying them. This phenomenon reflects that a dislike of one native pest species does not warrant a universal negative opinion from respondents towards all wild birds. This warrants additional information on producer values as they relate to mitigating bird impacts, given Stephenson et al. (2022) shows that producers who transitioned to organic agriculture systems were motivated by their personal values over their potential for profit.

We see that the technique used to estimate damage is an important factor in the formation of producer estimates and opinions. The relevance of the estimation technique used indicates that further research involving how producers and researchers have historically and currently assess damage is necessary. In addition to techniques, further research on the temporal and spatial variability of damage within a field will inform us of the accuracy of different estimation methods. Blackbird damage to sunflower in North Dakota is on average below the 5% threshold held by the industry, however researchers (0–31%) and producers (0–100%) report a wide range of damage severity, with some areas and producers experiencing economically-impactful damage levels. The efficacy of current and future management techniques relies on accurate damage estimates. In order to conserve wildlife and alleviate the economic losses of producers, research on estimation methods and potential improvements or alternative are required.

Our surveys may have been biased in that participants may not be representative of the total population of sunflower producers. Farmers may have been more likely to respond to the survey if they have experienced blackbird damage at any point in their career. Our survey did not include farmers who no longer plant sunflower due to blackbird damage, but include those willing to endure blackbird damage as evidenced by continual planting of the crop. Additional unknown biases may be present in the mailing list (e.g., biased by age and only includes farmers requesting information from the National Sunflower Association).

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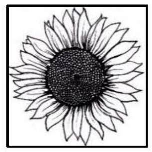
# APPENDIX. COVER LETTER AND SURVEY OF BLACKBIRD DAMAGE TO SUNFLOWER IN NORTH DAKOTA

## Bird Damage to Sunflower Crops

*A Survey of Sunflower Producers*

NDSU



National Sunflower Association

Research conducted by:

**North Dakota State University, Department of Biological Sciences**

North Dakota State University and the National Sunflower Association appreciates you taking the time to fill out the following survey regarding bird damage to sunflower. Your responses will help us to understand the nature of the issue, economic impacts, and efficacy of current management techniques. We intend to use your feedback to direct future research addressing bird damage and improve sunflower production. Even if you do not experience bird damage, it is still crucial for us to hear from you.

The following survey will require approximately 15 minutes to complete. Please return your completed survey in the enclosed pre-paid envelope at your earliest convenience. Alternatively, you could complete an online version of the survey using the link or scanning the QR code below. Your participation is voluntary, and all responses are kept strictly confidential. You may decline to participate or leave blank any questions you do not wish to answer.

We sincerely thank you for taking the time out of your busy schedule to respond! Your input and involvement in this survey is incredibly valuable. In sharing your farming knowledge and expertise, you are contributing essential information for developing methods to combat bird damage.

If you are interested in participating in future sunflower/blackbird research, would like a summary of our findings, or if you have any questions or concerns, please contact us:

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P.O. Box 6050, Department 2715
Fargo, ND 58102

**Use the link or scan the QR code to access the online survey:**
https://ndstate.co1.qualtrics.com/jfe/form/SV_1UoXI3SKIKGW8PH

***Thank you for your help with this important study!***

## Your Farm and Farming Experience

1. Did you grow a sunflower crop on your farm in 2020? ☐ Yes ☐ No

   If no, what was the last year you planted a sunflower crop? _______________

2. Where was the majority of your sunflower crop planted in 2020?

   State(s): __________ County(s): ______________________ Zip Code(s): ______________

3. Provide your 2020 planting practices for each crop (Fill in the table below for the crops you produce. Write "0" in the Seeding Rate column if you do not grow that crop):

| Crop | Seeding Rate (plants per acre) | Solid Seeded | Row | Row Spacing | Organic (mark if yes) |
|---|---|---|---|---|---|
| **Confection** | _________ | ☐ | ☐ | _____ in. | ☐ |
| **Oilseed** | _________ | ☐ | ☐ | _____ in. | ☐ |
| **Conoil** | ________ | ☐ | ☐ | _____ in. | ☐ |

4. What other crops did you plant in 2020? (Mark all that apply.)

   ☐ Corn ☐ Soybean ☐ Small Grain ☐ Pulses ☐ Hay ☐ Other: ______________

5. How often do you grow at least one field with a sunflower crop?

   ☐ Annually ☐ Occasionally ☐ Rarely ☐ Never

6. Do you grow organic sunflower? ☐ No ☐ Yes, some ☐ Yes, all

7. What are your most important reasons for reducing or not planting sunflower in a given year? Rank (1 to 5) the following in order of importance (1 is most important, 5 is least important).

| Blackbird Damage | Disease | Insects | Market Price | Weather |
|---|---|---|---|---|
| ______ | ______ | ______ | ______ | ______ |

8. Based on your 2020 growing season, please provide acreage and approximate damage by birds for each crop (Fill in the table below for the crops you produce. Write "0" in the acreage column if you do not grow that crop):

| Crop | Acreage | Yield in 2020 | % Yield Lost to Bird Damage | Approximate Date Planting Started | Approximate Date Harvesting Started |
|---|---|---|---|---|---|
| **Confection** | ________ | ________ lbs/ac | ________ | __________ | __________ |
| **Oilseed** | ________ | ________ lbs/ac | ________ | __________ | __________ |
| **Conoil** | ________ | ________ lbs/ac | ________ | __________ | __________ |
| **Corn** | ________ | ________ bu/ac | ________ | __________ | __________ |

9. How did you arrive at % bird damage estimate in Question 8? (Mark all that apply.)

   ☐ Visual ☐ Combine (Yield Monitor) ☐ Expected Yield vs. Actual Yield ☐ Other: _______

10. Over the last 5 years, what is the average % yield lost to bird damage? ___________%

11. Would you plant more sunflower acres if blackbird damage was not a concern? ☐ Yes ☐ No

    If yes, how many more acres would you plant in a given year? ___________ ac

12. Did you reduce sunflower acreage in 2020 due to previous blackbird damage? ☐ Yes ☐ No

    If yes, list the crop and acreage planted instead:

    1. ______________ / _______ ac    3. ______________ / _______ ac

    2. ______________ / _______ ac    4. ______________ / _______ ac

13. What is your estimated cost of controlling bird damage to sunflower in 2020?
    Write "0" if you spent no money trying to control bird damage in 2020. $___________

14. Did you observe blackbird flocks in your sunflower in 2020? ☐ Yes ☐ No

    If yes, how many blackbirds would you estimate were in the largest flock observed?
    ☐ Less than 10,000 ☐ 10,000 – 100,000 ☐ More than 100,000

15. In your experience, what landscape features increase bird damage to sunflower? Rank (1-6) the following in order of importance (1 is most important, 6 is least important).

| Wetlands | Trees | Power lines | Manmade structures | Adjacent corn | Adjacent sunflower |
|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ |

16. In your experience, what weather conditions increase bird damage to sunflower? Rank (1-4) the following in order of importance (1 is most important, 4 is least important).

| Wet years | Dry years | Cool years | Hot years |
|---|---|---|---|
| _____ | _____ | _____ | _____ |

## Your Opinion on Blackbirds and Blackbird Damage

17. What are your general feelings toward blackbirds in/around the land that you farm?

    ☐ I have no particular feelings towards blackbirds
    ☐ I enjoy blackbirds AND I do not worry about the problems they may cause
    ☐ I enjoy blackbirds BUT I worry about the problems they may cause
    ☐ I do not enjoy blackbirds and regard them as a pest

18. Which statement best describes the current impact of blackbird damage to your sunflower production profits?

    ☐ Blackbird damage has little or no influence on profits in a given year
    ☐ Blackbird damage is one of several significant factors affecting profits in a given year
    ☐ Blackbird damage is the most significant factor affecting profits in a given year

19. Which statement best describes your opinion about blackbird damage to sunflower?

    ☐ Blackbird damage has been increasing over the past 5 years
    ☐ Blackbird damage has remained relatively stable over the past 5 years
    ☐ Blackbird damage has been decreasing over the past 5 years

20. Excluding blackbirds, what are your general feelings toward birds in/around the land that you farm?

    ☐ I have no particular feelings towards birds
    ☐ I enjoy birds AND I do not worry about the problems they may cause
    ☐ I enjoy birds BUT I worry about the problems they may cause
    ☐ I do not enjoy birds and regard them as a pest

## Your Damage Control Techniques

21. Do you take any action to prevent or reduce bird damage to your crops? ☐ Yes ☐ No

22. Mark if you have used a method and your opinion of overall method effectiveness in sunflower. Please rate your opinion of effectiveness even if you have not used the method:

| **Method** (Mark all that you have used) | **Not at all effective** | **Slightly effective** | **Moderately effective** | **Very effective** | **No opinion** |
|---|---|---|---|---|---|
| ☐ **Crop Desiccation** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ **Decoy Crops** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ **Planting at Same Time as Neighbors** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ **Cattail Management** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ **Chemical Repellents (Avian Control)** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ **Lethal Shooting (Shotgun)** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ **Non-lethal Shooting (Rifle)** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ **Propane Cannons** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ **Pyrotechnics** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ **Acoustics (Distress & Predator Calls)** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ **Unmanned Aircraft Systems (Drones)** | ☐ | ☐ | ☐ | ☐ | ☐ |
| ☐ **Other:** ________________________ | ☐ | ☐ | ☐ | ☐ | ☐ |

23. How do you determine effectiveness of a bird damage control method or tool? Rank (1-3) the following in order of importance (1 is most important, 3 is least important).

__ Visual reduction in the number of blackbirds in or around your crop

__ Increase in crop yield after the tool or method is implemented

__ The amount of time and effort taken to implement the tool

24. In your experience, what is the most important factor to consider when implementing bird damage control methods or tools? (Select one)

☐ Cost ☐ Labor Intensity ☐ Effectiveness ☐ Ease of use

25. What is your estimated annual cost ($) of controlling bird damage to sunflower?
Write “0” if you spend no money trying to control bird damage. $______________

26. What is the most you are willing to spend ($) annually to control bird damage to sunflower?
Write “0” if you are not willing to spend any money trying to control bird damage. $ ________

27. How often do you contact USDA Wildlife Services for assistance with blackbird damage?

☐ Every year ☐ Years I plant sunflower ☐ Years with severe damage ☐ Never

28. If you have ever contacted USDA Wildlife Services, how do you rate (1-5) your overall satisfaction with their customer service? (1 is "highly satisfied", 5 is "highly unsatisfied") ______

29. How could USDA Wildlife Services improve? ______________________________________

________________________________________________________________

________________________________________________________________

30. Has an Unmanned Aircraft System (drone) ever been flown on your property? ☐ Yes ☐ No

31. How willing are you to allow drone operations on your property? Mark one box per question.

| Questions | Not Willing | Less Willing | Neutral | More Willing | Very Willing |
|---|---|---|---|---|---|
| **How willing would you be to allow drones on your property to haze blackbird flocks?** | ☐ | ☐ | ☐ | ☐ | ☐ |
| **How willing would you be to allow a drone that applies a registered pesticide (example: Avian Control)?** | ☐ | ☐ | ☐ | ☐ | ☐ |
| **How willing would you be to operate a drone that applies a registered pesticide (requires obtaining FAA pt. 137 Agriculture Operations license)?** | ☐ | ☐ | ☐ | ☐ | ☐ |
| **How willing would you be to hire a licensed aerial applicator to operate a drone that applies a registered pesticide?** | ☐ | ☐ | ☐ | ☐ | ☐ |

Do you have any additional comments/ideas that you would like to share?

________________________________________________________________

________________________________________________________________

________________________________________________________________

## Additional Questions

32. What generation of farmer would you describe yourself as:

☐ 1st generation ☐ 2nd generation ☐ 3rd generation ☐ 4th generation or more

33. Is farming your primary occupation? ☐ Yes ☐ No

34. How many years have you been farming? _____________

How many of those years have you had a sunflower crop? ________________

35. Gender: ☐ Male ☐ Female ☐ Other: ____________

36. Age: ________

37. Highest level of education completed: ☐ High School ☐ College ☐ Graduate School