



## AN ABSTRACT OF THE THESIS OF

Erin R. Harrington for the degree of Master of Science in Wildlife Sciences presented on July 29, 2016.

Title: A Comparative Study of Foraging Behavior and Disturbance Regimes in Urban Versus Agricultural Habitats used by Cackling Geese Wintering in the Willamette Valley, Oregon.

Abstract approved:

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Bruce D. Dugger

The Cackling goose (*Branta hutchinsii minima*) population has increased from a low of 20,000 in 1984 to the current population of 220,000-300,000 (Stehn 2012, Sanders 2013). As the Cackling goose population began to recover in the late 1990s, the majority of the population relocated from wintering in California to the Willamette Valley, Oregon (Pacific Flyway Council 1999, Mini 2012). Cackling geese in Oregon now commonly use exurban, suburban, and urban areas (Mini 2012). The reasons for Cackling goose use of urban areas are still unclear as they did not commonly use this habitat type on their traditional wintering areas in California or initially upon showing up in Oregon. Given what we know about habitat selection in geese and the Willamette Valley system, we tested three different hypotheses that seem to have the greatest utility for explaining the recent use of urban habitats in Oregon's Willamette Valley: 1) Foraging opportunity in urban habitats is higher due to lower perceived, or

actual, predation risks, 2) Foraging efficiency in urban habitats is higher in urban landscapes due to a difference in forage characteristics between landscape types, and 3) Quality of forage in urban habitats is higher due to a difference in nutritional content and regrowth rate. My field work centered on collecting data to test predictions deduced from my hypotheses.

From November 2013-April 2014 and November 2014-April 2015, I conducted a total of 278 hour-long disturbance surveys and 238 behavioral time-activity budget scans in 109 different sites in the Willamette Valley, Oregon within urban areas in Portland, Eugene, and Salem and agricultural areas in the Willamette Valley National Wildlife Refuge Complex and nearby private fields. Consistent with the Safe Habitat Hypothesis, predator-related disturbances in urban landscapes were significantly lower than in agricultural landscapes: only one avian predator-related disturbance was observed in urban landscapes throughout the entire study. Geese spent more time feeding ( $69.0 \pm 1.9\%$  vs.  $55.0 \pm 2.1\%$ ), less time flying ( $3.0 \pm 1.1\%$  vs.  $6.6 \pm 1.3\%$ ) and less time vigilant ( $2.1 \pm 0.2\%$  vs.  $5.6 \pm 0.5\%$ ) in urban landscapes than in agricultural landscapes. The frequency of the eight disturbance types differed between landscape types ( $n = 988$ ,  $\chi^2 = 308$ ,  $df = 8$ ,  $P < 0.001$ ). Vigilance (70% vs. 56%,  $\chi^2 = 22.9$ ,  $df = 1$ ,  $P < 0.001$ ) occurred more often in agricultural landscapes and walking away responses (19% vs. 3%,  $\chi^2 = 64.49$ ,  $df = 1$ ,  $P < 0.001$ ) occurred more often in urban landscapes.

I measured forage biomass, daily regrowth rate, and nutritional content from 58 plots in December of 2014, and 60 plots in December of 2015 at a total of 6 fields

in urban landscapes and 6 fields in agricultural landscapes. Mean grass biomass did not vary significantly between urban ( $32.0 \pm 7.5 \text{ g m}^{-2}$ ) and agricultural landscapes ( $22.0 \pm 4.2 \text{ g m}^{-2}$ ,  $n = 12$ ,  $P = 0.4$ ), and average daily regrowth rate did not vary significantly between urban ( $0.08 \pm 0.01 \text{ cm/d}$ ) and agricultural landscapes ( $0.12 \pm 0.02 \text{ cm/d}$ ,  $n = 12$ ,  $P = 0.09$ ). Average grass height in agricultural landscapes was  $7.1 \pm 0.7 \text{ cm}$  and average height in urban landscapes was  $3.8 \pm 0.3 \text{ cm}$ . Percent crude protein did not vary significantly between urban ( $18.4 \pm 0.97\%$ ) and agricultural landscapes ( $17.0 \pm 1.3\%$ ,  $n = 12$ ,  $P = 0.64$ ). Percent ADF did not vary significantly between urban ( $35.3 \pm 1.8\%$ ) and agricultural landscapes ( $36.7 \pm 2.4\%$ ,  $n = 12$ ,  $P = 0.84$ ).

My results are consistent with the Safe-habitat Hypothesis which states Cacklers may be now using urban landscapes partially in response to an increasing Bald Eagle population. Ultimately, if nutritional quality of forage is the same between landscapes types, but Cacklers are disturbed more often by predators in agricultural landscapes, Cacklers in urban landscapes may have a higher net energy gain than Cacklers foraging on refuges; therefore, use of urban areas by Cacklers might increase. Coordinated management plans with private landowners, public school districts, and Parks and Recreation departments in the Willamette Valley that maximize preferred foraging conditions on refuges and minimize preferred foraging conditions in urban areas may attract more geese to protected areas in agricultural landscapes.

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A Comparative Study of Foraging Behavior and Disturbance Regimes in Urban  
Versus Agricultural Habitats used by Cackling Geese Wintering in the Willamette  
Valley, Oregon

by  
Erin R. Harrington

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Erin R. Harrington, Author

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Dr. Bruce Dugger helped to acquire funding, and assisted with all aspects of this project. Bruce Davitt and B.J. Blatner provided nutritional analysis of forage. Anne Mini, Brandon Reishus, and Steve Olson provided me with access to data necessary for preliminary analysis during my project.

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## **A COMPARATIVE STUDY OF FORAGING BEHAVIOR AND DISTURBANCE REGIMES IN URBAN VERSUS AGRICULTURAL HABITATS USED BY CACKLING GEESE WINTERING IN THE WILLAMETTE VALLEY, OREGON**

### **INTRODUCTION**

The Cackling goose (*Branta hutchinsii minima*) population has increased from a low of 20,000 in 1984 to the current population of 220,000-300,000 (Stehn 2012, Pacific Flyway Council 1999). As the Cackling goose population began to recover in the early 1990s, the majority of the population relocated from wintering in California to the Willamette Valley, Oregon (Pacific Flyway Council 1999, Mini 2012). As a result, human-goose conflicts in Oregon have increased (Powell et al. 2003, Whitford 2003, Clark and Sullivan 2003, Mini 2012, Stehn 2012). Additionally, Cackling geese in Oregon now commonly use exurban, suburban, and urban areas (Mini 2012). This increased use of urban areas by geese has created additional conflicts with an increasingly diverse group of constituents. The reasons for Cackling goose use of urban areas are still unclear as they did not commonly use this habitat type on their traditional wintering areas in California or initially upon showing up in Oregon. Without an understanding of why geese now use urban areas, we cannot design effective management strategies targeted at influencing goose use of urban ecosystems (Ankney 1996, Mini 2012).

Given what we know about habitat selection in geese, there are six possible explanations for this change in distribution. First, during population increases a switch in habitat use might track density dependent changes in food abundance or be an indication of food depletion (Sutherland et al. 2002, Black et al. 2007). Second, previous studies have found

younger birds may be more likely to colonize new foraging sites, so younger geese may be colonizing urban landscapes (Swingland and Greenwood 1984, Black et al. 2007, reviewed in Baldassarre 2014). Third, previous studies have found differences in landscape composition may affect goose distribution; for example, a recent study by Jankowiak et al. (2015) found goose habitat selection to be positively correlated to larger water body size and percent coverage of artificial, urban areas. Fourth, we know that disturbance from human activities, hunting in particular, can locally affect spatial distribution of migratory and wintering waterfowl, (Madsen 1995); therefore, hunting in agricultural habitats may be shifting goose distribution. Fifth, the Safe-habitat Hypothesis states that in more developed and urbanized landscapes, both perceived and actual predation risks are lower for some species, and a lower predator presence is correlated to lower vigilance and higher foraging effort; therefore, urban habitats are more suitable for certain species (Tomialojc 1982, Ydenberg and Dill 1986, Lima and Dill 1990, Lima 1998, Shochat et al. 2010). Finally, optimal foraging theory states that foraging performance (i.e. foraging profitability and foraging efficiency) affects how individuals distribute themselves spatially (Sutherland and Parker 1985, Sutherland et al. 2002, Black et al. 2007, Mini and Black 2009). While availability of forage is likely not a limiting factor for Cacklers in the Willamette Valley (Mini 2012), foraging efficiency and foraging opportunity for Cacklers in urban landscapes may be higher than in traditional agricultural habitats. If the nutritional quality of grass does not vary between landscape types, but foraging efficiency and foraging opportunity is higher in urban landscapes, this may indicate higher foraging profitability overall in urban landscapes.

Although the first and second aforementioned explanations may appear ecologically valid for Cacklers, they likely do not apply to the Willamette Valley system, specifically. First, these mechanisms do not account for the fact that Cacklers were not using urban landscapes on their traditional wintering sites in California, or upon first showing up in the Willamette Valley, OR. Additionally, Mini et al. (2012) found that total food energy available on public and private lands in the Willamette Valley is not a limiting factor for the Cackler population, so buffer effects due to food depletion and density dependence in the Willamette Valley are unlikely. Therefore, the most likely reasons for this change in distribution could be explained by an increased threat of predation, by both natural predators and hunters in agricultural landscapes, and/or changes in foraging efficiency and opportunity, over time.

The Safe-habitat Hypothesis states that predation risk is reduced in urban areas, therefore making habitat patches more profitable, and thus more preferable for some wildlife (Tomialojc 1982, Shochat et al. 2010); urban areas may allow for longer foraging times because decreases in perceived predation risk, would decrease the effort allocated to vigilance (Caraco 1979, Ydenberg and Dill 1986, Lima and Dill 1990, Lima 1998). In addition, proponents of the Safe-habitat Hypothesis state that urbanization can cause a decrease in the abundance of native predators (Lima and Dill 1990, Shochat et al. 2010), which reduces actual predation risk in urban habitats. Although humans could be considered a type of predator, urban birds may become acclimatized to human disturbance and do not interpret humans as potential predators (Owens 1977, Lima and Dill 1990, Caro 2005).

Given the current increasing Bald Eagle (*Haliaeetus leucocephalus*) population nationwide (Eakle et al. 2015) and in Oregon, specifically (Isaacs and Anthony 2011, Eakle et



al. 2015), Cacklers may be experiencing increased disturbances and predation risk. The Bald Eagle breeding population in Oregon has increased an average of 7.3% per year (Isaacs and Anthony 2011). The breeding range of Bald Eagles in the Willamette Valley specifically, has been expanding exponentially since 1978 (Isaacs and Anthony 2011). Therefore, Cackling geese may be colonizing novel urban ecosystems in response to increasing predation and predator-related disturbances.

Optimal foraging theory states that foraging performance within habitats should influence how individuals are spatially and temporally distributed (Charnov 1976) and geese will switch to new sites to optimize foraging performance (Sutherland and Parker 1985, Sutherland et al. 2002, Black et al. 2007 Mini and Black 2009). We know from previous research that although northern-nesting geese demonstrate high site fidelity while foraging on wintering and spring staging grounds (Black et al. 2007), colonization of novel habitats may occur if traditional sites become less energetically profitable due to decreased quality of forage (Gauthier et al. 1984, Black et al. 1991, Prop and Black 1998, Prop et al. 1998), increased disturbances (Madsen 1985), and increased predation risks (Prop and Black 1998, Prop et al. 2003, Mini and Black 2009).

Previous studies (Heuermann et al. 2011, Mini 2012) have investigated foraging efficiency for Cackling geese. One element of foraging efficiency, peck rate, is directly related to handling time (Durant et al. 2003) and handling time can be influenced by habitat conditions. Small geese peck fastest in shorter grass with less biomass and have more difficulty handling taller grass (Durant et al. 2003, Heuermann et al. 2011). For example, Heuermann et al. 2011 found that optimum bite volume for Cacklers was reached at a forage biomass of 36 g m<sup>-2</sup> and

plant height of 11 cm, while optimum bite volume for large bodied geese was reached at a forage biomass of  $79 \text{ g m}^{-2}$  and plant height of 18 cm. If foraging efficiency is higher in urban habitats due to a difference in forage characteristics between landscape types, then biomass and grass height in urban landscapes might be closer to these optimum foraging values than biomass and grass height in agricultural landscapes. Therefore, because Cacklers prefer shorter browse and lower biomass, foraging efficiency in urban habitats may higher than in agricultural habitats, and ultimately, may be more suitable for Cacklers than agricultural habitats.

## LITERATURE REVIEW

### URBAN ECOLOGY

The concept of urban ecosystems did not arise in academia until the late 1970's, and was not popularized in North America until the 1980's (Marzluff et al. 2008). Additionally, the term, urban wildlife, was not formally introduced until Lowell (1994). This relatively new research field has been deemed necessary by many ecologists and biologists because there are distinct differences between natural and urban ecosystems and we have yet to fully understand these differences and their underlying mechanisms. Studies worldwide, however, have found a number of consistent patterns in urban ecosystems: species diversity tends to decrease while population density tends to increase (Marzluff 2001); community composition shifts as native species are replaced by non-native species (Emlen 1974); and evenness sometimes decreases, with urban specialists constituting a high proportion of the community (Marzluff 2001, Shochat et al. 2004, Adams et al. 2006). However, the mechanisms that drive these patterns still remain unclear (Shochat et al. 2004, Lin et al. 2012) and the resulting changes in behavior, physiology, and life history of urban wildlife are poorly understood (Diamond 1986, Klausnitzer 1989). Several mechanisms have been proposed to account for these distributional and community composition changes in urban areas, such as increased availability of food, reduced natural predators, changes in vegetation complexity, and reduction in extreme climatic conditions (Shochat et al. 2004, Adams et al. 2006).

The ability of Cackling geese, and other species that use urban habitats, to tolerate and adapt to urban environments is connected to habitat needs, resource requirements, reproductive strategy, and survival rate (Lin et al. 2012, Shochat et al. 2010). Birds using urban areas are

able to adapt to urban environments because of behavioral flexibility, physiological flexibility and, specifically, the ability to use novel resources (Schoech et al. 2004, Bonier et al. 2007, Møller 2009, Lin et al. 2011). For example, many urban species have become accustomed to human presence and have lost some of their natural cautious behavior when in close proximity to humans (Prange et al. 2003, Adams et al. 2006). In addition, studies have found feeding strategies may change in urban habitats due to the availability of novel food sources (Belant et al. 1997, Adams et al. 2006). Furthermore, and perhaps most pertinent to my own study, some populations of Canada geese (*Branta canadensis*) have abandoned their historical migration patterns altogether and have become year-round urban residents (Hope 2000, Baldassarre 2014).

Despite this body of urban ecology research and theory, however, the urban wildlife field is not well developed as an academic discipline. There are limited resources and research support available to those interested in urban ecology research, many species of urban wildlife have yet to be studied, and urban wildlife management techniques have yet to be implemented (Adams et al. 2006). The Cackling goose population in the Willamette Valley is illustrative of this lack of development in urban ecology as a field of research; although the Cackling goose population has been shifting its historical distribution and using novel urban landscapes for almost two decades, the mechanisms behind these shifts have yet to be studied, and the management implications are unclear.

#### SUITABILITY AND PROFITABILITY OF URBAN LANDSCAPES

The major distributional change of wintering Cackling geese between California and Oregon may, in part, be due to a change in forage abundance along the traditional migratory

route (Raveling and Zezulak 1992, Pacific Flyway Council 1999, Mini 2012). The suitability and profitability of habitat patches influences where individuals are distributing themselves to forage, despite the fact that colonization of novel sites is rare for geese (Owen 1980, Sutherland et al. 2002, Mini 2012). Many studies have found that although migratory geese have high site fidelity, they will shift to alternative foraging sites when their foraging performance, and subsequent suitability and profitability of a foraging site, deteriorates (Owen 1980, Madsen 1985, Prop et al. 1998, Mini 2005, Black et al. 2007, Mini 2012). Therefore, Cackling Geese may be moving to urban areas because these novel habitat patches are becoming more suitable and profitable.

Optimal foraging theory states that foragers should distribute themselves according to the distribution of available resources in the environment (Fretwell 1972, Charnov 1976, Prop and Black 1998, Prop et al. 2003 and Shochat 2004). Studies suggest that feeding strategies and time activity budgets for geese, specifically, tend to vary depending on habitat composition and quality, and goose body size (Owen 1980, Black et al. 2007, Mini 2012). For example, Mini 2012 found that smaller bodied geese, such as Cacklers, may be able to move more freely within the foraging landscape to exploit dispersed resources (Robbins 2001) or higher quality foods (Durant et al. 2004, Black et al. 2007) while avoiding greater predation risk (Inger et al. 2006), thus minimizing energy expenditure (Mini 2012). Furthermore, previous studies have found Cacklers to be specialist grazers of short green browse (Johnson and Raveling 1988, Mini 2012) and although nutritional content of food resources often influences field selection, habitat preferences based on foraging efficiency, rather than solely foraging profitability, may

be a more important factor for Cacklers (Durant et al. 2003, 2004, Therkildsen and Madsen 2000, Heuermann et al. 2011).

## DISTURBANCE REGIMES

There are various theories regarding how predation risk, perception of predation risk, and disturbance varies between natural and urban ecosystems. Additionally, there are many intersecting factors that influence the way in which birds respond to human disturbance, such as body size (Fernandez-Juricic et al. 2004, Møller and Erritzoe 2010), previous experience, learning ability (Kulemeyer et al. 2009) and each species' specific phylogeny (Møller, 2009). Furthermore, many studies have found that a variety of factors influence the way that birds respond to predator disturbance, specifically, such as the size and type of predator, directness of approach, speed of approach, size of the flock being depredated, and the quality of the habitat being used by the flock (Cresswell et al. 2000, Mori et al. 2001, Stankowich and Blumstein 2005, Ydenberg & Dill 1986, Lima 1990).

Flock size and/or the number of detectors (i.e., the first birds which leave in response to a predator) can affect the timing and impact of disturbance for birds that rely on detectors in a flock (Ydenberg & Dill 1986, Lima 1994, reviewed in Caro 2005). Predation risk can influence the decision to join flocks of different sizes, since larger groups can detect predators earlier and reduce the per capita risk of capture (dilution effect, reviewed in Krause and Ruxton 2002 and Caro 2005, Valcarcel and Fernández-Juricic 2009). Specifically, small geese such as Cacklers congregate in large flocks in the winter either to facilitate optimal grazing conditions or as a response to predation risk, or a combination of the two (Madsen 1985, Johnson and Raveling 1988, McWilliams and Raveling 1998, and Mini 2005). However, despite all of this knowledge

about the various factors involved in disturbance response and disturbance tolerance, some experts argue that a better theoretical framework, based on optimal foraging theory incorporating predation risk is required (Madsen 1995) — my research project aims to contribute to such a framework.

Disturbance from human activities can cause temporary changes in behavior and locally affect temporal and spatial distribution of migratory and wintering waterfowl (Madsen 1995). Human activity causes wintering waterfowl, specifically, to expend energy on avoidance behavior at a time in their annual cycle when energy conservation is important to survival, migration, and acquisition of breeding reserves (Pease et al. 2005). For example, Belanger and Bedard (1990) found that human disturbance increased energy expenditure by birds, due to both alertness and escape flights, and reduced their energy intake, due to decreased feeding rate. Furthermore, the spectrum of response types to disturbance can vary in intensity (e.g., alertness vs. walking/swimming away vs. escape flight) and distance (Owens 1977, Be'chet et al. 2004), and the severity of the response may be indicative of the perceived costs of a disturbance (Ydenberg and Dill 1986, reviewed in Caro 2005). Unsurprisingly, this range of response intensity has different associated energetic consequences for each category of response (Madsen and Fox 1995). Although previous studies have observed this range of disturbance responses for geese, no studies have yet investigated this disturbance response gradient in an urban landscape context specifically. I will be investigating this in my study in order to determine if geese engage in different disturbance response behaviors in different landscape types. Different response types have different energetic costs, and may suggest differences in perceived risks and acclimation to certain types of disturbances (Owens 1977,

Caro 2005).

Foraging effort by Cacklers in the Willamette Valley may come at a cost to predator avoidance (Owen 1972, Caraco 1979, Black et al. 1991, Mini 2012), thus urban areas may be less costly overall due to reduced predator risk. The Bald Eagle is a known predator to Cackling geese, and Bald Eagle attacks on Cacklers were observed during Mini's 2012 study on Cacklers in agricultural landscapes in the Willamette Valley. Furthermore, the Bald Eagle population in Oregon has increased 400% from its ESA listing in 1978 to 2007, and is continuing to increase (Isaacs and Anthony 2011, Horton 2014). It is also noteworthy that the Oregon Bald Eagle population has been found to be largest during late winter, based on survey data from 1978-2007 (Isaacs and Anthony 2011), and winter is when foraging profitability is traditionally lowest for Cackling geese. Additionally, geese are hazed by farmers (Mini 2012), and these disturbances may disproportionately affect small Cacklers because farmers tend to target larger flocks of geese. Cacklers feed in significantly larger flocks than other species of geese, and Cacklers spend more time in fields during the day feeding (Giroux and Patterson 1995, Gill 1994; Bos and Stahl 2003, Béchet et al. 2003, 2004, Tombre et al. 2005, Mini 2012). Furthermore, recreational hunting in the Willamette Valley now occurs over a longer time period than it once did 30 years ago (Mini 2012). Therefore, hunting, landowner disturbance, or increased predation risk from Bald Eagles, or a combination of these factors, may be driving use of urban landscapes by Cacklers in the Willamette Valley.



## OBJECTIVES

My review of the literature leads me to believe that three hypotheses have the greatest utility for explaining the recent use of urban habitats in Oregon's Willamette Valley:

- 1) Safe-habitat Hypothesis: Foraging opportunity in urban habitats is higher than in non-urban habitats due to lower perceived, or actual, predation risks.

*Prediction:* Predator-related disturbances in urban landscapes will be lower than in agricultural landscapes.

*Prediction:* Cacklers will spend less time vigilant and more time feeding in urban landscapes.

Optimal Foraging Hypotheses:

- 2) Foraging efficiency for Cackling geese is higher in urban landscapes than in agricultural landscapes due to a difference in forage characteristics between landscape types.

*Prediction:* Biomass of grass in urban landscapes will be closer to the foraging optimum of  $36 \text{ g m}^{-2}$  than in agricultural landscapes.

*Prediction:* Average height of forage in urban landscapes will be closer to the foraging optimum of 11 cm than in agricultural landscapes.

- 3) Quality of forage for Cackling geese is higher in urban landscapes than in agricultural landscapes due to a difference in nutritional content and regrowth rate between landscape types.

*Prediction:* Percent protein in grass will be higher in urban landscapes than agricultural landscapes.

*Prediction:* Percent fiber (ADF) in grass will be lower in urban landscapes than agricultural landscapes.

*Prediction:* Regrowth rate of forage will be higher in urban landscapes than agricultural landscapes.

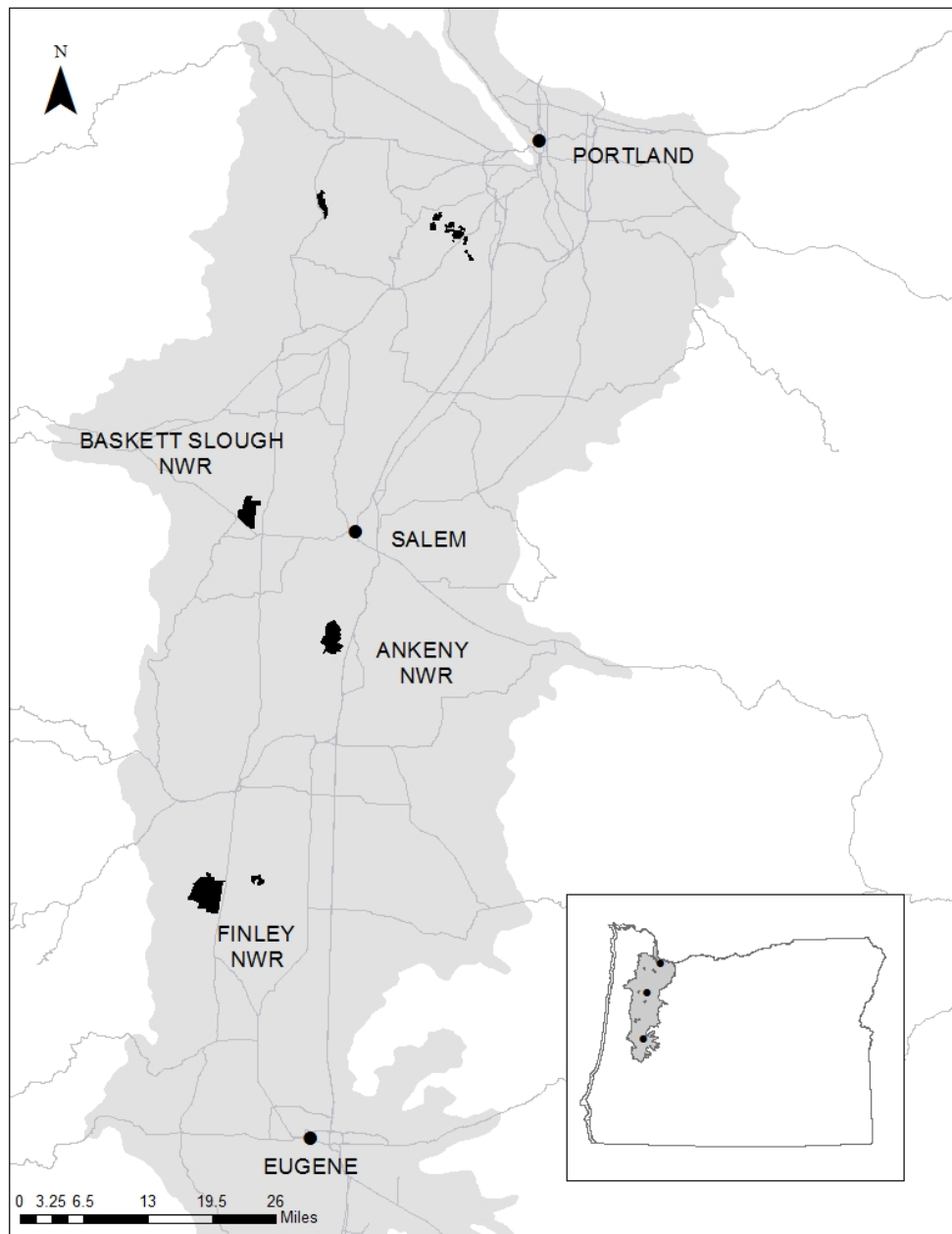
While previous research has found that food availability, specifically, is not a limiting factor in Cackler abundance in the Willamette Valley (Mini 2012) there may be a difference in forage quality and/or foraging efficiency that is driving Cackler use of urban habitats. Therefore, if the change in Cackler distribution between landscape types was linked to a difference in foraging opportunity, foraging profitability, and/or foraging efficiency, this difference should be reflected in a comparison of the sites, and urban landscapes should be more suitable and profitable overall.

My field work centered on collecting data to test predictions deduced from my hypotheses. Specifically, I attempted to:

- 1) quantify and describe all disturbances to Cackling geese in traditional, agricultural landscapes and novel, urban landscapes,
- 2) quantify the average percentage of time spent feeding and vigilant in both landscape types,
- 3) measure foraging behavior of geese in both landscape types, and
- 4) measure and compare the forage quality and biomass of habitat patches in both landscape types.

## STUDY AREA

My study was conducted from November 2013-April 2014 and November 2014-April 2015 in the southern Willamette Valley of western Oregon. My urban study sites included two primary urban study areas: Salem-Keizer and Eugene-Springfield, and a secondary area: Portland, OR. Salem has a population size of 161,637, a population density of 1246.5/ km<sup>2</sup> and an urban boundary that is 125.48 km<sup>2</sup> (U.S. Census 2013). Eugene has a population size of 160,562, a population density of 1379.3/ km<sup>2</sup> and an urban boundary that is 113.29 km<sup>2</sup> (U.S. Census 2013). Portland has a population size of 619,360, a population density of 1,689.2/ km<sup>2</sup> and an urban boundary that is 376 km<sup>2</sup> (U.S. Census 2013). For comparison with urban areas, I collected data at three sites that traditionally support wintering geese in the Willamette Valley: Finley National Wildlife Refuge, Ankeny NWR, and Baskett Slough NWR. I also collected data on private lands within 10 km surrounding the three federal refuges. Finley National Wildlife Refuge (FNWR) is a 2,155 ha federal refuge established in the 1960s to provide habitat for wintering Dusky Canada Geese (*B. c. occidentalis*); FNWR winters up to 36,000 (average 25,000) geese. Ankeny NWR (ANWR) consists of 1,765 acres of cropland, which provide forage for wintering geese (Mini 2012). Baskett Slough NWR (BSNWR) consists of 1,173 acres of cropland, which provide forage for wintering geese, 550 acres of grasslands, 500 acres of shallow water seasonal wetlands and 35 acres of permanent open water. Based on flyoff counts, in 2012 ANWR roosted roughly 20,000 geese, and BSNWR roosted roughly 25,000 geese (Mini 2012). These refuges were also the main study sites for Mini's 2012 study of wintering goose behavior in the Willamette Valley.



**Figure 1.** Map depicting study areas in the Willamette Valley, Oregon: Eugene, Salem, Portland, Finley NWR, Ankeny NWR, and Baskett Slough NWR.

## **METHODS**

For this study, urban sites were defined as any site within a large, central place and adjacent densely settled census blocks that together have a total population of at least 50,000 (U.S. Census), and having a building density of at least 2.5/ha (Marzluff et al. 2001). Traditional, agricultural landscapes were defined according to Marzluff et al. 2001 as any private- or government-owned agricultural habitat being used by geese, with a building density of < 2.5/ha; all of my agricultural study sites had a building density of <0.01/ha. Agricultural study sites served as a control to compare against novel, urban treatment sites.

### **BEHAVIORAL SURVEYS**

For behavioral observations, sites were randomly sampled and recorded within the larger refuges and urban study areas based upon presence or absence of geese. From 2014-2015, I stratified my sampling effort by month (November-April) and time of day: (1-hour blocks from 1 hour after sunrise-sunset). I collected between 3-6 disturbance and behavioral surveys per 1-hour time period per month (Mini 2012). Because flock size can influence behaviors (Owen 1972; Inglis and Lazarus 1981), I only recorded data on Cackler flocks > 100 individuals, and I otherwise controlled for flock size in my analyses.

I located flocks to observe by driving roads throughout the study area. After locating a flock, I waited five minutes before beginning surveys to minimize the chance of recording observer-influenced behavior. Prior to beginning observations, I estimated flock size to the nearest 100 individuals. To obtain a roughly even amount of time activity budget scans and disturbance surveys per hour-long block per day, I used a predetermined sampling schedule to decide in advance whether to conduct a disturbance survey or time activity scan for each flock.

Depending on the distance of the flock, I observed either with 10x48 binoculars, a 20x spotting scope, or without any visual assistance.

Disturbance surveys consisted of 60 minutes of continuous observation on a single flock, unless the flock left my line of sight due to an escape flight, or movement while foraging. For each disturbance within an hour-long session, I recorded: 1) type of disturbance, 2) approximate percentage of flock disturbed, 3) response to disturbance, and 4) duration of response (in seconds). I recorded the cause of disturbance as: 1) automobiles; 2) human-related aerial (helicopters, airplanes, and ultra-light aircraft); 3) human-related activities such as walking, jogging, bicycling, and farming activities; 4) hazing, including active hazing by farmers and hunting noises; 5) dogs; 6) avian, such as American Crows (*Corvus brachyrhynchos*), European Starlings (*Sturnus vulgaris*), Northern Harriers (*Circus cyaneus*), Red-tailed Hawks (*Buteo jamaicensis*), and other geese; 7) avian predators, such as Golden Eagles (*Aquila chrysaetos*) and Bald Eagles (*Haliaeetus leucocephalus*), 8) Other animals, such as coyotes (*Canis latrans*), and 9) unknown sources. Possible responses to a disturbance, categorized from lowest energetic expense to highest energetic expense, included: 1) vigilance (head up and in an erect posture), 2) walking away, 3) jump flight, 4) short escape flight (i.e. flying to a different part of the same site), and 5) full escape flight (i.e., flying away from a site).

Disturbance responses that were a combination of two or more categories were categorized as combination and the percentage of the flock that engaged in each different response was recorded. When a disturbance may have been caused by more than one category, cause of disturbance was categorized as combination for later statistical analysis, and both

causes of disturbance were recorded in the data. When birds moved or flew out of sight and observations had to end early, I recorded the survey as out of view. If there was no disturbance observed for an entire hour, I recorded the session as a zero disturbance session.

I used instantaneous scan sampling (Altmann 1974, Martin and Bateson 1993, Bart et al. 1998) to characterize and quantify the diurnal activity patterns of Cacklers throughout both wintering seasons. I alternated the start of scans on the far left or right side of a flock. I scanned individuals from all sections of the flock, using a back and forth motion across the flock, to maximize the likelihood of collecting a representative sample. Behaviors were recorded as: 1) feeding; 2) vigilant (head up and erect); 3) locomotion (walking or swimming); 4) flying; 5) resting or standing; 6) comfort (a variety of behaviors including preening, wing flapping, drinking and bathing); and 7) interactions, including aggressive encounters. The samples were 15-minute continuous observation sessions on a single flock, though not all sessions lasted for a full 15 minutes due to disturbances. Samples lasting 5-15 minutes were included in the analysis (Mini 2012). Behaviors were dictated onto digital voice recorders and later transcribed manually. For each behavior scan, I summarized data as the percent of time spent performing each behavioral activity (Black et al. 1991, Owen et al. 1992, McWilliams and Raveling 1998 and Mini 2012).

To quantify peck rates, I conducted separate peck rate surveys by observing 5–10 focal individuals in a flock from a variable number of independent flocks throughout a week. I stratified my peck rate surveys of geese by different parts of the flock (front, back, or edge) to minimize sampling bias due to social organization (Black et al. 1991, Mini 2012). I recorded

the number of seconds needed to complete 25 pecks (McWilliams and Raveling 1998) and standardized the data into pecks  $\text{min}^{-1}$ .

#### ENERGY EXPENDITURE

To determine whether energetic expense of disturbances varied between landscape types, I first calculated basal metabolic rate (BMR) using the equation in Miller and Eadie (2006) for ducks and geese:  $\text{BMR (kJ/day)} = 417 * m^{0.71}$ , where  $m$  is body mass in kg. I derived an average body mass of 1,345g for Cacklers from McWilliams and Raveling (2004). This resulted in a BMR of 20.92  $\text{kJ h}^{-1}$  for Cackling geese. I calculated energetic costs of activities and disturbances using multiples of BMR based on values for behavioral parameters (foraging, 1.7; alert, 1.7; preening, 1.8; resting, 1.6; walking, 1.9; interacting, 1.9; drinking, 1.7) that were derived in a laboratory study on Aleutian cackling geese (Stahl 2001). I calculated energetic costs of flying as 14 x BMR, based on methods outlined in Mini (2005).

#### FORAGE QUALITY AND BIOMASS

I conducted grass surveys in three urban fields and three agricultural fields in December of 2014 and 2015 for a total of 12 fields. Surveys were conducted in December because previous studies have found grass biomass and regrowth rates, and thus energetic profitability, for wintering geese to be lowest in December (Owen et al. 1992 and Mini 2012). I measured height, biomass, daily regrowth rates and nutritional content of grass in grazed fields at BSNWR, ANWR, FNWR, Salem, and Eugene. Fields were selected based on presence of geese and accessibility.

For each survey, I randomly established two transects through the interior portion of each field, where geese grazed, and systematically marked ten  $0.25\text{m}^2$  plots in 2014 and  $0.5\text{m}^2$



plots in 2015 (Owen 1972 and Mini 2012). I randomly assigned half the plots as grazed and used these to measure biomass and assigned the other half of the plots to an enclosure treatment to measure grass height after goose use and measure grass regrowth rate (Owen 1972 and Mini 2012). Enclosures, which kept geese from grazing the plot, consisted of 30 cm tall, chicken wire squares, zip-tied to wooden stakes placed at the corner of each plot. Grass height was measured to the nearest 0.1 cm by sliding a 15 cm<sup>2</sup> polystyrene disc with a hole in the center down a measuring stick flush with the ground (Ydenberg and Prins 1981, Summers 1990, Stewart et al. 2001). I returned to each field roughly two weeks after establishing transects to determine regrowth rate at treatment plots. Total growth (cm) was then divided by the number of days between the first measurement and second measurement to calculate daily growth rate.

To test for differences in nutritional quality among habitat types, I collected samples of grass from each control plot for a total of 5 samples per field. Clipped samples were first weighed for initial biomass, all dead grass material was removed, and then samples were weighed again to determine forageable biomass (Mini 2012). Samples were dried at 60° C for 24 hours (Mini 2012) and analyzed for crude protein and fiber (acid detergent fiber; ADF), which are important determinants of nutritional quality for geese (Owen 1972, Mini 2012).

#### STATISTICAL ANALYSES

To test for normality and linearity in all of my analyses of continuous variables, I used the MASS package in R to determine the distribution of each response variable. If the distribution was non-normal (poisson, gamma, binomial, etc.) this was accounted for in the analysis by identifying the distribution family in the model; no data were transformed for normality. All GLMM analyses were conducted using “lme4” in R version 3.2.2 (R Foundation

for Statistical Computing, Vienna, Austria) and all other analyses were conducted using the “stats” package in R, unless otherwise noted. Values are reported as mean  $\pm$  SE of non-transformed data.

To test if the frequency of types of disturbances and disturbance response types differed between urban and agricultural landscapes, I used a Pearson’s chi-squared test, adding a Yate’s continuity correction when appropriate. I then used post hoc proportion test analysis to test for landscape differences in proportions of specific behavioral categories, e.g. full escape flights versus all other responses, vigilance versus all other responses, etc. All full escape flights that were caused by an unknown disturbance were excluded from the analysis because there was no way of knowing with full certainty that geese were flying away due to a disturbance; all other disturbance response types can only be attributed to disturbance, and so were left in the analyses. Because “other geese” cannot be defined as an actual disturbance to geese, but rather simply as a disruption from foraging opportunity, goose-related disturbances were not included in the cause of disturbance analysis.

GLMMs were used to test for differences between landscape types for all continuous response variables. Generalized linear mixed models can be used to test non-normal, non-linear data, and can also be used to account for issues with potential pseudoreplication of data (Jiang 2007 and Stroup 2012). Because behavioral surveys and grass surveys were conducted repeatedly at multiple sites, I accounted for potential non-independence and pseudoreplication of this data by including site as a random effect in all of my models. Based on a literature review, I knew that flock size could affect disturbance responses, so I included flock size as a random effect in my behavioral survey analysis as well.

To test for landscape differences between average duration of disturbance, average time until first disturbance, foraging opportunity, average number of disturbances per hour, and zero disturbances per hour, I used a generalized linear mixed model. Foraging opportunity was defined as the average percentage of time that geese could be on the ground to feed per survey session without being disturbed or flushed into the air. Because I was specifically interested in measuring foraging opportunity and efficiency in my study, and other geese do affect both of these factors, goose-related disturbances were included in these analyses. I used a generalized linear mixed model to compare percentage of time spent foraging and vigilant and peck rates between urban and agricultural sites. The response variables for time activity budget analysis were percent time spent foraging and percent time vigilant. The response variable for peck rate analysis was pecks  $\text{min}^{-1}$ . I used a generalized linear mixed model to compare total energy expenditure per hour and total kilojoules per hour spent in each behavioral category between urban and agricultural landscapes.

To test for nutritional differences in forage between landscape types, I compared percent crude protein and ADF with a generalized linear mixed model. The fixed effect was landscape type and the random effects were site and year. I also compared biomass and daily regrowth rates between urban and agricultural landscape types with a generalized linear mixed model.

## RESULTS

### BEHAVIORAL SURVEYS

From November 2013-April 2014 and November 2014-April 2015, I conducted a total of 278 disturbance surveys ( $n = 137$  in urban landscapes,  $n = 141$  in agricultural) and observed 1,007 different disturbance events; 47.7% of disturbance events were in urban landscapes while 52.3% were in agricultural landscapes. During that same time period I conducted 238 time-activity budget scans, and 515 peck rate measurements; 49.6% of time-activity budget surveys were in urban landscapes while 50.4% were in agricultural landscapes and 55.3% of peck rate measurements conducted ( $n = 285$ ) were in urban landscapes while 44.7% were in agricultural landscapes ( $n = 230$ ). Mean flock size was  $2,681 \pm 113$  in agricultural landscapes and  $674 \pm 30$  in urban landscapes.

Geese spent more time feeding ( $69.0 \pm 1.9\%$  vs.  $55.0 \pm 2.1\%$ ), less time flying ( $3.0 \pm 1.1\%$  vs.  $6.6 \pm 1.3\%$ ) and less time vigilant ( $2.1 \pm 0.2\%$  vs.  $5.6 \pm 0.5\%$ ) in urban landscapes than in agricultural landscapes (Table 1). The mean peck rate in urban landscapes was significantly higher than in agricultural landscapes ( $139.5 \text{ pecks min}^{-1} \pm 2.2$  vs.  $107.3 \text{ pecks min}^{-1} \pm 2.1$ ;  $P < 0.001$ ).

At the most basic level, the proportion of disturbance sessions where no disturbance was observed for a full session was similar between urban (13%) and agricultural (4%) landscapes ( $n = 138$ ,  $\chi^2 = 2.4$ ,  $df = 1$ ,  $P = 0.12$ ). The average number of disturbances per hour ( $P = 0.38$ ) and the mean time until first disturbance ( $P = 0.69$ ) was similar between landscapes, but the mean disturbance length was significantly shorter in urban landscapes ( $24.1 \pm 1.3\text{s}$  vs.

$35.4 \pm 2.2s$ ,  $P = 0.001$ ) and the mean foraging opportunity (i.e., percent of time undisturbed) was higher in urban landscapes ( $94.3 \pm 1.2\%$  vs.  $90.8 \pm 1.4\%$ ,  $P = 0.05$ )

When disturbances occurred, the frequency of the nine disturbance types differed between landscape types ( $n = 988$ ,  $\chi^2 = 308$ ,  $df = 8$ ,  $P < 0.001$ ). Geese in agricultural landscapes were disturbed most by birds, both possible predators and other birds, while geese in urban landscapes experienced more disturbances from humans and automobiles (Fig. 2). Avian predators accounted for 40 out of the 280 disturbances in agricultural landscapes, but only one avian predator was observed in urban landscapes for the entirety of the study. Non-predator avian disturbances in both landscape types were caused primarily by European Starlings, Red-tailed Hawks and Northern Harriers. Other birds observed to cause disturbances, in order of prevalence, included gulls, American Crows, Great Blue Herons (*Ardea herodias*), Turkey Vultures (*Cathartes aura*), ducks, American Kestrels (*Falco sparverius*), and Great Egrets (*Ardea alba*). Active hazing by humans was a comparatively rare cause of disturbance and occurred fairly equally among habitat types; 2 out of the 3 active hazing events in agricultural landscapes were on private fields and all six active hazing events in urban landscapes were at parks and/or schools.

The frequency of the five disturbance responses differed significantly between landscape types ( $\chi^2 = 77.1$ ,  $df = 5$ ,  $P < 0.001$ ). Vigilance (70% vs. 56%,  $\chi^2 = 22.9$ ,  $df = 1$ ,  $P < 0.001$ ) occurred more often in agricultural landscapes and walking away responses (19% vs. 3%,  $\chi^2 = 64.49$ ,  $df = 1$ ,  $P < 0.001$ ) occurred more often in urban landscapes. Full escape flights (3% vs. 4%,  $\chi^2 = 0.45$ ,  $df = 1$ ,  $P = 0.51$ ), short escape flights (6% vs. 9%,  $\chi^2 = 1.88$ ,  $df = 1$ ,  $P = 0.17$ ) and jump flights (6% vs. 6%,  $\chi^2 = 0.02$ ,  $df = 1$ ,  $P = 0.89$ ) were similar between landscape

types (Fig. 3). Vigilance was most often caused by birds in both landscape types. Vehicles caused roughly one half of walking away responses in both landscape types. The remainder of walking away responses was caused by birds in agricultural landscapes and by humans and dogs in urban landscapes. The proportion of response types from avian predators in agricultural landscapes was 16.3% full escape flights, 32.7% short escape flights, 14.3% jump flights, and 36.7% vigilance. The one avian predator-related disturbance that was observed in an urban landscape caused vigilance. The proportion of response types from humans between the two landscape types was markedly different. Over the entirety of the study, only two disturbance events were caused by indirect human disturbance in agricultural landscapes; both of these tangential human disturbances caused vigilance. Direct human disturbances (i.e., human disturbances other than active hazing) in urban landscapes accounted for 43% of human-related disturbance events, while the remainder was tangential human disturbances. Of the direct human disturbances in urban landscapes, 35.8% caused walking away responses, 18.8% caused vigilance, 16.9% caused short escape flights, 7.5% caused jump flights, and only 1.9% caused full escape flights. However, 37.5% of the six active hazing events in urban landscapes caused full escape flights, 25% caused short escape flights, 12.5% caused vigilance, and the remainder caused a combination of vigilance, walking away behavior, and full escape flights. Of the three active hazing events in agricultural landscapes, one caused vigilance, one caused a short escape flight, and one caused a full escape flight.

Goose response to avian predators versus humans and cars was markedly different. The proportion of the much more energetically expensive flight-related responses to avian predators in agricultural areas was almost twice as high as vigilance responses, and walking away

behavior was never observed as a response to avian predators. Conversely, Cackler response to humans in urban landscapes was significantly different: roughly 1/3 of human disturbances caused walking away behavior, and only one human disturbance caused a full escape flight. In addition, the average energetic expense of avian predator disturbances was roughly four times higher than that of human disturbances ( $4.36 \pm 0.84 \text{ kJ h}^{-1}$  vs.  $0.84 \pm 0.24 \text{ kJ h}^{-1}$ ). Furthermore, Cackler response to automobiles was almost 50% vigilance, 50% walking away, and the combination of all flight-related responses only accounted for roughly 8% of automobile disturbances.

#### FORAGE QUALITY AND BIOMASS

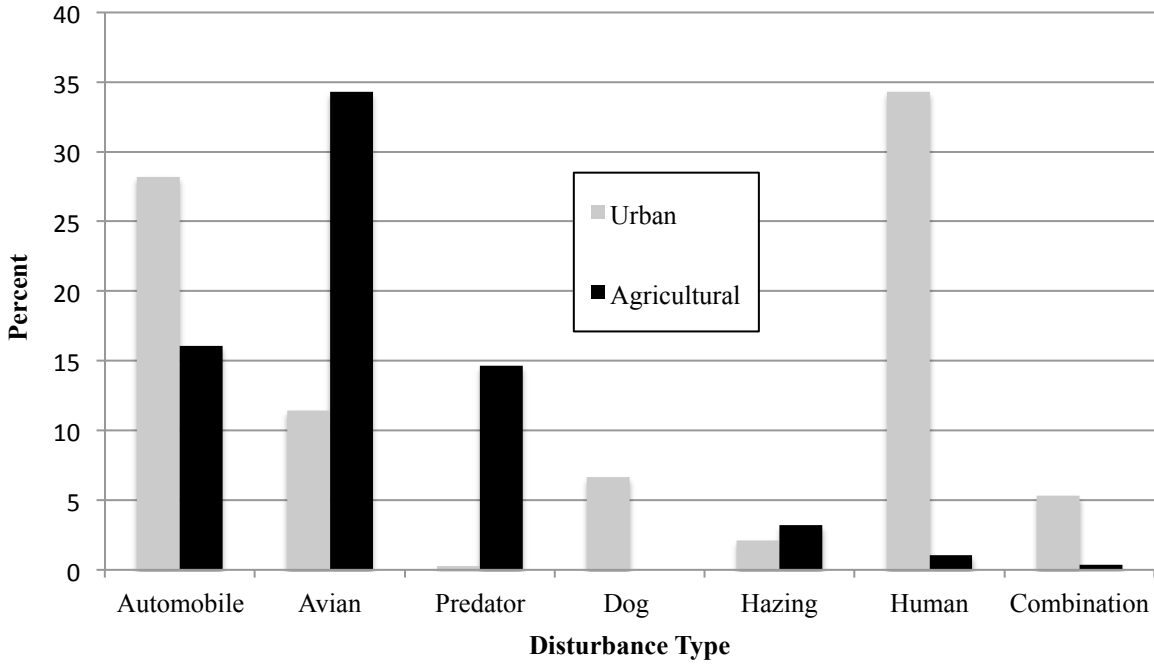
I measured forage biomass, daily regrowth rate, and nutritional content from 58 plots in December of 2014, and 60 plots in December of 2015 at a total of 12 fields in urban landscapes and 12 fields in agricultural landscapes. Grass samples were collected from 29 plots in December of 2014 and 30 plots in December of 2015. Regrowth rate measurements were conducted at all plots for both years.

Mean grass biomass did not vary significantly between urban ( $32.0 \pm 7.5 \text{ g m}^{-2}$ ) and agricultural landscapes ( $22.0 \pm 4.2 \text{ g m}^{-2}$ ,  $n = 12$ ,  $P = 0.4$ ), and average daily regrowth rate did not vary significantly between urban ( $0.08 \pm 0.01 \text{ cm/d}$ ) and agricultural landscapes ( $0.12 \pm 0.02 \text{ cm/d}$ ,  $n = 12$ ,  $P = 0.09$ ). Average grass height in agricultural landscapes was  $7.1 \pm 0.7 \text{ cm}$  and average height in urban landscapes was  $3.8 \pm 0.3 \text{ cm}$  ( $n = 12$ ,  $P = 0.02$ ). Percent crude protein did not vary significantly between urban ( $18.4 \pm 0.97\%$ ) and agricultural landscapes ( $17.0 \pm 1.3\%$ ,  $n = 12$ ,  $P = 0.64$ ). Percent ADF did not vary significantly between urban ( $35.3 \pm 1.8\%$ ) and agricultural landscapes ( $36.7 \pm 2.4\%$ ,  $n = 12$ ,  $P = 0.84$ ).

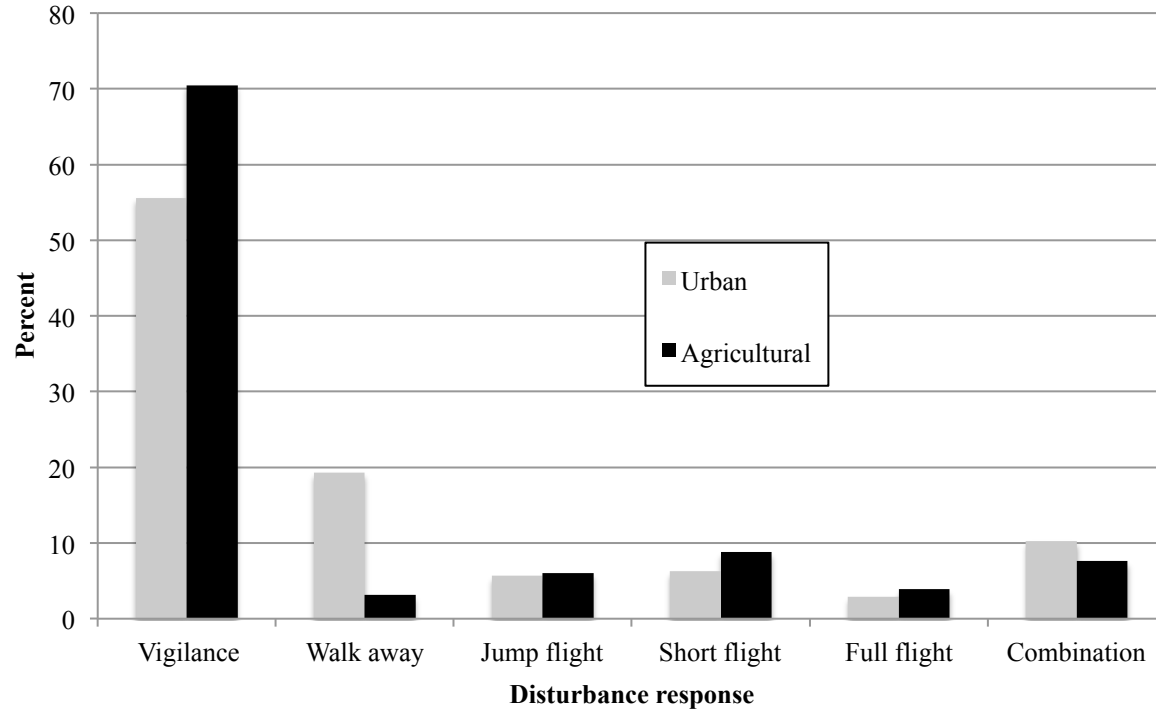
**Table 1.** Comparisons of mean percent time ( $\pm$  SE) spent in six behavioral categories in urban ( $n = 118$ ) and agricultural ( $n = 120$ ) landscapes in the Willamette Valley, OR from November 2013-April 2014 and November 2014-April 2015.

<b>Behavior</b>	<b>Urban</b>	<b>Agricultural</b>	<b><i>P</i>-value</b>
Vigilance	2.1 $\pm$ 0.2	5.6 $\pm$ 0.5	< 0.001
Foraging	69.0 $\pm$ 1.9	55.0 $\pm$ 2.1	0.02
Flying	3.0 $\pm$ 1.1	6.6 $\pm$ 1.3	0.05
Comfort	7.7 $\pm$ 0.9	11.1 $\pm$ 1.4	0.10
Resting	8.9 $\pm$ 0.9	7.7 $\pm$ 0.6	0.26
Locomotion	9.0 $\pm$ 0.8	13.3 $\pm$ 0.9	0.02





**Figure 2.** Proportion of disturbances to Cackling geese caused by seven disturbance categories in urban ( $n = 376$ ) and agricultural ( $n = 280$ ) landscapes in the Willamette Valley, OR from 2013 to 2015.



**Figure 3.** Proportion of disturbance responses from Cackling geese in urban ( $n = 477$ ) and agricultural ( $n = 511$ ) landscapes in the Willamette Valley, OR from 2013 to 2015.

**Table 2.** Average energy expenditure ( $\text{kJ h}^{-1} \pm \text{SE}$ ) of Cackling goose activities in urban and agricultural landscapes in the Willamette Valley, OR from 2013-2015.

<b>Behavior</b>	<b>Urban</b>	<b>Agricultural</b>
Vigilance	$0.7 \pm 0.1$	$2.0 \pm 0.2$
Foraging	$24.6 \pm 0.7$	$19.7 \pm 0.7$
Flying	$8.6 \pm 3.3$	$19.5 \pm 3.8$
Comfort	$2.9 \pm 0.3$	$4.2 \pm 0.5$
Locomotion	$3.6 \pm 0.3$	$5.3 \pm 0.3$
Resting	$3.0 \pm 0.3$	$2.6 \pm 0.2$
Interaction	$0.1 \pm 0.0$	$0.2 \pm 0.0$
Total	$43.5 \pm 2.9$	$53.3 \pm 3.3$

## DISCUSSION

Previous goose studies have attempted to measure disturbance quality (Owens 1977, reviewed in Madsen and Fox 1995, Mini et al. 2009), but my study is the first to test competing hypotheses to explain the use of urban habitats by geese. Consistent with the Safe-habitat Hypothesis, predator-related disturbances in urban landscapes were significantly lower than in agricultural landscapes; in fact, only one avian predator-related disturbance was observed in urban landscapes throughout the entire study. Previous studies have found eagles to cause significant disruptions to goose foraging opportunity throughout the day (McWilliams et al. 1994, Mini and Black 2009, Mini et al. 2012). The Oregon eagle population has increased 400% since 1978 and is predicted to continue increasing 2-3 fold before carrying capacity is reached (Isaacs and Anthony 2011); thus, avian predator-related disturbances to Cacklers in the Willamette Valley have almost certainly increased since Cacklers first colonized the Willamette Valley. Although I did not witness any successful attacks or kills of Cackling geese by eagles during my study, 41% of avian predator disturbances in agricultural landscapes were the result of unsuccessful attack attempts by eagles. These data suggest predation pressure is higher in agricultural landscapes than in urban landscapes.

The lower rate of avian predator-related disturbances in urban areas was associated with geese spending more time feeding and less time being vigilant. My study found that geese spent 3.6% less time flying, spent 14% more time feeding and had 3.5% higher foraging opportunity in urban landscapes. Furthermore, this increased time spent foraging was in spite of the fact that urban geese occurred in significantly smaller flocks than geese in agricultural habitats (Owen 1972, Inglis and Lazarus 1981). While a 3.5% difference in foraging

opportunity is statistically significant, this difference is likely not biologically significant. What may ultimately be more important is how geese in agricultural landscapes are spending their time when they are not feeding. Geese spent 3.6% more time flying, 3.5% more time vigilant, 3.4% more time engaged in comfort behavior, and 4.3% more time engaged in locomotion in agricultural landscapes. Although the individual difference in time spent in any single behavior might be considered comparatively small, the cumulative total effect of these differences on estimates of daily energy expenditure was not. During daylight hours, I estimated the average energy expenditure for daily activities to be 522 kJ in urban landscapes and 639.6 kJ in agricultural landscapes. This constitutes a 19% difference in energy expenditure during the day, which is likely biologically significant.

It is noteworthy that when Cacklers wintered in the Central Valley of California, they did not use urban habitats. This difference may be due to the fact that four decades ago, the Bald Eagle population was close to extinction in California, and didn't begin recovering until the 1980's with much of its range expanding into northern California areas, rather than central California (Grier 1982, CDFG 2016). The breeding Bald Eagle population in California then steadily increased from 1981-1999 (CDFG 2016). In the early 1990's, the majority of the Cackler population switched from wintering in California to wintering in Oregon. Although the California Bald Eagle population increased steadily during this time, the most recent estimate of pair counts for Bald Eagles in California is 200, while the pair count in Oregon is more than twice that size at 470, and is continuing to increase every year (U.S. Department of the Interior 2007, Isaacs and Anthony 2011). Geese in the Central Valley, California almost certainly were

not experiencing disturbance from avian predators as often as they are now in the Willamette Valley.

My data suggest foraging efficiency and forage quality are not higher overall in urban landscapes than agricultural landscapes. Biomass of urban grass was closer to the foraging optimum than agricultural grass, but height of grass in agricultural landscapes was closer to the foraging optimum (Heuermann et al. 2011); without experimentation, it is difficult to determine how these differences might affect intake rate. I did not conduct experiments to test if bite mass differed between landscape types; therefore, although Cacklers pecked at higher rates on average in urban landscapes, I could not determine if geese were in fact obtaining higher densities of forage per peck. Further research would be necessary to determine if intake rates of forage, and therefore forage profitability, is higher in urban landscapes than in agricultural landscapes.

I was not able to test if hunting disturbances contributed to use of urban habitats by Cacklers in the Willamette Valley. Hunting is known to change the geographical distribution of birds (Tamisier et al. 2003) and a recent study that tracked Cacklers in agricultural landscapes in the Willamette Valley during hunting and non-hunting seasons found that during the break in hunting, Cacklers changed roost complexes more often, commuted greater distances, and were more likely to be found foraging on private lands away from hunting refuges (Mini 2012). Additionally, hazing and hunting activities generate disturbances of high severity that have direct energetic and ecological costs (Bélanger and Bédard 1990; Riddington et al. 1996, Be'chet et al. 2004). Therefore, hunting disturbances may be encouraging geese to use urban landscapes. However, in California, Cackling geese were hunted, but did not use urban habitats

in response to hunting disturbance. This may be due to differences in landscape size and composition between the Central Valley and Willamette Valley; in general, refuges in the Central Valley are larger, grouped more closely together, and are not as bisected by roads and towns. Geese in the Central Valley likely did not have to fly over roads or urban areas after hunting disturbances, and therefore were not being acclimated to humans and urban landscapes in the same ways that Cacklers in the Willamette Valley might be.

One other possible mechanism driving the distributional shift in the Willamette Valley could be changing landscape composition over time. Mini (2012) found that of the few radio-collared Cacklers that moved within city limits in the Willamette Valley, 16.7% of the fields that those geese used were within 250 m of an urban growth boundary in Eugene, Junction City, Corvallis or Philomath. Given that geese show high site fidelity to fields and urban growth has been expanding over time, this may have facilitated acclimation to humans and urban landscapes. I would recommend an additional study on the temporal changes of landscape composition in the Willamette Valley to better determine if changing landscapes may have caused acclimation over time, and is therefore a mechanism driving the change in Cackler distribution.

## CONCLUSION

My data indicate that Cacklers in urban landscapes are becoming acclimated to humans. In particular, geese showed a comparatively weak response to cars and human-related disturbances in contrast to avian predators. Ultimately, if nutritional quality of forage is the same between landscape types, but Cacklers are disturbed more often by predators in agricultural landscapes, Cacklers in urban landscapes may have a higher net energy gain than Cacklers foraging on refuges; therefore, use of urban areas by Cacklers might continue to increase. If encouraging geese to leave urban areas is a management objective, my results indicate coordinated management efforts with private landowners, public school districts, and Parks and Recreation departments in the Willamette Valley that maximize preferred foraging conditions on refuges and minimize preferred foraging conditions in urban areas may attract more geese to protected areas in agricultural landscapes. My data suggest controlled hazing efforts would make urban habitats more energetically expensive, and might encourage relocation of urban Cacklers. Furthermore, a recent study on Pink-footed geese in agricultural habitats found that systematic hazing efforts did encourage relocation of geese, but that hazing must reach a certain level of consistency and intensity to be effective (Ernberg Simonsen et al. 2016). Currently, management plans for wintering Cackling geese treat all habitats as equal, however, my research suggests a need to consider urban areas separately from agricultural areas. Management plans for Cacklers in the Willamette Valley that also incorporate urban management are especially important considering that many literature reviews have found waterfowl populations are likely limited more by the carrying capacity of their wintering and staging areas rather than by breeding areas (Bell and Owen 1990, Madsen and Fox 1995). I



would recommend managers provide enough habitat with little disturbance to Cackling geese as predation pressures continue to increase and their distribution continues to change in the Willamette Valley.

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