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:

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 ± 1.9% vs. 55.0 ± 2.1%), less time flying (3.0 ± 1.1% vs. 6.6 ± 1.3%) and less time vigilant (2.1 ± 0.2% vs. 5.6 ± 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 ± 7.5 g m^{-2}) and agricultural landscapes (22.0 ± 4.2 g m^{-2}, $n = 12$, $P = 0.4$), and average daily regrowth rate did not vary significantly between urban (0.08 ± 0.01 cm/d) and agricultural landscapes (0.12 ± 0.02 cm/d, $n = 12$, $P = 0.09$). Average grass height in agricultural landscapes was 7.1 ± 0.7 cm and average height in urban landscapes was 3.8 ± 0.3 cm. Percent crude protein did not vary significantly between urban (18.4 ± 0.97%) and agricultural landscapes (17.0 ± 1.3%, $n = 12$, $P = 0.64$). Percent ADF did not vary significantly between urban (35.3 ± 1.8%) and agricultural landscapes (36.7 ± 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.

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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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.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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^{-2} and plant height of 11 cm, while optimum bite volume for large bodied geese was reached at a forage biomass of 79 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 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^2 and an urban boundary that is 125.48 km^2 (U.S. Census 2013). Eugene has a population size of 160,562, a population density of 1379.3/ km^2 and an urban boundary that is 113.29 km^2 (U.S. Census 2013). Portland has a population size of 619,360, a population density of 1,689.2/ km^2 and an urban boundary that is 376 km^2 (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.

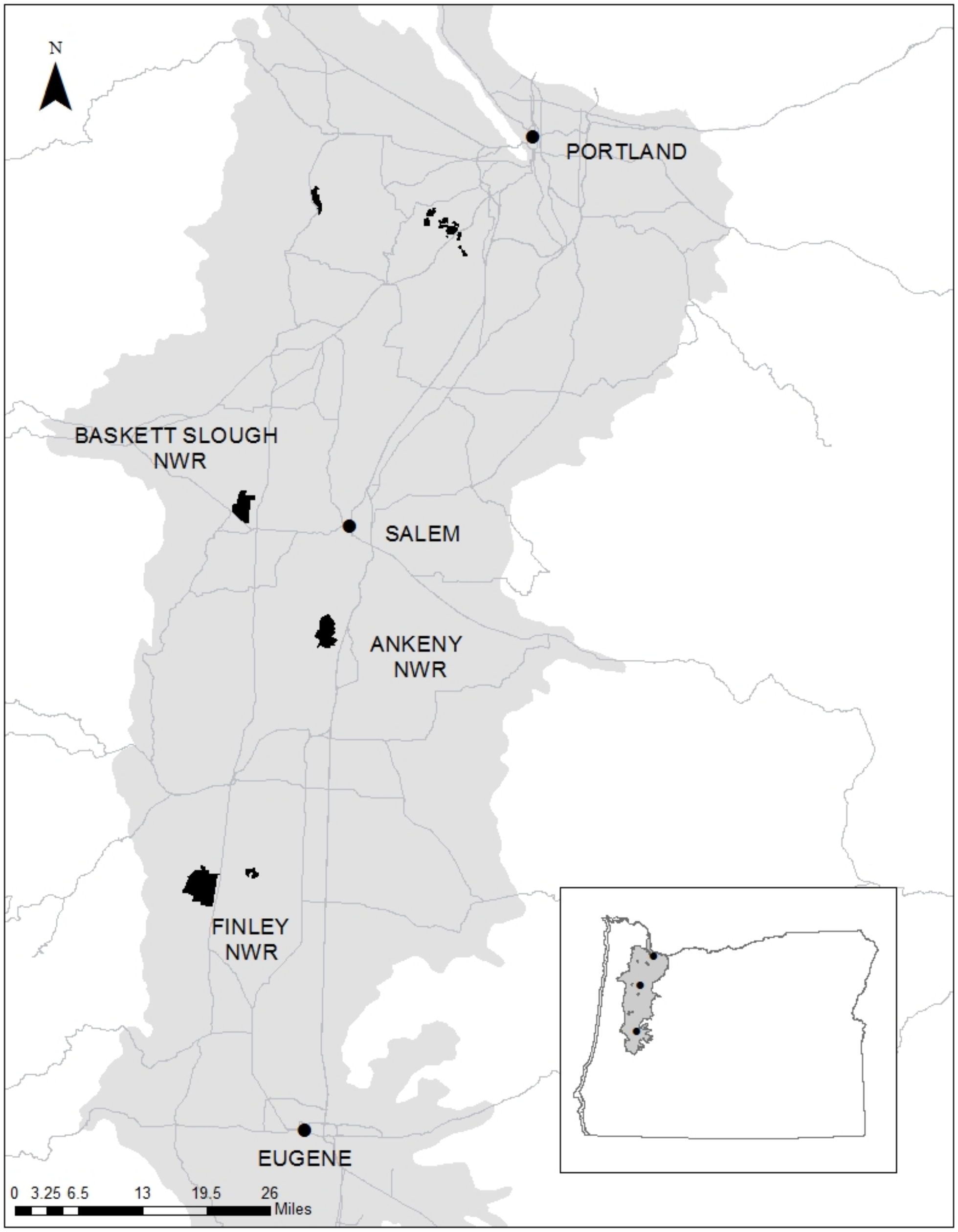

Figure 1. Map depicting study areas in the Willamette Valley, Oregon: Eugene, Salem, Portland, Finley NWR, Ankeny NWR, and Baskett Slough NWR.

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 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: 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 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 0.25m^2 plots in 2014 and 0.5m^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 exclosure treatment to measure grass height after goose use and measure grass regrowth rate (Owen 1972 and Mini 2012). Exclosures, 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^2 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 ± 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 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 ± 113 in agricultural landscapes and 674 ± 30 in urban landscapes.

Geese spent more time feeding (69.0 ± 1.9% vs. 55.0 ± 2.1%), less time flying (3.0 ± 1.1% vs. 6.6 ± 1.3%) and less time vigilant (2.1 ± 0.2% vs. 5.6 ± 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 pecks min^{-1} ± 2.2 vs. 107.3 pecks min^{-1} ± 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 ± 1.3s vs.

35.4 ± 2.2s, $P = 0.001$) and the mean foraging opportunity (i.e., percent of time undisturbed) was higher in urban landscapes (94.3 ± 1.2% vs. 90.8 ± 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 ± 0.84 kJ h^{-1} vs. 0.84 ± 0.24 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 ± 7.5 g m^{-2}) and agricultural landscapes (22.0 ± 4.2 g m^{-2}, $n = 12$, $P = 0.4$), and average daily regrowth rate did not vary significantly between urban (0.08 ± 0.01 cm/d) and agricultural landscapes (0.12 ± 0.02 cm/d, $n = 12$, $P = 0.09$). Average grass height in agricultural landscapes was 7.1 ± 0.7 cm and average height in urban landscapes was 3.8 ± 0.3 cm ($n = 12$, $P = 0.02$). Percent crude protein did not vary significantly between urban (18.4 ± 0.97%) and agricultural landscapes (17.0 ± 1.3%, $n = 12$, $P = 0.64$). Percent ADF did not vary significantly between urban (35.3 ± 1.8%) and agricultural landscapes (36.7 ± 2.4%, $n = 12$, $P = 0.84$).

Table 1. Comparisons of mean percent time (± 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.

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

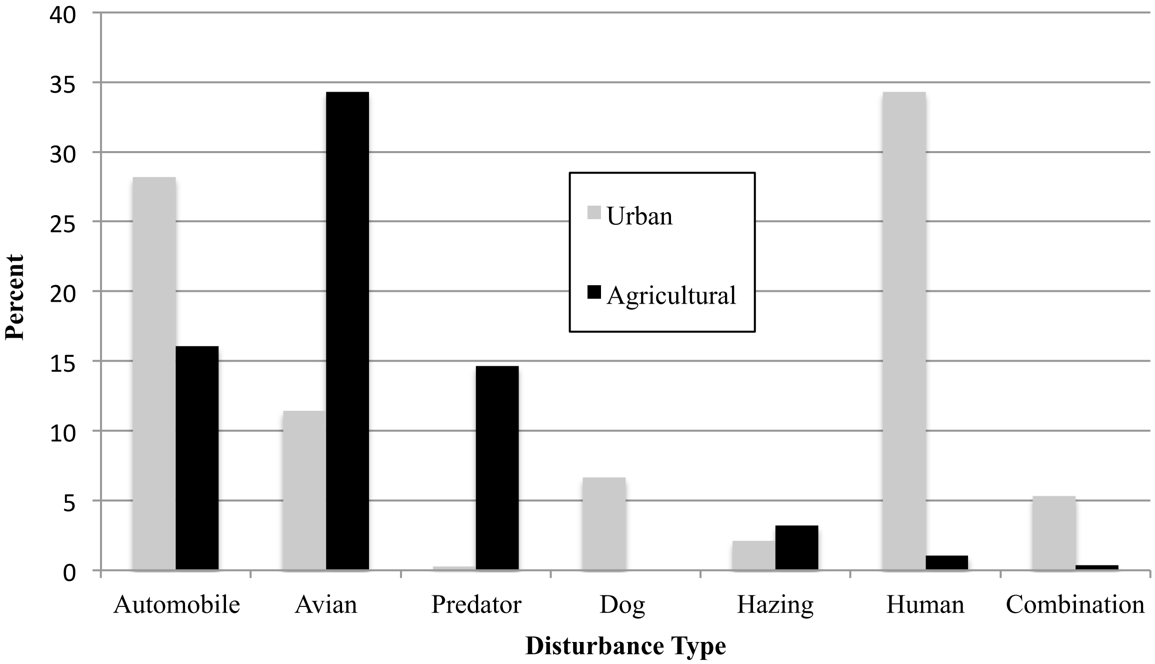

Figure 2. Proportion of disturbances to Cackling geese caused by seven disturbance categories in urban (*n* = 376) and agricultural (*n* = 280) landscapes in the Willamette Valley, OR from 2013 to 2015.

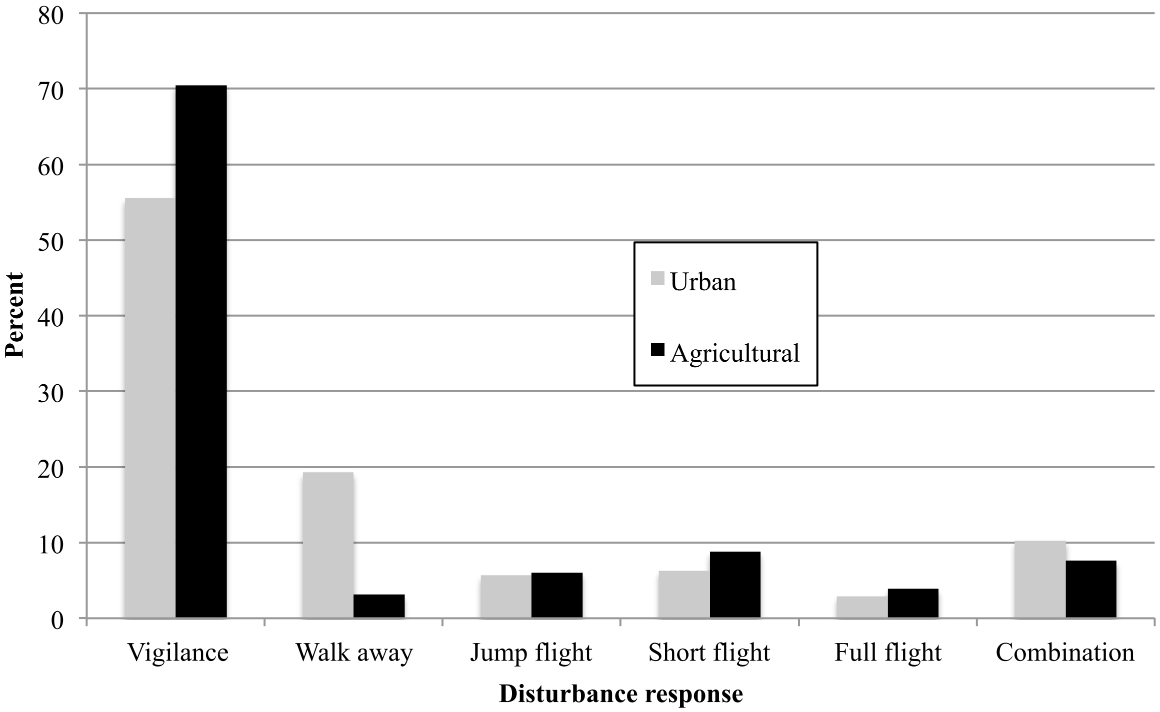

Figure 3. Proportion of disturbance responses from Cackling geese in urban (*n* = 477) and agricultural (*n* = 511) landscapes in the Willamette Valley, OR from 2013 to 2015.

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

Behavior	**Urban**	**Agricultural**
Vigilance	0.7 ± 0.1	2.0 ± 0.2
Foraging	24.6 ± 0.7	19.7 ± 0.7
Flying	8.6 ± 3.3	19.5 ± 3.8
Comfort	2.9 ± 0.3	4.2 ± 0.5
Locomotion	3.6 ± 0.3	5.3 ± 0.3
Resting	3.0 ± 0.3	2.6 ± 0.2
Interaction	0.1 ± 0.0	0.2 ± 0.0
Total	43.5 ± 2.9	53.3 ± 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.

LITERATURE CITED

Adams, C. E., K. J. Lindsay, and S. Ash. 2006. Urban Wildlife Management. Taylor & Francis Group. Boca Raton, FL.

Adams, L.W. 2005. Urban wildlife ecology and conservation: a brief history of the discipline. Urban Ecosystems 8:139–156.

Amano, T., K. Ushiyama, G. Fujita, and H. Higuchi. 2007. Predicting grazing damage by white-fronted geese under different regimes of agricultural management and the physiological consequences for the geese: Predicting grazing damage and fat deposition by geese. Journal of Applied Ecology 4:33.

Anderson, D. R., K. P. Burnham, and W. L. Thompson. 2000. Null hypothesis testing: problems, prevalence, and an alternative. Journal of Wildlife Management 64:912-923.

Ankney, C.D. 1996. An embarrassment of too many riches: too many geese. Journal of Wildlife Management 60:217–223.

Ankney, C. D. and C. D. MacInnes. 1978. Nutrient reserves and reproductive performance of female lesser snow geese. Auk 95:459–471.

Arthur, S.M., B.F.J. Manly, L.L. McDonald, and G.W. Garner. Assessing Habitat Selection when Availability Changes. Ecology 77:1.

Baldassarre, G. 2014. Ducks, Geese and Swans of North America. Johns Hopkins University Press, Baltimore, MD.

Béchet, A., J.F Giroux, G. Gauthier, J.D. Nichols, and J.E. Hines. 2003. Spring hunting changes the regional movements of migrating greater snow geese. Journal of Applied Ecology 40:553–564.

Be´chet, A., J. Giroux, and G. Gauthier. 2004. The effects of disturbance on behaviour, habitat use and energy of spring staging snow geese. Journal of Applied Ecology 41:689–700.

Bélanger, L. and J. Bédard. 1990. Energetic cost of man-induced disturbance to staging Snow Geese. Journal of Wildlife Management 54:36-41.

Belant, J. L., L. A. Tyson, T. W. Seamans, and S. K. Ickes. 1997. Evaluation of lime as an avian feeding repellent. Journal of Wildlife Management 61:917–924.

Bell, D.V. and M. Owen. 1990. Shooting disturbance — a review. In Managing Waterfowl Populations. Proc. IWKB Symp., Astrakhan 1998 (ed. G.V.T. Matthews).

Black, J. M., and M. Owen. 1988. Variations in pair bond and agonistic behaviors in barnacle geese in the wintering grounds. Pages 39–57 in M. W. Weller, editor. Waterfowl in winter. University of Minnesota Press, Minneapolis, USA.

Black, J. M., C. Deerenberg, and M. Owen. 1991. Foraging behaviour and site selection of barnacle geese Branta leucopsis in a traditional and newly colonized spring staging habitat. Ardea 79:349–358.

Black, J. M., P. F. Springer, E. T. Nelson, K. M. Griggs, T. D. Taylor, Z. D. Thompson, A. Maguire, and J. Jacobs. 2004. Site selection and foraging behavior of Aleutian Canada geese in a newly colonized spring staging area. Pages 106–113 in T. J. Moser, R. D. Lein, K. C. VerCauteren, K. F. Abraham, D. E. Anderson, J. G. Bruggink, J. M. Coluccy, D. A. Graber, J. O. Leafloor, D. R. Luukkonen, and R. E. Trost, editors. Proceedings of the 2003 International Canada Goose Symposium, 19–21 March 2003, Madison, WI, USA.

Black, J. M., J. Prop, and K. Larrson. 2007. Wild goose dilemmas: population consequences of individual decisions in barnacle geese. Branta Press, Groningen, The Netherlands.

Blair, R.B. 1999. Land Use and Avian Species Diversity Along an Urban Gradient. Ecological Applications 6:2.

Blumstein, D.T. 2006. Developing an evolutionary ecology of fear: how life history and natural history traits affect disturbance tolerance in birds. Animal Behaviour 71:2.

Bonier, F., P.R. Martin, and J.C. Wingfield. 2007. Urban birds have broader environmental tolerance. Biology Letters 3:6.

Bos, D., and J. Stahl. 2003. Creating new foraging opportunities for Dark-bellied Brent Branta bernicla and Barnacle Geese Branta leucopsis in spring— insights from a large-scale experiment. Ardea 91:153–166.

California Department of Fish and Game. 2016. Bald Eagles in California. https://www.wildlife.ca.gov/Conservation/Birds/Bald-Eagle.

Caraco, T. 1979. Time budgeting and group size: a test of theory. Ecology Ecological Society of America 60:618-627.

Caro, T. 2005. Antipredator defenses in birds and mammals. University of Chicago Press, Chicago, IL.

Charnov, E. L. 1976. Optimal foraging, the marginal value theorem. Theoretical Population Biology, 9:2, 129-136.

Cherry, S. 1998. Statistical tests in publications of The Wildlife Society. Wildlife Society Bulletin 26:947-953.

Clark and Sullivan. 2003. Prevalence of *escherichia coli* serogroups and human virulence factors Crin feces of urban Canada geese. Proceedings of the 2003 International Canada Goose Symposium, Madison, WI.

Clausen, K., P. Clausen, A. Fox, C. Faelled, and J. Madsen. 2013. Varying energetic costs of Brent Geese along a continuum from aquatic to agricultural habitats: the importance of habitat-specific energy expenditure. Journal of Ornithology 154:1.

Cresswell, W., G.M. Hilton, and G.D. Ruxton. 2000: Evidence for a rule governing the avoidance of superfluous escape flights. Proceedings of the Royal Society of London series B-Biological Sciences 267:733-737.

Crooks, K.R., Soulé, M.E., 1999. Mesopredator release and avifaunal extinctions in a fragmented system. Nature 400:563–566.

Crooks, K.R., Riley, S.P.D., Gehrt, S.D., Gosselink, T.E., Van Deelen, T.R., 2010. Community ecology of urban carnivores. In: Gehrt, S.D., Riley, S.P.D., Cypher, B.L. (Eds.), Urban Carnivores: Ecology, Conflict, and Conservation. John Hopkins University Press, Baltimore, MD, USA, pp. 185–196.

Dearborn, D.C., S. Kark. 2010. Motivations for conserving urban biodiversity. Conservation Biology 24:432–440.

Diamond, JM. 1986. Rapid evolution of urban birds. Nature 324:107–108.

Dooley, J.L., T.A. Sanders, and P.F. Doherty. 2010. Mallard Response to Experimental Walk-In and Shooting Disturbance. The Journal of Wildlife Management 74:8.

Durant, D. 2003. The digestion of fibre in herbivorous Anatidae—a review. Wildfowl 54:7–24.

Durant, D., H. Fritz, and P. Duncan. 2004. Feeding patch selection by herbivorous Anatidae: the influence of body size, and of plant quality and quantity. Journal of Avian Biology 35:144–152.

Eakle, W., L. Bond, M. Fuller, R. Fisher, K. Steenhof. 2015. Wintering Bald Eagle Count Trends in the Conterminous United States, 1986-2010. HHS Public Access 49(3): 259–268.

Ely, C.R. 1992. Time allocation by Greater White-fronted Geese: influence of diet, energy reserves and predation. Condor 94:857–870.

Emlen, J. T. 1974. An urban bird community in Tucson, Arizona: derivation, structure, regulation. Condor 76:184–197.

Ernberg Simonsen, C., J. Madsen, I.M. Tombre, and J. Nabe-Nielsen. 2016. Is it worthwhile scaring geese to alleviate damage to crops? – An experimental study. Journal of Applied Ecology 53:916-924.

Faeth, S.H., P.S. Warren, E. Shochat, W.A. Marussich. 2005. Tropic dynamics in urban communities. BioScience 55:399–407.

Fernandez-Juricic, E., J.T Erichsen, A. Kacelnik. 2004. Visual perception and social foraging in birds. Trends in Ecology & Evolution 19:1.

Forman, R.T.T., D. Sperling, J.A. Bissonette, A.P Clevenger, C.D. Cutshall, V.H. Dale, L. Fahrig, R. France, , C.R. Goldman, K. Heanue, J.A. Jones, F.J. Swanson, T. Turrentine, and T.C. Winter. 2003. Road Ecology: Science and Solutions. Island Press, Washington, DC.

Frankham, R., 2006. Genetics and landscape connectivity. In: Crooks, K.R., Sanjayan, M. (Eds.), Connectivity Conservation. Cambridge University Press, United Kingdom, pp. 72–96.

Fredrick, R. B., W. R. Clark, and E. E. Klaas. 1987. Behavior, energetics, and management of refuging waterfowl: a simulation model. Wildlife Monographs 96:3–35.

Fretwell, S. D. 1972. Population in a Seasonal Environment. Princeton University Press.

Gauthier, G., J. Bedard, and Y. Bedard. 1984. Comparison of daily energy expenditure of greater snow geese between two habitats. Canadian Journal of Zoology 62:1304–1307.

Gill, J.A. 1994. Habitat choice and distribution of wintering pink-footed geese, Anser brachyrhynchus. PhD thesis, University of East Anglia.

Gill, JA, W.J. Sutherland, A.R. Watkinson. 1996. A Method to Quantify the Effects of Human Disturbance on Animal Populations. Journal of Applied Ecology 33:4

Giroux, J., and I.J. Patterson. 1995. Daily movements and habitat use by radio-tagged Pink-footed Geese Anser brachyrhyncus wintering in northeast Scotland. Wildfowl 46:31–44.

Grier JW. Ban of DDT and subsequent recovery of reproduction in Bald Eagles. 1982. Science 218:1232–1235.

Heuermann, N., F. van Langevelde, S.E. van Wieren, and H.H.T. Prins. 2011. Increased searching and handling effort in tall swards lead to a Type IV functional response in small grazing herbivores. Oecologia 166:659–669.

Hobbs, R.J., 2006. Novel ecosystems: theoretical and management aspects of the new ecological world order. Global Ecology & Biogeography 15:1.

Hope, J., 2000. The geese that came in from the wild. Audubon 102: 122–127.

Horton, C. A. 2014. Top-down influences of Bald Eagles on Common Murre populations in Oregon. MS thesis, Oregon State University.

Inger, R., S. Bearhop, J.A. Robinson, and G. Ruxton. 2006. Prey choice affects the trade-off balance between predation and starvation in an avian herbivore. Animal Behaviour 71:1335–1341.

Inglis, I. R., and J. Lazarus. 1981. Vigilance and flock size in brent geese: the edge effect. Zeitschrift für Tierpsychologie 57:193–200.

Isaacs, F. B., and R. G. Anthony. 2011. Bald eagles (*Haliaeetus leucocephalus*) nesting in Oregon and along the lower Columbia River, 1978-2007. Final Report, 18 March 2011. Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon, USA.

Jankowiak Ł., P. Skórka, Ł Ławicki., P. Wylegała, M. Polakowski, A. Wuczyński, and P. Tryjanowski. 2015. Patterns of occurrence and abundance of roosting geese: the role of spatial scale for site selection and consequences for conservation. Ecological Research 30:833-842.

Jiang J. 2007. Linear and Generalized Linear Mixed Models and their Applications. New York, NY: Springer-Verlag.

Johnson, J.C., and D.G. Raveling. 1998. Weak family associations in Cackling Geese during winter: effects of body size and food resources on goose social organization. Pages 71–89 in M.W. Weller, editor. Waterfowl in Winter. University of Minnesota Press, Minneapolis, Minnesota.

Klaassen, M., S. Bauer, J. Madsen, and I. Tombre. 2006. Modelling behavioural and fitness consequences of disturbance for geese along their spring flyway. Journal of Applied Ecology 43:92–100.

Klausnitzer, B. 1989. Verstädterung von Tieren. Wittenberg Lutherstadt: Neue Brehm-Bücherei.

Kowarick, Ingo. 2011. Novel urban ecosystems, biodiversity, and conservation. Environmental Pollution 159:8-9.

Krause, J. and G.D. Ruxton. 2002. Living in Groups. New York: Oxford University Press.

Kulemeyer C, K. Asbahr, P. Gunz. 2009. Functional morphology and integration of corvid skulls – a 3D geometric morphometric approach. Front Zool. 6:2.

Lima. S.L.1998. Stress and decision making under the risk of predation: recent developments from behavioral, reproductive, and ecological perspectives. Adv Study Behav 27:215–290.

Lima, S.L. and L.M. Dill. 1990. Behavioral decisions made under the risk of predation: A review and prospectus. Canadian Journal Of Zoology 68:4.

Lin, T., T. Coppack, Q. Lin., C. Kulemeyer, A. Schmidt, H. Behm, and T. Luo. 2012. Does avian flight initiation distance indicate tolerance towards urban disturbance? Ecological Indicators 15:1.

Madsen, J. 1985. Relations between change in spring habitat selection and daily energetics of pink-footed geese *Anser brachyrhynchus*. Ornis Scandinavica 16:222-228.

Madsen, J. 2001. Spring migration strategies in pink-footed geese Anser brachyrhyncus and consequences of spring fattening and fecundity. Ardea 89:43–55.

Madsen, J. and A.D. Fox. 1995. Impacts of hunting on waterbirds: a review. Wildlife Biology 1:193–207.

Magle, S.B., V.M. Hunt, M .Vernon, and K.R. Crooks. 2012. Urban wildlife research: Past, present, and future. Biological Conservation 155:23–32.

Magle, S.B., D.T Theobald, and K.R Crooks. 2009. Comparing isolation metrics predicting the distribution of a highly interactive species across an urban gradient. Landscape Ecology 24: 267–280.

Mayer, P., 2010. Urban ecosystems research joins mainstream ecology. Nature 467:153.

Martin, P., and P. Bateson. 1993. Measuring behaviour. An introductory guide. Second edition. Cambridge University Press, Cambridge, United Kingdom.

Marzluff, J. M. 2001. Worldwide increase in urbanization and its effects on birds, p. 19-47. In J. M. Marzluff, R. Bowman, and R. Donnelly [editors], Avian ecology and conservation in an urbanizing world. Kluwer Academic, Norwell, MA.

Marzluff, J. M., R. Bowman, and R. Donnelly. 2001. A historical perspective on urban bird research: trends, terms and approaches, p. 1-17. In J. M. Marzluff, R. Bowman, and R. Donnelly [editors], Avian ecology and conservation in an urbanizing world. Kluwer Academic, Norwell, MA

Marzluff, J.M., Schulenberger, E., Endlicher, W., Alberti, M., Bradley, G., Ryan, C., Simon, U., ZumBrunnen, C. (Eds.), 2008. Urban Ecology: An International Perspective on the Interaction Between Humans and Nature. Springer, New York, New York, USA.

Mcdonald, R.I., Kareiva, P., Forman, R.T.T., 2008. The implications of current and future urbanization for global protected areas and biodiversity conservation. Biological Conservation 141:1695–1703.

McKinney, M.L., 2002. Urbanization, biodiversity, and conservation. Bioscience 52: 883–890.

McWilliams, S.R., and D.G. Raveling. 2004. Energetics and time allocation of cackling Canada geese during spring. Pages 99-110 *in* T.J. Moser, R.D. Lien, K.C. VerCauteren, K.F. Abraham, D.E. Andersen, J.G. Bruggink, J.M. Coluccy, D.A. Graber, J.O. Leafloor, D.R. Luukkonen, and R.E. Trost, editors. Proceedings of the 2003 International Canada Goose Symposium, Madison, WI.

McWilliams, S.R., J.P. Dunn, and D.G. Raveling. 1994. Predator-prey interactions between eagles and Cackling Canada and Ross' Geese during winter in California. Wilson Bulletin 106:272–288.

Miller, J.R. and R.J. Hobbs. 2002. Conservation where people live and work. Conservation Biology 16:330–337.

Miller, M.R., and J. Eadie. 2006. The allometric relationship between resting metabolic rate and body mass in wild waterfowl (Anatidae) and an application to estimation of winter habitat requirements. Condor 108:166–177.

Mini, A.E. 2005. Energy expenditure and body reserves of Aleutian Cackling Geese utilizing three spring staging areas in northwestern California. M.Sc. Thesis, Humboldt State University, Arcata, California, USA.

Mini, A. E. 2012. The role of body size in the foraging strategies and management of avian herbivores: a comparison of Dusky Canada (*Branta canadensis occidentalis*) and Cackling Geese (*B. hutchinsii minima*) wintering in the Willamette Valley of Oregon. Oregon State University, Ph.D dissertation.

Mini, A.E. and J.M. Black. 2009. Expensive traditions: energy expenditure of Aleutian Geese in traditional and recently colonized habitats. Journal of Wildlife Management 73:385–391.

Mini, A. E., D. C.. Bachman, J. Cocke, and J. M. Black. 2011. Recovery of the Aleutian Cackling Goose Branta Hutchinsii Leucopareia: 10-year Review and Future Prospects. Wildfowl 61:3–29.

Møller, A.P. 2008. Flight distance of urban birds, predation, and selection for urban life. Behavioral Ecology and Sociobiology 63:1.

Møller, A.P. 2009. Successful city dwellers: a comparative study of the ecological characteristics of urban birds in the Western Palearctic. Oecologia 159:4.

Møller, AP and J Erritzøe. 2010. Flight distance and eye size in birds. Ethology 116:458-465.

Mori, Y., N.S. Sodhi, S. Kawanishi, and S. Yamagishi. 2001. The effect of human disturbance and flock composition on the flight distances of waterfowl species. Journal of Ethology 19:115–119

Newton, I. 1977. Timing and success of breeding in tundra-nesting geese. Pages 113–126 in B. Stonehouse and C. Perrins, editors. Evolutionary ecology. University Park Press, Baltimore, MD, USA.

Owen, M. 1972. Some factors affecting food intake and selection in White-fronted Geese. Journal of Animal Ecology 41:79–92.

Owen, M. 1980. Wild geese of the world: their life history and ecology. B.T. Batsford, London, UK.

Owen, M. 1990. The damage-conservation interface illustrated by geese. Ibis 132:238–252.

Owen, M., L. Wells, and J. M. Black. 1992. Energy budgets of wintering barnacle geese: the effects of declining food resources. Ornis Scandinavica 23:451–458.

Owens, N.W. 1977. Responses of wintering Brent Geese to human disturbance. Wildfowl 28:5-11.

Pacific Flyway Council. 1999. Pacific Flyway management plan for the Cackling Canada goose. Pacific Flyway Study Committee, Subcommittee on Cacklling Canada geese, Portland, Oregon, USA.

Pacific Flyway Council. 2016. Pacific Flyway management plan for the

Cackling Canada goose [draft]. Pacific Flyway Study Committee, Subcommittee on Cackling Canada geese, Cannon Beach, Oregon, USA. Unpubl. Rept.

Pease, M. L., R. K. Rose, and M. J. Butler. 2005. Effects of human disturbance on the behavior of wintering ducks. Wildlife Society Bulletin 33:103-112.

Percival, S. M., and P. R. Evans. 1997. Brent geese Branta bernicla and Zostera; factors affecting the exploitation of a seasonally declining food resource. Ibis 139:121–128.

Pickett, S.T.A., M.L. Cadenasso, J.M. Grove, P.M. Groffman, L.E. Band, C.G. Boone, W.R. Burch Jr., C.S.B. Grimond, J. Hom, J.C. Jenkins, N.L. Law, C.H. Nilon, R.V Pouyat, K. Szlavecz, P.S. Warren, M.A. Wilson. 2008. Beyond urban legends: an emerging framework of urban ecology, as illustrated by the Baltimore ecosystem study. BioScience 58:139–150.

Powell, L. A., M. J. Conroy, G. D. Balkcom, Caudwell, and N. Joe. 2003. Urban Canada geese in Georgia: assessing a golf course survey and a nuisance relocation program. Proceedings of the 2003 International Canada Goose Symposium, Madison, WI.

Prange S, SD Gehrt, EP Wiggers. 2003. Demographic factors contributing to high raccoon densities in urban landscapes. Journal of Wildlife Management 67:324–333.

Preisler, H.K., A.A. Ager, and M.J. Wisdom. 2006. Statistical methods for analysing responses of wildlife to human disturbance. Journal of Applied Ecology 43:1

Prop, J., and C. Deerenberg. 1991. Spring staging in Brent geese Branta bernicla: feeding constraints and the impact of diet on the accumulation of body reserves. Oecologia 87:19–28.

Prop, J.. and J. M. Black. 1998. Food intake, body reserves and reproductive success of barnacle geese Branta leucopsis staging in different habitats. Norsk Polarinstitutt Skrifter 200:175–193.

Prop, J., J. M. Black, P. Shimmings, and M. Owen. 1998. The spring range of barnacle geese Branta leucopsis in relation to changes in land management and climate. Biological Conservation 86:339–346.

Prop, J., J. M. Black, and P. Shimmings. 2003. Travel schedules to the high arctic: barnacle geese trade-off the timing of migration with accumulation of fat deposits. Oikos 103:403–414.

Prop, J., W. D. van Marken Lichtenbelt, J. H. Beekman, and J. F. Faber. 2005. Using food quality and retention time to predict digestion efficiency in geese. Wildlife Biology 11:21–29.

R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Ramalho, C.E., Hobbs, and R.J., 2012. Time for a change: dynamic urban ecology. Trends in Ecology and Evolution 27:179–188.

Raveling, D.G., and D.S. Zezulak. 1992. Changes in distribution of Cackling Canada Geese in autumn. California Fish and Game 78:65–77.

Raveling, D.G., J.D. Nichols, J.E. Hines, D.S. Zezulak, J.G. Silveira, J.C. Johnson, T.W. Aldrich, and J.A. Weldon. 1992. Survival of Cackling Canada Geese, 1982-1988. The Journal of Wildlife Management 56:1.

Riddington, R., M. Hassal, S.J. Lane, and P.A. Turner. 1996. The impact of disturbance on the behavior and energy budget of brent geese *Branta b. bernicla*. *Bird Study* 43:269–279.

Robbins, C.T. 2001. Wildlife Feeding and Nutrition. Second edition. Academic Press, Inc., San Diego, CA.

Rosin, Z., P. Skorka, P. Wylegala, P. Krakowski, M. Tobolka, L. Myczko, T. Sparks, and P. Tryjanowski. 2012. Landscape structure, human disturbance and crop management affect foraging ground selection by migrating geese. Journal of Ornithology 153:3.

Schoech, S.J., and R. Bowman. 2001. Variation in the timing of breeding between suburban and wildland Florida scrub-jays: Do physiologic measures reflect different environments? p. 289–306. *In* J.M. Marzluff et al. (ed.) Avian ecology and conservation in an urbanizing world. Kluwer Academic Publ., Boston, MA.

Seastedt, T.R., R.J. Hobbs, K.N. Suding. 2008. Management of novel ecosystems: are novel approaches required? Frontiers in Ecology & the Environment 6:10.

Shochat, E., P.S. Warren, S.H. Faeth, N.E. McIntyre, and D. Hope. 2004. From patterns to emerging processes in mechanistic urban ecology. Trends in Ecology & Evolution 21:4.

Shochat E, SB Lerman, JM Anderies, PS Warren, SH Faeth, CH Nilon. 2010. Invasion, competition, and biodiversity loss in urban ecosystems. BioScience 60:199–208.

Springer, P. F., G. V. Byrd, and D. W. Woolington. 1978. Re-establishing Aleutian Canada geese. Pages 331–338 in S. A. Temple, editor. Endangered birds: management techniques for preserving threatened species. University of Wisconsin Press, Madison, USA.

Springer, P. F. and R. W. Lowe. 1998. Population, distribution, and ecology of migrating and wintering Aleutian Canada geese. Pages 425– 434 in D. H. Rusch, M. D. Samuel, D. D. Humburg, and B. D. Sullivan, editors. Biology and management of Canada geese. Proceedings of the 1998 International Canada Goose Symposium, 23–25 April 1991, Milwaukee, WI, USA.

Stabins, H. C., C. E. Grue, D. A. Manuwal, and S. L. Paulus. 2002. Time allocation by Aleutian Canada geese during the nonbreeding season in California. California Fish and Game 88:186–195.

Stahl, J. 2001. Limits to the co-occurrence of avian herbivores. Dissertation, University of Groningen, Groningen, The Netherlands.

Stankowich, T. and D. Blumstein. 2005. Fear in animals: a meta-analysis and review of risk assessment. Proceedings of the Royal Society.

Stehn, R. 2012. Discussion of a Population Goal for Cackling Canada geese: Information relating to population size and the management of crop depredation in Oregon. USFWS, Migratory Bird Management Report, Anchorage.

Stewart, K.E.J., N.A.D. Bourn, and J.A. Thomas. 2001. An evaluation of three quick methods commonly used to assess sward height in ecology. Journal of Applied Ecology 38:1148–1154.

Stroup, WW. 2012. Generalized linear mixed models: modern concepts, methods and applications. CRC Press. Boca Raton, FL, U.S.A.

Summers, R.W. 1990. The effect on winter wheat of grazing by Brent Geese Branta bernicla. Journal of Applied Ecology 27:821–833.

Summers, R. W., and J. Stansfield. 1991. Changes in the quantity and quality of grassland due to winter grazing by brent geese Branta ber Agriculture, Ecosystems, and Environment 36:51–57.

Sutherland, W. J., J.A. Gill, and K. Norris. 2002. Density-dependent dispersal in animals: concepts, evidence, mechanisms and consequences. Pages 134-151 *in* J.M. Bullock, R.E. Kenward, and R.S. Hails, editors. Dispersal Ecology. Blackwell Publishing, Oxford, United Kingdom.

Sutherland, W. J., and G. A. Parker. 1985. Distribution of unequal competitors. Pages 255–273 in R. M. Sibley and R. H. Smith, editors. Behavioural ecology: ecological consequences of adaptive behavior. Blackwell Science, Cambridge, MA, USA.

Swingland, I.R. and P.J. Greenwood. 1984. The ecology of animal movements. Oxford

University Press, Inc., New York, NY.

Tamisier, A., A. Be´chet, G. Jarry, J-C. Lefeuvre, and Y. Le Maho. 2003: Effets du de´rangement par la chasse sur les oiseaux d'eau. Revue delitte´rature. - Revue d'E´ cologie (La Terre et la Vie) 58:435-449. (In French).

Therkildsen, O.R., and J. Madsen. 2000. Energetics of feeding on winter wheat versus pasture grasses: a window of opportunity for winter range expansion in the Pink-footed Goose Anser brachyrhyncus. Wildlife Biology 6:65–74.

Tombre, I.M., J. Madsen, H. Tømmervik, K. Haugen, and E. Eythórsson. 2005. Influence of organized scaring on distribution and habitat choice of geese on pastures in Northern Norway. Agriculture, Ecosystems and Environment 111:311–320.

Tomialojc, L. 1982. Synurbanization of birds and the prey-predator relations. Pages 131–137 *in* M. Luniak and B. Pisarski, editors. Animals in Urban Environment: Proceedings of Symposium Warszawa-Jablonna. Wroclaw, Poland.

U.S. Census Bureau, Population Division. 2013. Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2013.

U.S. Department of the Interior. 2007. Endangered and Threatened Wildlife and Plants; Removing the Bald Eagle in the Lower 48 States From the List of Endangered and Threatened Wildlife. Federal Register. 72:130.

U.S. Fish and Wildlife Service. 2001. Endangered and threatened wildlife and plants: final rule to remove the Aleutian Canada goose from the federal list of endangered and threatened wildlife. Federal Register 66:15634–15656.

U.S. Fish and Wildlife Service. 2005. Waterfowl population status, 2005. U.S. Department of the Interior, Washington, D.C., USA. Vickery, J. A., A. R. Watkinson, and W. J. Sutherland. 1994. The solutions to the brent goose problem: an economic analysis. Journal of Applied Ecology 31:371–382.

Valcarcel, A., and E. Fernández-Juricic. 2009. Antipredator strategies of house finches: are urban habitats safe spots from predators even when humans are around? Behavioral Ecology and Sociobiology 63:673–685.

Whitford, P. C. 2003. Alarm/alert call playback and human harassment to end Canada goose problems at an Ohio business park. 2003 International Canada Goose Symposium.

Ydenberg, R.C. and L.M. Dill. 1986. The economics of fleeing from predators. Adv. Study Behavior 16:229-249.

Ydenberg, R.C., and H.H.T. Prins. 1981. Spring quality and the manipulation of food quality by Barnacle Geese. Journal of Applied Ecology 18:443–453.

Zillich, U., and J. M. Black. 2002. Body mass and abdominal profile index in captive Hawaiian geese. Wildfowl 53:67–77.