AN ABSTRACT OF THE DISSERTATION OF

Anne E. Mini for the degree of Doctor of Philosophy in Wildlife Science presented on October 11, 2012.
Title: The Role of Body Size in the Foraging Strategies and Management of Avian Herbivores: A Comparison of Dusky Canada Geese (*Branta canadensis occidentalis*) and Cackling Geese (*B. hutchinsii minima*) Wintering in the Willamette Valley of Oregon

Abstract approved:

Bruce D. Dugger

Body size explains much of the interspecific variation in the physiology, behavior, and morphology of birds, such as metabolic rate, diet selection, intake rate, gut size, and bill size. Based on mass-specific metabolic requirements and relative energetic costs of activities, being a certain body size has both advantages and disadvantages. In particular, avian herbivores such as geese possess a relatively simple digestive system, consume foods with low digestibility and poor nutrient content, and have increased energetic demands compared to other bird taxa; therefore, any effects of body size on foraging strategies should be readily apparent in this foraging guild. The influence of body size on the behavior and management of Canada Geese (*Branta canadensis*) and Cackling Geese (*B. hutchinsii*) as avian herbivores has not been well studied.

My dissertation explores the role of body size in comparative foraging behavior, habitat selection, and winter conservation planning for two congeneric geese, the Dusky Canada Goose (*B. c. occidentalis*; hereafter Duskys) and the

Cackling Goose (*B. h. minima*; hereafter Cacklers). These two taxa share the same over-winter foraging environment (grass seed fields) in the same restricted geographic area (the Willamette Valley) during winter. Duskys and Cacklers differ by more than a factor of two in body size and have different relative bill sizes and social organization. Because of smaller body size, Cacklers have greater relative energy demands and less fasting endurance compared to Duskys; however, Cacklers have comparatively low energetic costs for flight and transport. Duskys, however, have higher total energy requirements than Cacklers. Additionally, Cacklers form large, high-density flocks and have a total over-wintering population size in the study area of about 200,000. Duskys occur in relatively small family groups and have a total over-wintering population size of about 13,000.

My study demonstrated that interspecific differences in body size between Cacklers and Duskys was associated with differences in foraging behavior, movements, and habitat selection. Cacklers foraged a greater percentage of time (30%) in all habitats and across the entire winter compared to Duskys. Cacklers had higher peck rates (up to 100 pecks min^{-1} greater) than Duskys in all foraging habitats expect pasture. The pecking rate of Cacklers was greatest in fields of young grass (200 pecks min^{-1}), which may indicate that Cacklers had relatively high intake rates in this foraging habitat. Based on differences in foraging behavior among habitats, Cacklers may have the foraging strategy of energy intake maximizers, whereas the foraging strategy of Duskys is more towards time-energy expenditure minimizers, at least for part of the winter. Cacklers moved across the landscape very differently from

Duskys, exhibiting less site fidelity and greater commuting distances to foraging areas. Cacklers showed a preference for young grass during all periods of the winter, reaffirming that Cacklers are specialized grazers on short green forage, whereas Duskys preferred young grass and pasture. Fields of young grass were the preferred foraging habitat of Cacklers, had less standing crop biomass, and may have enabled higher foraging efficiencies, which may have led to higher intake rates.

The ability of the landscape to support wintering geese changed across the winter because total available plant biomass fluctuated with the rate of grass regrowth. The estimated carrying capacity of the landscape for geese decline by almost one-half during mid-winter (mid-December to mid-February) compared to early winter or late winter periods. Although Cacklers have lower individual energy requirements compared to Duskys, due to a much larger target population size, Cacklers required 89% more foraging habitat than Duskys. Forage requirements encountered a bottleneck during mid-winter, when grass regrowth rates were low and day length was short. Commensurate with this pattern of forage availability, goose body condition declined during the mid-winter period. To support Pacific Flyway target populations for geese, approximately 18,000 ha of total grazing habitat in young and mature grass is needed in the Willamette Valley to support a total over-wintering population composed of 340,000 geese belonging to four subspecies.

The role of body size in influencing the foraging behavior and decisions of over-wintering geese has important implications for conservation planning of goose populations. Small-bodied Cacklers are selective in field choice, yet more likely to redistribute across the landscape. Disturbances (*e.g.*, hunting, hazing, or predation) will have a disproportionate effect on the movements of smaller-bodied geese compared to larger geese. These characteristics of Cacklers will make conservation planning to retain geese on public land more difficult. Coordinated management with private landowners and farming practices that maximize preferred goose foraging habitat on public lands may attract geese to utilize protected areas and minimize conflicts with agriculture in the Willamette Valley. Availability of resources during critical periods in winter is an important factor affecting the distribution of geese, but may affect small and large bodied geese differently. Management could be targeted during these critical time periods. By considering the role of body size in the context of life history characteristics, foraging behavior and habitat selection, appropriate management strategies can be developed and implemented to reduce the effects of agricultural depredation by geese, while promoting the future conservation of wintering geese in the Willamette Valley.

The Role of Body Size in the Foraging Strategies and Management of Avian Herbivores: A Comparison of Dusky Canada Geese (*Branta canadensis occidentalis*) and Cackling Geese (*B. hutchinsii minima*) Wintering in the Willamette Valley of Oregon

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APPROVED:

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

Anne E. Mini, Author

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CONTRIBUTION OF AUTHORS

Dr. Bruce Dugger acquired funding and made significant contributions to all aspects of this project, including preparation of manuscripts. Dr. George Mueller-Warrant provided information on habitat availability in Chapter 3. Mark Keller provided nutritional analysis of forage for Appendix C.

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Chapter 1

GENERAL INTRODUCTION

Anne E. Mini

Agriculture is the primary land use in Oregon's Willamette Valley and grass seed farming is the dominant practice (Oregon Seed Extension Program 2012). The Willamette Valley includes approximately 151,000 ha of forage and turf grass seed crop (Oregon Seed Extension Program 2011), which produces nearly two-thirds of the United States' total grass crop (Oregon Seed Extension Program 2012). Hence, the Willamette Valley is referred to as "the grass seed capital of the world" (Oregon Seed Extension Program 2012). In 2011, approximately 283,774,000 kg of grass seed were produced, which generated $298,562,000 in sales (Oregon Seed Extension Program 2011). Although grass seed is harvested in late June or early July, fields are generally seeded in early fall and green vegetative growth occurs over winter and through the spring (Oregon Seed Extension Program 2012).

The abundance of green forage along the traditional migratory route of many arctic-nesting geese is likely a factor contributing to a major change in the distribution of wintering Canada Geese (*Branta canadensis*) and Cackling Geese (*B. hutchinsii*) between California and Oregon (Raveling and Zezulak 1992, Pacific Flyway Council 1999). Historically, only 20,000–50,000 Dusky Canada Geese (*B. c. occidentalis*) wintered in the Willamette Valley (Jarvis and Cornely 1989). Currently, five subspecies winter in the Willamette Valley and the wintering goose population has increased to over 200,000 birds (Pacific Flyway Council 1998, 2008).

State and federal agency lands that were originally managed for Dusky Canada Geese are insufficient to support the current much larger winter population of geese; consequently, many geese forage on private lands (Pacific Flyway Council 1998).

The sight of large flocks of geese feeding in fields and the visible forage biomass reduction due to grazing geese has created conflict between private agricultural interests and geese (Moser and Kalden 1992). Private landowners in the Willamette Valley are concerned that the increasing wintering goose population, which grazes on their fields from October through April, significantly reduces summer grass seed yields (Pacific Flyway Council 1998, Borman et al. 2002). For example, Oregon Department of Agriculture estimated goose damage to grass seed crops in 1997 at $5,738,000 (Oregon Agricultural Statistics Service 1998). In the short-term, activities such as hazing can scare geese from fields; however, these methods can become less effective over time as birds acclimate to the disturbances or return to sites after disturbance ceases (Percival et al. 1997, York et al. 2000, Sherman and Barras 2004, Werner and Clark 2006). Because short-term solutions can be ineffective, longer-term solutions, such as refuge establishment, may be more cost-effective (Vickery et al. 1994) and necessary to address crop depredation concerns while providing for the winter forage needs of geese (Black et al. 2007).

Enhancing the availability of undisturbed feeding opportunities for a larger number of geese on public land can achieve long-term solutions to crop depredation through alleviating grazing damage on private lands. Such a strategy has proven successful in several regions in Europe (Vickery and Gill 1999, Bos and Stahl 2003, Black et al. 2007). The necessary first step is to determine the food requirements of geese relative to the supply of food, which determines how many geese the landscape can energetically support or carrying capacity (*sensu* Goss-Custard et al. 2003, Stephens et al. 2003, Baveco et al. 2011). Feeding opportunities for the population of geese can then be enhanced through providing more food on what is currently federally-owned land or by acquiring additional federal lands to support a greater number of birds (van Roomen and Madsen 1992). The present carrying capacity of public lands for over-wintering geese in the Willamette Valley is unknown; therefore, managers do not know how many geese public lands can currently support or how many additional acres might be needed to meet the food requirements of over-wintering populations (Black et al. 2007).

Ultimately, daily energy expenditure determines the daily energy requirements of geese and daily energy expenditure is closely linked with body size. Hence, average body size influences how many geese the landscape can support. Animals must over the long-term maintain energy balance in order to exist (Robbins 2001) and basal metabolic rate (a fractional power of body size) determines daily existence requirements (Kleiber 1947). Larger animals require more total energy to exist; however, smaller animals have higher mass-specific metabolic rates (Demment and Van Soest 1985). Geese have higher metabolic rates than many other bird species (Miller and Eadie 2006) and are herbivorous hindgut fermenters that are relatively inefficient at processing the fibrous components of plant cell walls (Prop and Vulink 1992). Inefficient digestion and assimilation makes obtaining nutrients more difficult. Digestive efficiency is negatively affected by the small body size of geese relative to many herbivorous mammals and by relatively small gut size, presumably to reduce flight costs. Thus, geese of smaller body size have higher metabolic demands relative to their ability to digest and assimilate forage (McWilliams 1999). Smaller geese also have lower gut retention times for ingesta due to shorter gut length and smaller volume (van Gils et al. 2008). Consequently, compared to larger geese, smaller geese have more difficulty processing forage high in fiber (Bruinzeel et al. 1998), more difficulty in accumulating endogenous energy stores (Afton and Paulus 1992), less fasting endurance (Skutch 1962, Afton 1980), and must spend more time feeding when forage availability is held constant (Cope et al. 2005, but see McWilliams 1999). Due to their greater total energy need, larger geese should engage in less energy-consuming activities (Robbins 2001) and reduce flight distances (Møller 2009). Smaller-bodied geese may move 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). These trade-offs in body size would be expected to strongly influence goose foraging behavior, as well as habitat use and movement patterns, particularly during winter when thermostatic costs are higher, most above-ground plant parts are dormant, and day length is reduced (Gauthier et al. 1992, Owen et al. 1992).

Body size varies from 1.2 to 3.0 kg among the five subspecies of geese that over-winter in the Willamette Valley and all five subspecies most co-exist for an extended period of time in a similar foraging environment. However, foraging efficiency, intake rates, and energetic balance can differ with body size in the same habitat (Durant et al. 2003, 2004; Jónsson and Afton 2009; Heuermann et al. 2011). Thus, foraging behavior and decisions may not be the same across the more than twofold range in goose body sizes, which might lead to subspecies specific management strategies for dealing with crop depredation.

To gain further insight into goose winter ecology and the influence of body size on foraging ecology, in addition to addressing management concerns related to crop depredation on private grass seed fields, I investigated the comparative foraging ecology of Dusky Canada Geese and Cackling Geese and then estimate the carrying capacity of public lands in the Willamette Valley for wintering geese. Dusky Canada Geese are relatively large bodied geese (body mass = 1.2-1.5 kg) and the least abundant subspecies in the Willamette Valley, whereas Cackling Geese are the smallest (body mass = 3.5-4.5 kg), but most abundant subspecies, and the cause of most crop depredation concerns. My dissertation addresses the following questions: 1) does body size and its allometric constraints influence the foraging behavior of Dusky Canada Geese and Cackling Geese; 2) what are the implications, if any, of body size differences between Dusky Canada Geese and Cackling Geese for movements and habitat selection; and 3) how do differences in body size and population size determine carrying capacity of public lands for over-wintering geese.

In Chapter 2, I quantified the daily time-activity budgets, peck rates, and step rates of Dusky Canada and Cackling Geese during winter. I hypothesized that differences in body size between Dusky Canada and Cackling Geese would be associated with differences in foraging behavior. I predicted that 1) Cackling Geese would spend a greater percentage of time foraging than Dusky Canada Geese; 2) Cackling Geese, due to less fasting endurance, would be more responsive to weather events like changes in temperature (Lefebvre and Raveling 1967, McNab 1983, Paulus 1988); 3) Cackling Geese would peck and step at a higher rate than Dusky Canada Geese; and 4) Cackling Geese peck and step rates would be higher than those of Dusky Canada Geese in shorter grass with less standing crop biomass.

In Chapter 3, I determined the commuting distances, landscape movements, habitat use patterns, and habitat preferences of Dusky Canada Geese and Cackling Geese. I hypothesized that differences in body size between Dusky Canada Geese and Cackling Geese would influence their foraging decisions. I predicted that Cackling Geese would be less faithful to roost sites, spend more time in foraging fields, exploit a greater number of fields, use larger fields to reduce predation risk, travel farther to find suitable foraging fields, and be more selective in habitat types used for feeding.

In Chapter 4, I measured green forage biomass of public lands and estimated the carrying capacity of public lands for the over-wintering goose populations based on energetic requirements of each subspecies. To estimate carrying capacity, I needed to assess food supply (*i.e.*, forage biomass) and food demand (*i.e.*, goose daily food requirements). I provide information on food supply based on data on available acreage of habitat on local refuges. This final data chapter is designed to assist the management and conservation of over-wintering goose populations in the Willamette Valley.

In Chapter 5, the synthesis chapter, I address body size, foraging behavior and habitat use in the broader context of optimal foraging theory and foraging decisions that geese make across the landscape. I also place the factor of body size, as investigated in Chapters 2, 3, and 4, in the broader context of goose winter ecology, foraging behavior, and wintering conservation and management of over-wintering geese in North America. I hope that the findings of this dissertation will provide additional insight and alternative ways for managers across different flyways to think about managing geese in winter.

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Chapter 2

FORAGING ALONG A BODY SIZE GRADIENT: A COMPARISON OF WINTERING CANADA AND CACKLING GEESE

Anne E. Mini and Bruce D. Dugger

ABSTRACT

Body size strongly influences constraints on energy acquisition and allocation. Constraints may be exacerbated in avian herbivores that have a nutritionally poor diet and simple digestive system. The body size hypothesis suggests that smaller body sizes are associated with less fasting endurance and more time spent feeding. We tested this hypothesis by comparing the foraging behavior of Dusky Canada Geese (Duskys) and Cackling Geese (Cacklers) that have a two-fold difference in body mass. We predicted that smaller geese would spend a greater percentage of time feeding, especially during colder temperatures, and have higher peck and step rates, especially in short grass habitat. Smaller-bodied Cacklers spent 30% more time feeding compared to the larger-bodied Duskys ($F_{1,1478} = 441.4$, $P < 0.001$), which was consistent across winter and habitat types. Variation in ambient temperature effected each species differently; smaller Cacklers reducing feeding time at warmer temperatures in early ($F_{1,367} = 15.2$, $P < 0.001$) and late winter ($F_{1,522} = 18.0$, $P < 0.001$). Cacklers pecked ($F_{3,2525} = 8.88$, $P = 0.001$) and stepped ($F_{1,1890} = 4.54$, $P = 0.011$) at higher rates than Duskys, especially in short green forage. Geese of smaller body size face tradeoffs associated with foraging constraints (*e.g.*, time feeding vs. predation risk) that may leave relatively few options for reducing foraging intensity in response to factors like habitat type or temperature. Cacklers may operate as energy intake maximizers compared to Duskys, which are more foraging time minimizers. These inter-specific differences in foraging effort translate into differences in habitat selection and resource use across the landscape.

INTRODUCTION

Grass-eating waterfowl of the subfamily Anserinae comprise a relatively small foraging guild whose evolution has been shaped by the combination of a nutritionally poor diet and the constraints of body size on metabolic rate, digestive capacity, and flight capacity (Bruinzeel et al. 1997; Sedinger 1997; Klasing 1998). Grass is generally low in protein compared to animal tissues and high in refractory fiber compared to fruits or grains; additionally, grasses can contain anti-herbivory compounds that inhibit digestion (Robbins 2001). Nutrient assimilation from green forage is relatively inefficient in geese because of their simple digestive system, an adaptation for flight (Klasing 1998; McWilliams 1999). The ability to satisfy daily energy needs from grass varies with body size because total energetic costs increase with body size, but mass-specific costs decrease (Calder 1984). Therefore, smaller geese have relatively higher metabolic demands than larger geese (Miller and Eadie 2006), which reduces fasting endurance under similar levels of endogenous energy reserves (Calder 1984). Smaller geese with shorter guts have lower intake rates and shorter retention times than larger geese (van Gils et al. 2008). These challenges may strongly influence goose foraging behaviour, particularly during winter when thermostatic costs are high, forage availability is limited, and day length is short (Gauthier, Giroux, and Bédard 1992; Owen, Wells, and Black 1992). To satisfy their daily energy requirements during winter, geese spend a significant amount of time foraging (Owen 1980; Owen, Wells, and Black 1992; Black, Prop, and Larsson 2007), but foraging effort varies across species (Paulus 1988).

Body size has been hypothesized to strongly influence foraging behaviour for breeding and wintering birds. First proposed by Skutch (1962) to explain feeding behaviour during incubation and later extended to waterfowl (Afton 1980; Gloutney et al. 2001), the original body size hypothesis predicted that smaller birds have shorter incubation constancy (Skutch 1962; Afton 1980) because of less fasting endurance (Calder 1984) and thus must spend a greater proportion of the day foraging (Gloutney et al. 2001). More recently, Jónsson and Afton (2009) tested this hypothesis by examining differences in behaviour between Ross' geese (*Chen rossii*) and lesser snow geese (*C. caerulescens caerulescens*) during winter, predicting that smaller Ross' geese would feed more during colder weather, have higher peck rates, and spend more time alert. The prediction held for time spent foraging, but peck rates were only higher in one of two years and weather affected foraging in both species (Jónsson and Afton 2009). These inconsistent findings likely resulted because the study area was relatively far south (29°57′N) with mild temperatures and long day length and the study species supplemented their diet by grubbing for tubers, a relatively high quality food (Owen 1972; Owen, Wells, and Black 1992; Jónsson 2005; Jónsson and Afton 2009). In a poorer quality foraging environment with shorter day length, differences in foraging behaviour related to body size should be more pronounced.

Wintering geese display a variety of quantifiable foraging behaviors that lead to specific predictions of how foraging behaviour may vary across geese of different body sizes (Karasov 1990; McWilliams 1999; Jónsson and Afton 2009). Larger geese would be expected to reduce the total costs of non-foraging activities like locomotion (walking or flying) to compensate for their higher overall energy demands, or reduce step frequency, which reflects a reduction in search effort during foraging (Calder 1984; Eisenberg 1990). Smaller geese would be expected to spend a greater percentage of time foraging (Jónsson and Afton 2009) and increase their peck rate while foraging (Owen 1972; Black et al. 1992; Sedinger and Raveling 1998). Peck rate (peck min^{-1}), in addition to being an index of intake rate, is directly related to handling time (min peck^{-1}; Durant et al. 2003), and handling time can be influenced by habitat conditions. For example, smaller geese peck at a higher rate in shorter grass with lower standing crop biomass and at a lower rate in taller grass (Durant et al. 2003; Heuermann et al. 2011). Lastly, smaller geese in winter congregate in large flocks either as response to predation risk, to facilitate optimal grazing conditions, or a combination of both (Johnson and Raveling 1988; McWilliams and Raveling 1998).

Although a number of studies have examined foraging behavior in wintering geese (*e.g.*, Owen 1972; Ebbinge, Canters and Drent 1975; Johnson and Raveling 1988; Owen, Wells, and Black 1992; Jónsson and Afton 2009), none have explicitly compared the foraging behavior of two congeneric species of geese with significantly different body size that feed primarily by grazing on low-digestibility forage at a latitude with short winter day lengths. Here, we studied cackling and Canada geese that winter sympatrically and graze together on green forage in the Willamette Valley of Oregon (44°24′N) to test predictions of the body size hypothesis for foraging behaviour in wintering geese. Specifically, we examined cackling geese (*Branta hutchinsii minima*; hereafter “Cacklers”) and dusky Canada geese (*B. canadensis* *occidentalis*; hereafter "Duskys"). Cacklers are among the smallest northern hemisphere geese with an average body mass of 1.2–1.5 kg (Johnson et al. 1979). Duskys are considerably larger than Cacklers (3.5–4.5 kg) and they have a considerably longer bill (culmen length = 44.4–46.9 mm vs. 27.3–28.2 mm; Johnson et al. 1979). Until 2005 these two taxa were considered subspecies of a single species, the Canada goose (Banks et al. 2004). We predicted that: 1) Cacklers would spend a greater percentage of time feeding than Duskys, 2) Cacklers would increase the time spent feeding during colder ambient temperatures and reduce time spent feeding during warmer temperatures, while Duskys would show no trend in time spent feeding with ambient temperature (Lefebvre and Raveling 1967; McNab 1983; Paulus 1988); and 3) Cacklers would peck and step at higher rates than Duskys, especially in shorter grass with less standing crop biomass.

METHODS

Study site

We collected data in the Willamette Valley of northwestern Oregon, the primary wintering grounds for both Duskys and Cacklers (44º24′N, 123º20′W; Fig. 2.1). We focused data collection on three federally managed wildlife refuges that support significant numbers of geese (William L. Finley National Wildlife Refuge (NWR), Ankeny NWR, and Baskett Slough NWR). All three refuges were cooperatively farmed to provide foraging habitat for geese. We additionally collected data on geese foraging on private lands within 10 km of the three federal refuges, Fern Ridge Wildlife Area, and Knife River Pond (Fig. 2.1).

We observed geese foraging in four habitat types: fields planted in annual ryegrass (*Lolium multiflorum*), perennial ryegrass (*L. perenne*), perennial tall fescue (*Festuca arundinacea*), and pasture. For habitat comparisons, we considered first and second year annual ryegrass and all first year perennial grass fields as "young" grasses. Young grasses were seeded in the fall and formed dense even stands (Hanaway et al. 1999a). Perennial grasses were re-seeded every 2-15 years, formed tufted stands with distinct separated rows (Hanaway et al. 1999b, c). Compared to young grass, perennial grasses had higher standing crop biomass (mean ± SE; 653 ± 135 kg ha^{-1} vs. 117 ± 35 kg ha^{-1}), taller height (9.8 ± 0.7 cm vs. 5.4 ± 0.4 cm), and more dead organic material (dead vs. green material ratio: 4.5:1 vs. 0.16:1; Chapter 4). Pasture typically included a mixture of the ryegrasses, fescue, orchard grass (*Dactylis glomerata*), timothy grass (*Phleum pretense*), and clover (*Trifolium* sp.; Ogle, St. John, and Jensen 2010).

Behavior sampling

We used continuous scan sampling (Altmann 1974; Bart, Flinger, and Notz 1998) to characterize the diurnal activity patterns of Duskys and Cacklers from arrival in fall to departure in spring of 2006-2007 and 2007-2008. The sampling objective was a 10-min continuous observation session on a single flock, but we included all sessions that lasted ≥ 5 min in our analysis (Jónsson and Afton 2009). We summarized observation session duration for a random sample of half of the data (*n* = 738 sessions); 77% of the scans were ≥ 9 min and 92% were ≥ 7 min. One of the authors (AEM) and three technicians, trained and tested by AEM to ensure no observer effects, collected behaviour data using 20x spotting scopes.

We stratified our sampling effort by month (November-April) and time of day (1-h blocks from sunrise-sunset). We collected 10-12 scans per 1-h time period per month in 2006-2007 for each species and, based on the preliminary analysis of the data set, reduced sample size to 4-5 scans per 1-h time period per month in 2007-2008. Because small flocks can be biased towards increased vigilance (Owen 1972; Inglis and Lazarus 1981), only Dusky flocks $\geq$ 15 individuals and Cackler flocks $\geq$ 100 individuals were observed. Upon arriving at a flock, we waited 2-5 min before beginning an observation session and alternated the start of scans on the far left or right side of a flock. We scanned individuals from all sections of the flock, using a back and forth motion across the flock, to maximize our chance of collecting representative sample of behaviors. Behaviors were dictated onto a digital voice recorder and later transcribed using speech recognition software (Dragon Naturally Speaking Preferred version 9.1, Nuance Communications, Inc.). We tested the accuracy of the speech recognition software by comparing a subsample of voice-transcribed sessions against a hand-transcribed version of the same data using the activity category of feeding (n = 40 scans; n = 10 from each observer). We found no significant difference between percentage of time spent feeding from hand-transcribed data versus voice-transcribed data (two-sample t-test: $t_{76} = -0.2$, $P = 0.86$).

Behaviors were classified as either: 1) feeding, 2) vigilance, 3) locomotion (walking, swimming, or flying), 4) resting, or 5) comfort (a variety of behaviors including preening, wing flapping, and bathing). We recorded the habitat being used by each flock as young grass, perennial ryegrass, perennial tall fescue, or pasture, which also included wet prairie habitats and marsh levees. For each behavior scan, we summarized data as the percentage of time spent engaged in each category of behavioral activity. To quantify peck and step rates, we observed 5-10 focal individuals in a flock from a variable number of independent flocks throughout a week. We selected birds from different parts of the flock (front, back, or edge) to minimize sampling bias due to social organization (Black et al. 1992). We recorded the number of seconds needed to complete 25 pecks or 10 steps (McWilliams and Raveling 1998) and standardized the data into pecks min^{-1} or steps min^{-1}.

Data analysis

The response variable used in the analysis of time activity-budgets was percentage of time spent feeding during each observation session, calculated as the number of feeding observations in a scan sample session divided by the total number of observations recorded during the session. To achieve normality, constant variance, and eliminate zeros from the data set, we logit x+0.01 transformed the percentage of time spent feeding prior to analysis. We divided winter into early winter (25 October-15 December), mid (16 December-15 February), and late (16 February-1 April for Duskys and 16 February-15 April for Cacklers) periods based on patterns observed in abdominal profile indices (API; Owen 1981). API scores increased during early winter, decreased during mid-winter, and increased again during late winter (Appendix A). Additionally, we grouped data into three time periods during the day (morning [1 h after sunrise-1100], mid-day [1100-1400], and evening [1500-1 h before sunset]).

We compared the mean percent time feeding using a linear mixed model (Proc MIXED, SAS version 9.1, SAS Institute 2009) with two modeling approaches. The first model included fixed effects of species (Cackler vs. Dusky), winter period, time of day, and habitat type (young grass, perennial ryegrass, perennial tall fescue, or pasture). Year was included as a random effect. In addition to the main effects, we included two-way interaction terms of species with winter period, time of day, and habitat type. We report percentages using non-transformed data for ease of interpretation. We additionally compared mean percentage of time spent feeding as a function of weather (maximum daily temperature) using linear regression (Proc REG, SAS version 9.1) for each winter period (early, mid, and late) to assess the association with (positive or negative) and significance of temperatures for feeding in each species. Maximum daily temperatures were taken from Hyslop Farm Weather Station, Oregon State University, Corvallis, Oregon.

The response variables for peck rate and step rate analysis were pecks min^{-1} and steps min^{-1}. To achieve normality and constant variance, we log transformed peck rates and step rates. We analyzed peck and step rates using a linear mixed model (Proc MIXED, SAS version 9.1). Fixed effects were goose species, winter period, and habitat type; year was a random effect. We included two-way interaction terms of species with winter period and habitat type. Multiple comparisons were based on differences in least squares means using a Tukey-Kramer adjustment. Specifically, we were interested in whether Cacklers would peck and step at higher rates than Duskys in young grass because it was shorter and had less standing crop biomass than perennial grasses. Values are reported as mean ± SE of non-transformed data.

RESULTS

Cacklers spent more of the diurnal time period feeding (74 ± 0.5%, $n = 809$ flock scans) than did Duskys (44 ± 0.9%, $n = 686$; $F_{1,1478} = 441.4$, $P < 0.001$). Cacklers allocated the remaining 26% of their diurnal time period evenly among the four other categories of behaviors, whereas Duskys spent 40% of their time allocated to vigilance and resting (Table 2.1). The difference in foraging effort between Cacklers and Duskys was similar throughout the day ($F_{2,1476} = 0.3$, $P = 0.73$), but the magnitude of the interspecific difference varied with other explanatory variables as indicated by significant interactions between species and winter period ($F_{2,1478} = 43.7$, $P < 0.001$) and habitat type ($F_{3,1478} = 7.0$, $P = 0.001$).

The percentage of time spent feeding by Cacklers was consistently high across the three winter periods, whereas the percentage of time spent feeding for Duskys steadily increased (21%) from early to late winter (Fig. 2.2). Cacklers and Duskys showed a larger difference (ca. 30%) in percentage of time spent feeding among young grass, perennial ryegrass, and perennial tall fescue and a smaller difference (25%) in pasture (Fig. 2.3). Cacklers spent 4% more time feeding in perennial ryegrass compared to the other habitat types and spent a similar percentage of time feeding in the other three habitats ($P > 0.05$); Duskys spent more time feeding in perennial ryegrass and perennial tall fescue compared to pasture and young grass ($P < 0.002$; Fig. 2.3).

During early winter, Cacklers spent more time feeding during colder weather compared to warm weather ($b = -0.05$), while the opposite trend (reduced feeding during colder temperatures compared to warm temperatures [$b = 0.06$]) was observed in Duskys ($R^2 = 0.46$, $F_{1,367} = 15.2$, $P < 0.001$; Fig. 2.4). The same trend for Cacklers ($b = -0.05$) and Duskys ($b = 0.04$) existed in late winter, but the relationship was not as strong ($R^2 = 0.27$, $F_{1,522} = 18.0$, $P < 0.001$; Fig. 2.4). Time spent feeding by both Cacklers and Duskys was not related to temperature during mid-winter ($F_{1,594} = 1.2$, $P = 0.28$).

Cacklers pecked faster ($F_{3,2525} = 8.88$, $P = 0.001$) and stepped faster than Duskys in all three winter periods ($F_{1,1890} = 4.54$, $P = 0.011$; Table 2.2). Additionally, peck rate patterns among habitat types varied for both species ($F_{3,2525} = 29.1$, $P < 0.001$; Fig. 2.5). The difference between peck rates for Cacklers and Duskys was greatest in young grass (87 pecks min^{-1}), followed by perennial ryegrass (58 pecks min^{-1}), perennial tall fescue (34 pecks min^{-1}), and pasture (2 pecks min^{-1}). The patterns in step rates for each species were similar ($F_{3,1890} = 29.1$, $P = 0.10$), with the highest step rates in young grasses ($P < 0.001$), lower and similar step rates in pasture and perennial ryegrass ($P = 0.99$), and the lowest step rates in perennial tall fescue (Fig. 5).

DISCUSSION

Our results are consistent with the hypothesis that differences in body size influence the foraging behavior of geese in winter. Our study is the first to compare congeneric, sympatric goose taxa grazing on green forage during winter, while explicitly testing predictions on size-dependent foraging behaviors derived from the body size hypothesis. Cacklers, as the smaller herbivore, behaved much differently in the same foraging environment compared to Duskys. Cacklers spent an average of 30% more time feeding and this pattern was consistent across habitat types, winter periods, and time of day. In other comparative studies, smaller geese spent more time feeding than larger geese, regardless of whether the different taxa belonged to different genera (Gawlick and Slack 1996) or were congeneric (Jónsson and Afton 2009), while geese of similar body size spent a similar percentage of time foraging (McWilliams and Raveling 1998).

Percent time spent feeding by Cacklers in our study was similar to results from other small geese (Ebbinge et al. 1975, Owen et al. 1992, Jónsson and Afton 2009, Mini and Black 2009, Tinkler et al. 2009). However, Cacklers in the Willamette Valley spent a greater percent of time feeding than Cacklers that historically winter further south in California (74% vs. 68%; McWilliams and Raveling 1998). This difference can likely be explained at least in part by the shorter day length in winter at the more northerly latitudes of northwest Oregon. Taking latitude into account, our results fit well with patterns of foraging along a body size gradient across the globe (Fig. 2.6).

Small-bodied Cacklers may not be at a behavioral maximum for foraging because percent time spent feeding by Barnacle Geese (*B. leucopsis*) is greater at higher latitudes (Owen et al. 1992). However, further increases in foraging effort by Cacklers may come at a cost to predator avoidance (Owen 1972, Caraco 1979, Black et al. 1991). Predation risk appears high in the Willamette Valley based on observations of Bald Eagle (*Haliaeetus leucocephalus*) attacks on Cacklers in the study area, especially in post-arrival and mid-winter (A. Mini, pers. obs.). Cacklers in the Willamette Valley exhibited decreased vigilance in pre-departure (Appendix B) when Bald Eagles were less prevalent and increased vigilance in mid-day (Appendix B) when Bald Eagle activity can be greatest (McWilliams et al. 1994). Cacklers in the Klamath Basin did not increase percent time vigilance but instead used the roost more mid-day (McWilliams et al. 1994). Similarly, Cacklers in the Willamette Valley also used the roost more often in post-arrival (Chapter 3).

The greatest disparity in percent time foraging between Cacklers and Duskys came during early winter (38% difference). During early winter, Duskys did not feed much (33%), but increased foraging effort 21% through the late winter period. Duskys potentially had other food resources in early winter and mid-winter that provided an energy rich food source, thereby allowing relaxed foraging effort in grass fields (Ely 1992). Specifically, Duskys may have foraged on alternate foods available at the roost (*e.g.*, tubers in marshes), which reduced flight costs while potentially feeding on energy dense foods (A. Mini, pers. obs.; Petrie et al. 1998).

The difference in percent foraging between the two body sizes was least (20%) during late winter when foraging opportunity increased as days lengthened and grass regrowth rate increased (Chapter 4). Both geese were likely capitalizing on increasing daylight and sward height to gain energy reserves, but they responded in different ways. Cacklers may have increased foraging intake without changing percent time foraging, whereas Duskys changed percent time foraging. During late winter, grass grows more rapidly, increasing in biomass and length (Chapter 4), thus providing more biomass for consumption (Hassall et al. 2001, Durant et al. 2004). If coupled with retaining food longer as daylight lengthens (Prop and Vulink 1992, Prop et al. 2005), increasing gut length (van Gils et al. 2008) and/or selectively retaining digesta (McWilliams 1999), Cacklers could potentially increase the amount of consumed biomass without changing percent time feeding (Owen 1972, Black et al. 1992, Sedinger and Raveling 1998). Duskys are able to forage more efficiently during spring when blades are longer and responded with increased percent time foraging in better foraging conditions (Durant et al. 2003, Heuermann et al. 2011).

Although some geese will reduce feeding in mid-day (Owen 1972, Black et al. 1991), Cacklers and Duskys both fed consistently throughout the day. A break in feeding, which is representative of a digestive bottleneck, is usually taken when the gut is filled to capacity (Prop and Vulink 1992, Black et al. 2007). Duskys may be processing food more slowly with significant periods of rest (*i.e.*, loafing time) throughout the entire day that allows food to pass through the gut more slowly and potentially enhance digestion (Prop and Vulink 1992). Cacklers, on the other hand, may have a short retention time that is typical of small geese during winter (Prop and Vulink 1992, Black et al. 2007) and may not experience a digestive bottleneck (defined as food intake limited by the amount of food that can be processed or digestive capacity; Prop and Vulink 1992, Black et al. 2007). Due to their relatively short gut and potentially short retention time of that passes food quickly, food may be processed less efficiently but Cacklers would be able to continue feeding at a high rate throughout the day.

Percent time spent foraging did not vary by habitat type for Cacklers. Cacklers, once feeding in field, may have reduced flexibility to alter feeding rate, especially if short winter day lengths limit feeding opportunity (Owen et al. 1992). Cacklers foraged similarly in all habitats in the Klamath Basin (McWilliams and Raveling 1998). Duskys, in comparison, fed more in perennial ryegrass and tall fescue than young grass or pasture, suggesting that Duskys, as the larger herbivore, may have a more flexible habitat use strategy (Owen 1980, Ely and Raveling 2011). Duskys may not have needed consistently high foraging effort in all habitats, instead spending time devoted to other activities such as vigilance and resting. Although other geese have shown differences in percent time foraging between habitats (Therkildsen and Madsen 2000), the differences we found (2–6%) in foraging behavior among habitats may not be biologically significant for either Cacklers or Duskys.

Although percent time foraging was consistently high among winter periods, time of day, and habitat for Cacklers, geese can adjust foraging effort through peck or step rates (Owen 1972, Black et al. 1992, Sedinger and Raveling 1998). As we predicted, small-bodied Cacklers pecked and stepped at an elevated rate compared to Duskys. Peck and step rates decreased during mid-winter for both species. Geese typically lose body mass in mid-winter as a result of limited feeding opportunity (Gauthier et al. 1992, Owen et al. 1992; Appendix B) and will reduce walking rates when less food is available (Black et al. 2007). Thus, reduced peck and step rates during mid-winter in our study are likely a result of decreased grass biomass in fields during mid-winter (Chapter 4). Unlike percent time feeding, values for peck and step rates differed significantly with habitat. Thus, although percent time feeding was not different, Cacklers may be able to forage more efficiently in young grass due to the growth form of the grass, which has shorter sward height and less dead material (Durant et al. 2003, Heuermann et al. 2011). Cacklers also walked very quickly through young fields, indicating that search time may be minimal (Owen 1972). Peck rates were similar in pasture habitat; however, pasture habitats are of a mixed variety of grass species and Duskys may be less selective in blade choice than Cacklers or have reduced handling time (Durant et al. 2003, Heuermann et al. 2011).

Different foraging strategies have been proposed to explain habitat selection and diet choice (Schoener 1971, Hixon 1982) and the concepts of energy maximizer and time minimizer have been applied to foraging geese (Ely 1992, Amano et al. 2006). Hixon and Carpenter (1988) predicted that an energy maximizer would dedicate more time to foraging (*i.e.*, percent time feeding) and spend less time inactive, have a greater rate of foraging (*e.g.*, peck rate), gain mass more rapidly if energy intake translates into reserve acquisition, and have no other differences in behavioral activities. In contrast, a time minimizer would dedicate less time to foraging and more time to sitting bouts (inactivity), gain mass more slowly, and exhibit differences in other behavioral activities (Hixon and Carpenter 1988). Cacklers fed more, especially in cold weather and under high predation pressure, spent less time inactive, and had a greater rate of foraging, but the rate of reserve acquisition was difficult to compare between species. Cacklers also exhibited no difference in other behavioral activities. Most likely, Cacklers are energy maximizers in the Willamette Valley. Duskys were most likely time-minimizers, at least in early winter and mid-winter. Duskys behavior in late winter is unclear and may indicate behavioral plasticity by switching to an energy-maximizing strategy (Hixon and Carpenter 1988). Greater White-fronted Geese (*Anser albifrons*, ~2.2 kg) were time minimizers while feeding on high energy foods such as corn (*Zea mays*), potatoes (*Solanum* sp.), and seeds (Ely 1992), but energy-maximizers when feeding on rice (*Oryza sativa*) and wheat (*Triticum* sp.) leaves (Amano et al. 2004). Time minimizers are also likely to reduce foraging in periods of harsh weather or predation pressure (Ely 1992), and Duskys reduced feeding in colder temperatures. However, by late winter, Duskys had a greater rate of foraging, consistent with an energy maximizing strategy (Hixon and Carpenter 1988).

Larger geese potentially expend less energy, but have a higher total energy requirement that cannot be solely supported on green browse. Belovsky (1997) theorized that, if time and digestive capacity limited food intake, then an intermediate body size could be advantageous and result in greatest foraging efficiency. When foraging on a nutritionally poor resource, small body size in geese may be necessary to capitalize on the nutrition contained in short green browse in winter (Johnson and Raveling 1988). Small geese, with lower total energy requirements, forage better on short grass where they can increase peck rates to compensate for lower available biomass (Durant et al. 2003, Heuermann et al. 2011) and can potentially process larger quantities of green browse (Black et al. 2007). The differences in foraging behavior between the species may lead to further differences in optimal foraging decisions and habitat use across the landscape. Accordingly, Cacklers should prefer young grass that is shorter with less biomass where they have a better functional response (Heuermann et al. 2011) and thus experience the highest intake rate and energetic gains to maintain a positive energy balance in mid-winter and gain reserves in late winter.

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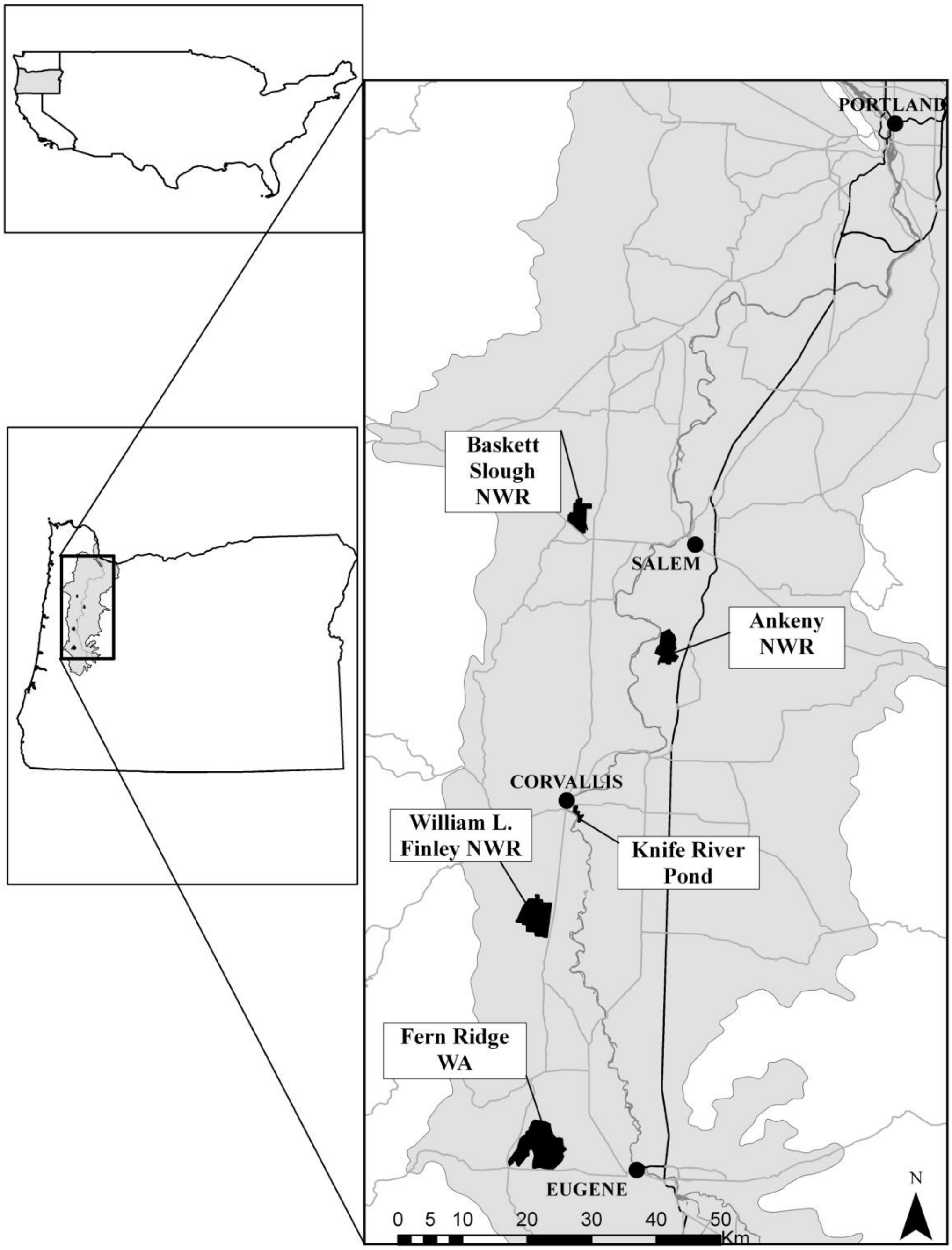

Figure 2.1. Federal, state, and private areas used to observe foraging geese in the Willamette Valley of Oregon (light gray shaded area). Federal refuges included William L. Finley National Wildlife Refuge (NWR), Ankeny NWR, and Baskett Slough NWR. The state wildlife area was Fern Ridge Wildlife Area (WA). The private area was Knife River Pond. Black circles label major Oregon cities in the study area.

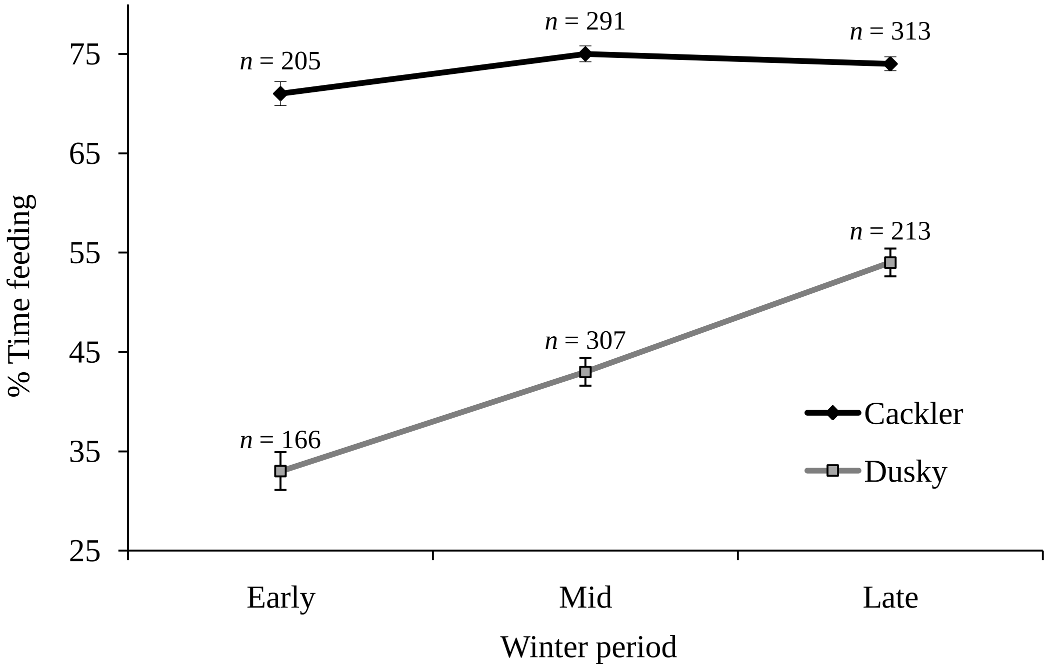

Figure 2.2. Percent of time ($\bar{x}$ ± SE) that Cackling Geese and Dusky Canada Geese spent feeding during three periods of the winter from November–April during the winters of 2006–2007 and 2007–2008 in the Willamette Valley, Oregon. Early winter was 25 October–15 December, mid-winter was 16 December–15 February, and late winter was 16 February–1 April for Dusky Canada Geese and 16 February-15 April for Cackling Geese. *n* represents sample size.

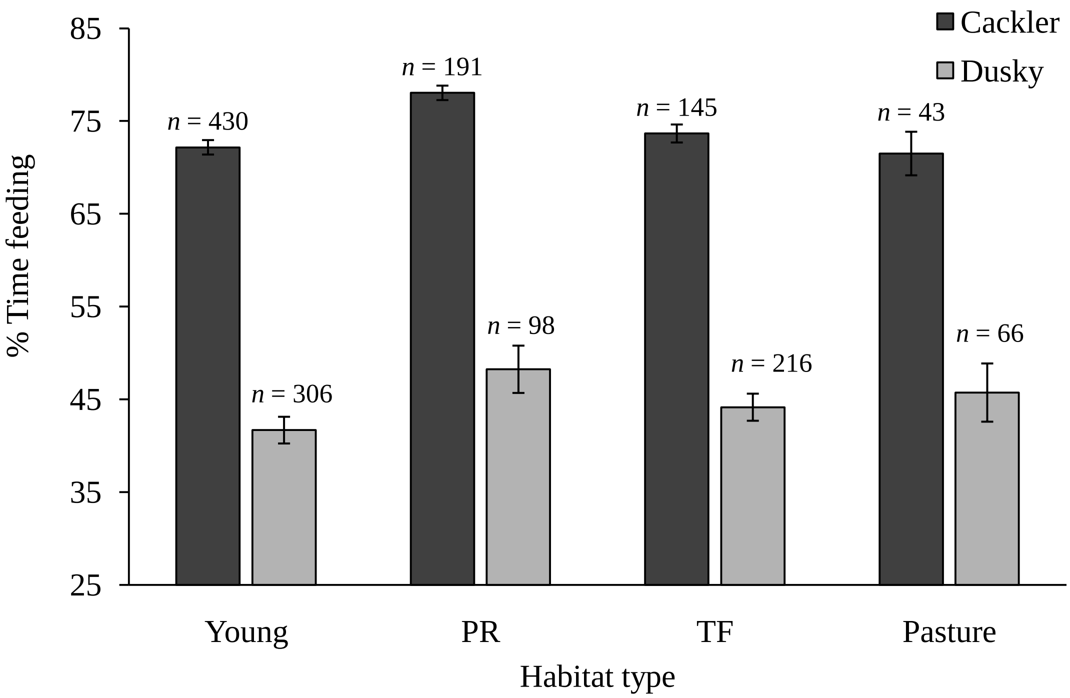

Figure 2.3. Percent of time ($\bar{x}$ ± SE) that Cackling Geese and Dusky Canada Geese spent feeding in four different habitat types from November–April during the winters of 2006–2007 and 2007–2008 in the Willamette Valley, Oregon. Young = young grass; PR = perennial ryegrass; TF = perennial tall fescue; pasture included managed mixed pasture and wet prairie habitats. *n* represents sample size.

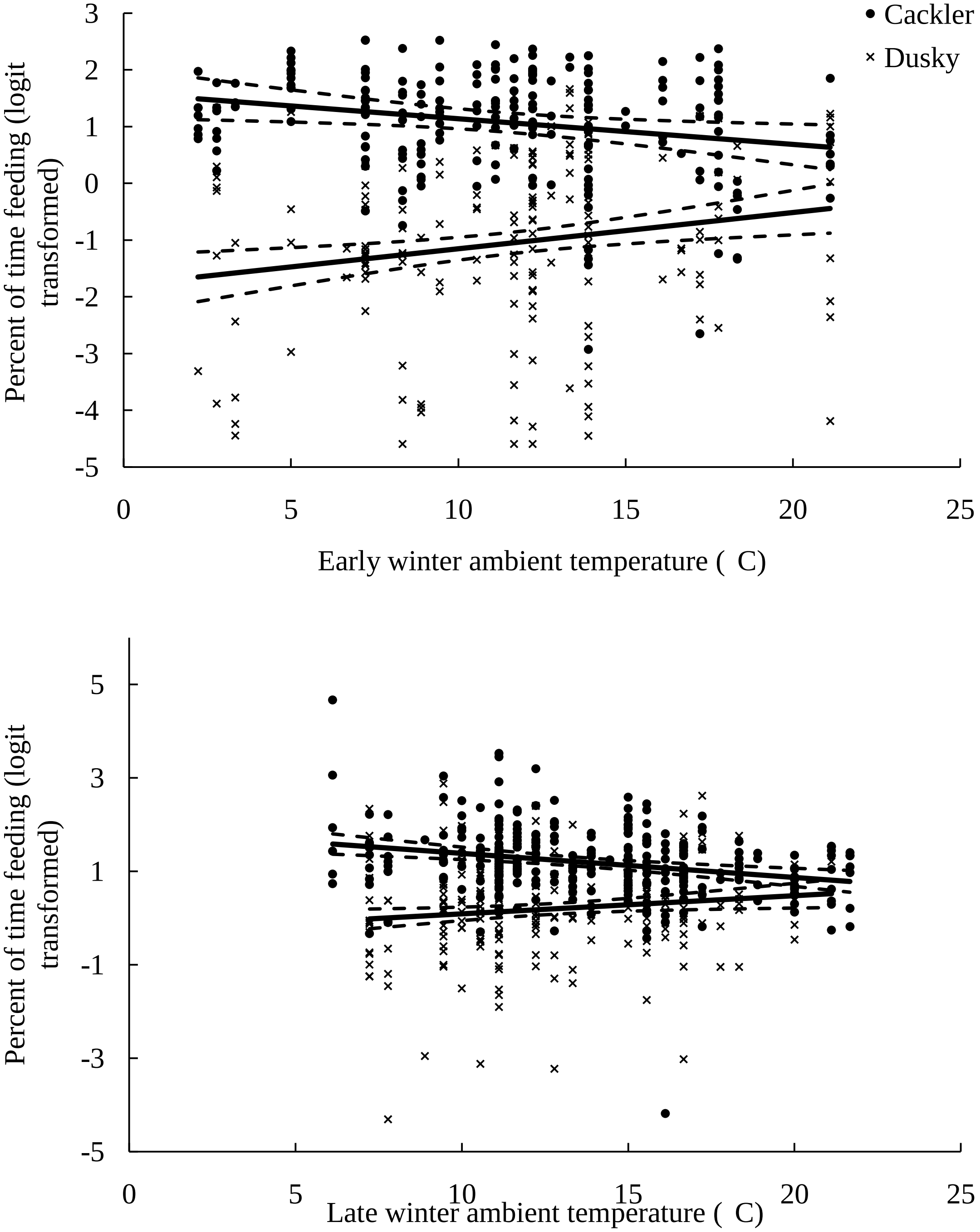

Figure 2.4. Percent of time spent feeding by Cackling Geese and Dusky Canada Geese across a range of ambient temperatures (°C) during early winter and late winter periods during the winters of 2006–2007 and 2007–2008 in the Willamette Valley, Oregon. Dashed lines represent 95% confidence limits for the predicted mean.

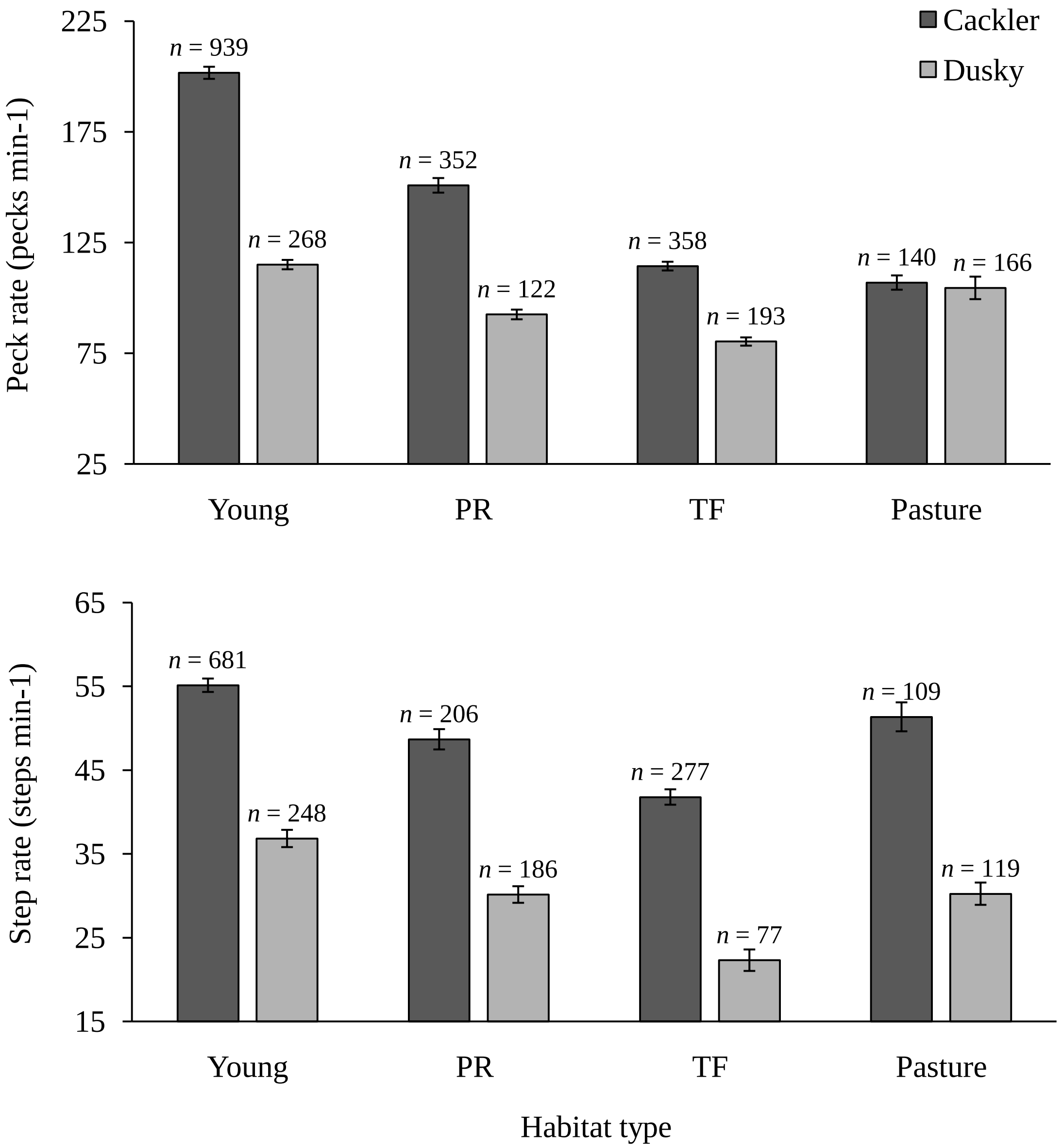

Figure 2.5. Peck rate (pecks min^{-1}) and step rate (steps min^{-1}) of Cackling Geese and Dusky Canada Geese in four different habitat types from November–April in 2006–2007 and 2007–2008 in the Willamette Valley, Oregon. Young = young grass; PR = perennial ryegrass; TF = perennial tall fescue; and pasture included managed mixed pasture and wet prairie habitats. Values are reported as $\bar{x}$ ± SE; *n* represents sample size.

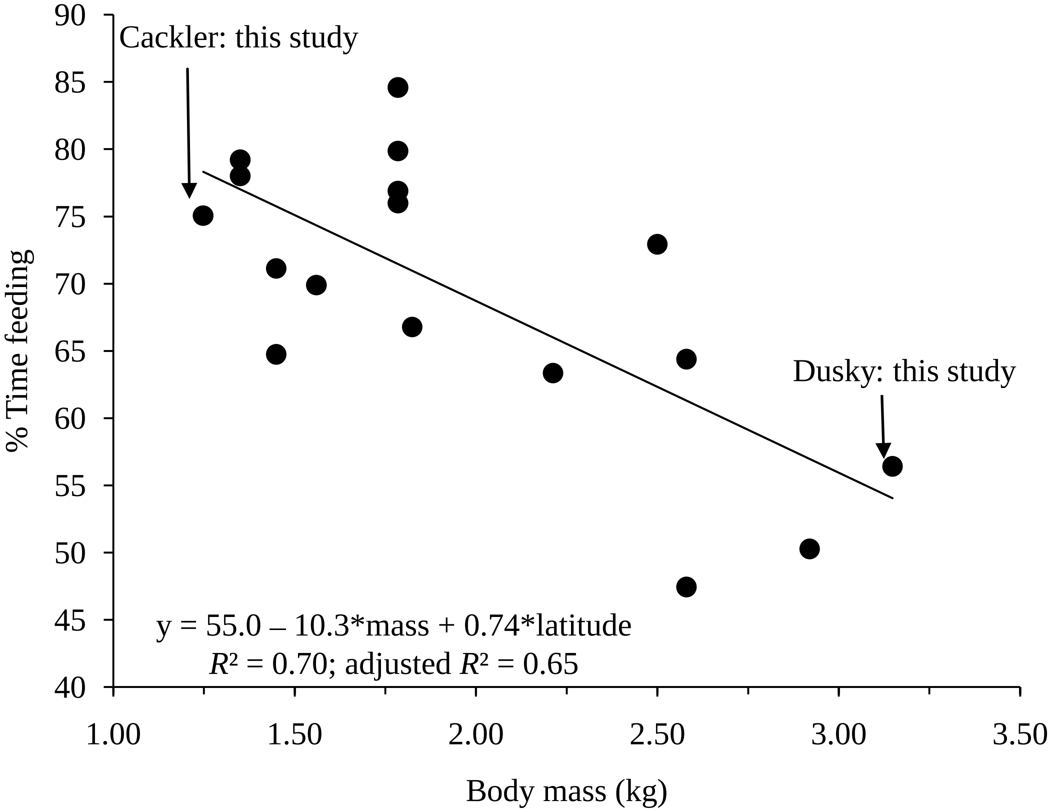

Figure 2.6. Percent of time spent feeding as a function of body mass in nine taxa of geese, while accounting for differences in latitude. The relationship between body mass and percent time spent feeding was significant ($F_{2,17} = 16.0$, $P < 0.001$). Values for geese of the same species at the same latitude from different studies were averaged. Goose taxa used include: Cackling Geese (McWilliams and Raveling 1998), Brent Geese (Summers and Critchley 1990, Riddington et al. 1996, Tinkler et al. 2009), Ross' Geese (McWilliams and Raveling 1998, Jónsson and Afton 2009), Barnacle Geese (Ebbinge et al. 1975, Black et al. 1991, Owen et al. 1992, Cope 2003), Aleutian Cackling Geese (Mini and Black 2009), Snow Geese (Belanger and Bédard 1992, Jónsson and Afton 2009), White-fronted Geese (Owen 1972, Ely 1992), Pink-footed Geese (Madsen 1985, Therkildsen and Madsen 2000), and Greylag Geese (Amat et al. 1991).

Table 2.1. Percent of time ($\bar{x}$ ± SE) that Cackling Geese (n = 809 flock scans) and Dusky Canada Geese (n = 686) spent in six behavior categories during diurnal hours from November–April during the winters of 2006–2007 and 2007–2008 in the Willamette Valley, Oregon.

	Behavior					
Species	Feeding	Vigilance	Resting	Comfort	Locomotion	Other
Cackler	74 ± 0.5	8 ± 0.2	4 ± 0.3	5 ± 0.2	9 ± 0.3	0 ± 0.0
Dusky	44 ± 0.9	18 ± 0.5	22 ± 0.9	7 ± 0.3	9 ± 0.3	0 ± 0.0

Table 2.2. Peck and step rates [$\bar{x}$ (SE)] of Cackling Geese and Dusky Canada Geese averaged across all three winter periods and among winter periods from November–April during the winters of 2006–2007 and 2007–2008 in the Willamette Valley, Oregon. Early winter (Early) was 25 October–15 December, mid-winter (Mid) was 16 December–15 February, and late winter (Late) to was 16 February–1 April for Dusky Canada Geese and 16 February - 15 April for Cackling Geese. *n* represents sample size.

	Peck rate (pecks min^{-1})				Step rate (steps min^{-1})			
		Winter Period				Winter Period		
Species	Average	Early	Mid	Late	Average	Early	Mid	Late
Cackler	167 (2)	205 (6)	132 (3)	179 (2)	51 (1)	56 (2)	49 (1)	52 (1)
n	1,789	337	654	798	1,273	239	630	404
Dusky	100 (2)	122 (6)	81 (3)	102 (1)	32 (1)	35 (1)	29 (1)	31 (1)
n	749	138	193	418	630	229	168	233

The Role of Body Size in the Foraging Strategies and Management of Avian Herbivores: A Comparison of Dusky Canada Geese (*Branta canadensis occidentalis*) and Cackling Geese (*B. hutchinsii minima*) Wintering in the Willamette Valley of Oregon

Chapter 3

COMPARATIVE WINTER MOVEMENTS AND HABITAT USE FOR TWO GOOSE SPECIES OF DIFFERENT BODY SIZES IN THE WILLAMETTE VALLEY, OREGON

Anne E. Mini, Bruce D. Dugger, and George W. Mueller-Warrant

ABSTRACT

Body size influences many life history traits in wintering geese. Compared to larger geese, smaller-bodied geese have different social structures, higher mass-specific metabolic rates and nutritional requirements, and reduced flight costs that may result in differences in resource acquisition and use of the foraging landscape. We investigated habitat use and movement patterns of Dusky Canada Geese (*Branta canadensis occidentalis*) and Cackling Geese (*B. hutchinsii minima*) that differ by more than a factor of two in body size and winter in the Willamette Valley of Oregon. According to the principles of the energetics of animal movements, we predicted that the smaller Cackling Geese (Cacklers) would be less faithful to their roost sites, use a greater number of fields for foraging, commute farther distances between roost sites and foraging sites, and be more selective in habitat choice. Cacklers changed roost sites, used more fields (t_{39}= 2.02, $P < 0.01$), and commuted nearly twice as far (5.2 ± 0.3 km vs. 3.0 ± 0.4 km) as Dusky Canada Geese (Duskys; $F_{1,1886} = 63.3$, $P < 0.001$). Cacklers spent 90% of their time in fields were they foraged, whereas Dusky spent 40% of their time at roosts. When foraging, Cacklers preferred young grass relative to other available habitats; Duskys preferred young grass as well as pasture. Managers may be able to strategically focus actions on over-wintering geese that take into account the movement patterns and habitat preferences of different sized geese to produce desired management outcomes. Coordinated management with private landowners and farming practices that maximize preferred goose foraging habitat on

public lands may attract geese to utilize protected areas and minimize conflicts with agriculture in the Willamette Valley.

INTRODUCTION

Body size has important implications for the ecology of wintering geese (Owen 1980, Johnson and Raveling 1998, Durant et al. 2004, Jónsson and Afton 2009, Chapter 2). Larger geese have greater total daily energy requirements, but smaller-bodied geese have higher mass-specific metabolic rates (Aschoff and Pohl 1970, Miller and Eadie 2009). This places a higher nutritional demand on smaller geese such that they forage more selectively (Durant et al. 2004). In contrast, larger geese can better process more fibrous material (Bruinzeel et al. 1997, Durant 2003) and use more diverse forage resources (Owen 1980). Because of their relatively high energy demands and nutrient requirements, smaller geese may need to compensate physiologically or behaviorally, such as faster food processing rates, reduced retention times (Karasov 1990, McWilliams 1999), or increased time spent foraging (Gawlick and Slack 1996, Jónsson and Afton 2009, Chapter 2). Thus, body size is associated with specific energetic demands on geese and will differentially influence how they satisfy daily food requirements.

Differences in nutritional requirements of herbivores associated with variation in body size can influence habitat use, resource partitioning, and distribution across the landscape (Dement and Van Soest 1985, Belovsky 1997, Cromsigt et al. 2009, Hopcraft et al. 2012). Larger geese can use a wider range of foraging habitats (Owen 1980), but because of their greater total energy requirements, larger geese would be expected to limit their energy expenditure (Robbins 2001) and flight distances (Møller 2009). Thus, smaller-bodied geese may be able to move more freely within the foraging landscape to exploit dispersed resources (Robbins 2001) or higher quality forage (Durant et al. 2004, Black et al. 2007), while avoiding areas of greater predation risk (Inger et al. 2006). Intake rates of smaller geese are more affected by changes in sward height and standing crop biomass (Durant et al. 2003, 2004; Heuermann et al. 2011), so when coupled with nutritional limitations, smaller geese should be more responsive to changing forage availability (Tinkler et al. 2009). Additionally, smaller body size may be advantageous for exploiting short grass more efficiently during winter, when both grass height and day length are short (Johnson and Raveling 1998). Within grass habitats, smaller geese forage more efficiently than larger geese when feeding on short sward heights (Durant et al. 2003, 2004) and exhibit extreme selectivity for food patches (Black et al. 2007).

Despite the relatively large influence that body size has on goose wintering ecology, few studies have specifically addressed how differences in body size may translate into differential use of the foraging landscape. To determine habitat use and preference, methods such as radio telemetry, which provide unbiased sampling of individuals and equal detection probabilities of individuals in all habitats, are important to reduce survey and observer bias (Bibby et al. 2000). Most studies of habitat use or commuting distance in geese have focused on a single species (*e.g.*, Raveling 1969a, Giroux and Patterson 1995, Hill and Frederick 1997, Ackerman et al. 2006). Those studies that have compared goose species of different body size used resightings of flocks or neck-collared individuals (*e.g.*, Havel and Jarvis 1988, McWilliams and Raveling 1998). A study using radio-telemetry to sample movement patterns, commuting distances, and habitat use by closely-related species of geese with significantly different body sizes in a common environment would clarify how foraging ecology and patterns of resource acquisition correlate with body size.

Five subspecies of Canada Geese (*Branta canadensis*) and Cackling Geese (*B. hutchinsii*) of differing body sizes migrate to the Willamette Valley of Oregon and winter sympatrically, providing an ideal study system to investigate how body size is associated with habitat use and movement patterns. Two subspecies of particular interest are Dusky Canada Geese (*B. c. occidentalis*) and Cackling Geese (*B. h. minima*). Dusky Canada Geese (hereafter Duskys) are the least abundant goose in the Willamette Valley and of conservation concern, whereas Cackling Geese (hereafter Cacklers) are the most abundant subspecies and the cause of widespread crop depredation complaints by local farmers. Cacklers are smaller-bodied geese (average body mass = 1,429 ± 200 g; Johnson et al. 1979) that maintain loose family groups but form large, dense flocks to feed (Raveling 1969b). Duskys are larger-bodied (average body mass = 2,936 ± 231 g; Johnson et al. 1979), maintain tight family groups, and feed in relatively small flocks (Johnson and Raveling 1988). We hypothesized that the more than two-fold difference in body size between these two geese, and the associated differences in energy requirements, flock associations, and predation risk, will affect how Cacklers and Duskys use the foraging landscape.

In this study, we used radio-telemetry to study movement patterns, commuting distances, and habitat selection of individual Cacklers and Duskys. We predicted that Cacklers, compared to Duskys, would to be less faithful to roost sites, spend more time in foraging fields, exploit a greater number of fields, use larger fields to reduce predation risk, commute farther to find suitable fields, and be more selective of habitat types used for feeding. Examining how geese of different body sizes use different habitats will not only provide insight into goose foraging ecology, but will also help inform management recommendations for winter conservation planning by focusing on the specific habitat needs of different-sized geese to alleviate crop depredation.

METHODS

Study site

Our study was conducted in the southern Willamette Valley of western Oregon (44º24′N, 123º20′W) and included several roosting complexes for geese on federal wildlife refuges, state wildlife areas, and private lands (Fig. 3.1). Capture and radio-tagging efforts were centered on William L. Finley National Wildlife Refuge (FNWR). FNWR is a 2,155-ha federal refuge established in the 1960s to provide habitat for wintering Duskys. FNWR winters up to 36,000 (average 25,000) Cacklers and Duskys (J. Beall, pers. comm.) and the two main roosts, Cabell marsh and McFadden marsh, are approximately 101 ha. Other public areas where geese roosted include Ankeny NWR (ANWR), Baskett Slough NWR (BSNWR), and Fern Ridge Wildlife Area (FRWA). The one roost site located on private property (Knife River Pond) was a 26 ha flooded gravel pit adjacent to the Willamette River.

The primary types of foraging habitat that we considered were agricultural fields of annual ryegrass (*Lolium multiflorum*), perennial ryegrass (*L. perenne*), perennial tall fescue (*Festuca arundinacea*), mixed pasture, and wheat (*Triticum* sp.); these habitat types differed in time of planting, standing crop biomass, growth rate, and structure. For habitat comparisons, fields of first- and second-year annual ryegrass and all first-year perennial grass fields were considered “young” grasses. Young grasses had been seeded the previous fall and formed dense, even stands of new growth throughout the winter (Hanaway et al. 1999a). Perennial grasses, or “mature” grass, are re-seeded every 2–15 years, form tufted stands with distinct, separated rows (Hanaway et al. 1999b, c), have much higher standing crop biomass (mean ± SE; 653 kg ha^{-1} ± 135 vs. 117 ± 35 kg ha^{-1}), taller grass height (9.8 ± 0.7 cm vs. 5.4 ± 0.4 cm), and include more dead organic material (green vs. dead material ratio: 4.5:1 vs. 0.16:1) compared to young grasses (Chapter 4). Pasture typically included a mixture of the ryegrasses, fescue, orchard grass (*Dactylis glomerata*), timothy grass (*Phleum pretense*), and clover (*Trifolium* sp.; Ogle et al. 2010).

Approximately 839 ha of FNWR were cooperatively farmed during our study to provide foraging habitat for geese, 580 ha of which was young grasses, 187 ha was mature grasses, and 72 ha was pasture. Privately-owned agricultural fields surround FNWR, and geese also used these for foraging. During 2005–2007, lands occurring within a 10-km radius of FNWR consisted of 27,749 ha of cropland of which 81% was grass seed (59% young grasses; 22% mature grasses), 16% mixed grass pasture/hay, 0.5% wheat, and 16.3% other crops (Mueller-Warrant et al. 2011). In 2008 and 2009, the same area included 76% grass seed (47% young grasses; 29% mature grasses), 9% mixed grass pasture/hay, 14% wheat, and 1.5% other crops (G. Mueller-Warrant, unpubl. data).

Capture and marking

We captured all geese during fall and winter using baited rocket nets on FNWR. During year one (2007–2008), Cacklers were captured in mid-November 2007 and Duskys were captured in January and mid-February 2008. In year two (2008–2009), Cacklers were captured in January 2009 and Duskys were captured in December 2008. We determined age and sex of all captured geese through cloacal examination. In year one, 35 adult male Cacklers and four adult male and female Duskys were radio-tagged by affixing radio transmitters (Advanced Telemetry Systems, Inc., Isanti, Minnesota, USA) to black, unnumbered neck collars (Spinner's Plastics, Springfield, Illinois, USA). In year two, 33 adult male and female Cacklers, and 21 adult male and female Duskys were radio-tagged in similar fashion. Cackler radio transmitters were 30 g in year one and 27 g in year two. Dusky radio transmitters were 35 g. Transmitter life was 180 days for Cacklers and 160 days for Duskys. Radios for Duskys in year one were programmed with a duty cycle to shut off on 15 May (after birds had left Oregon) and reactivate on 1 December after they had returned the following fall. We marked all geese with a standard United States Geological Survey metal leg band and released each bird within two hours of capture at the capture site. During the first three weeks after release, we observed birds to determine if all males and females could be considered independent samples (*i.e.*, that we had not unknowingly marked a mated pair). A bird was considered independent if it was not consistently associated with another marked bird of the opposite sex in the same flock on multiple occasions.

Tracking

We tracked geese primarily from trucks equipped with two 4-element yagi antennas and a null-peak system (Advanced Telemetry Systems, Inc.). We attempted to locate individual birds two to four times per week on night roosts and six times per week in feeding fields. Our diurnal feeding field locations were split into three time blocks (morning, sunrise–1100; afternoon, 1100–1500; and evening, 1500–sunset). Field locations were considered independent between time blocks if separated by more than two hours. If a marked goose was recorded using a public area throughout a given day, we assumed the goose would be roosting at that site. In most cases (95% for Cacklers; 77% Duskys), we confirmed habitat use from visual observation of the flock or collared goose. In the remaining cases, we triangulated the position of geese using Program LOCATE (Pacer Computer Software, Nova Scotia, Canada). When geese were triangulated, we plotted field location on a map and determined habitat type from known crop distribution maps, landowner information, checking the site at a later date, or the designation was unknown. We recorded habitat types as young grass, mature grass, mixed pasture, winter wheat, unknown, or roost.

Data analysis

We considered movements at landscape and roost complex spatial scales. At the landscape scale, fidelity to a roost complex was first summarized as the percent of radio-marked geese that moved between roost complexes and the number of times such movements occurred. We calculated this metric for the entire winter and separately for each of three winter periods (early winter, mid-winter, and late winter) that were defined based on changes in abdominal profile indices (API). Early winter (30 November–14 December) was defined as the period when API scores increased, mid-winter (15 December–14 February) was when API scores decreased, and late winter (15 February through April) was when API scores increased again (Appendix A). Results are presented as the average number of movements per bird-day because winter periods differed in length and the number of radio-marked birds varied among periods. We used a log-linear model to test if the percent of roost switches differed from what was expected within a winter period. Expected values were the proportion of total bird-days that a winter period represented.

We also summarized movement patterns relative to the hunting season. The hunting season in the Willamette Valley was split into three hunting periods with closures between these periods. Hunting Period 1 was 16 days from mid-October to early November, Period 2 was 58 days from late November to mid-January, and Period 3 was 23 days from early February to the first weekend in March. A 12- and 26-day hunting closure follow Periods 1 and 2, respectively. We used a log-likelihood contingency table to test if the percent of roost switches differed from what was expected based on hunting (Periods 1, 2, or 3) vs. non-hunting (closures between Periods 1, 2, and 3, plus after the end of hunting season) in mid-winter and late winter periods. We predicted that birds would be more likely to change roost complexes on non-hunting days (Humburg et al. 1985); thus, we used the proportion of non-hunting days during mid-winter and late winter periods as the expected proportion of movements between roosts.

At the scale of the roost complex, we compared how commuting distance varied by species. Commuting distance was calculated as the linear distance from a night roost to feeding fields and was measured using ArcGIS 9.3 (Environment Systems Research Institute, Redlands, CA). Only one measure of commuting distance was calculated per individual goose per day; thus, if a goose was located in multiple fields during a day, commuting distance was calculated as the field farthest from the roost. We used a mixed linear model (Proc MIXED, SAS version 9.1, SAS Institute, Inc., Cary, North Carolina, USA) to compare how commuting distance varied by species and how species differences were influenced by field location, winter period, and hunting period. Each bird was treated as a repeated measure, and year was included as a random variable. Fields were categorized as either public or private lands. For commuting distance, values were expressed as $\bar{x}$ ± SE based on least squares means. Multiple comparisons were made using Tukey-Kramer multiple comparisons.

We used ArcGIS to quantify the number of fields used by each radio-tagged Cackler and Dusky and compared the mean number of fields used with a two-sample t-test (Proc TTEST, SAS version 9.1). Values are expressed as $\bar{x}$ ± SE. We also measured field size to the nearest ha in ArcGIS 9.3 by delineating field boundaries and creating polygons with calculated area based on a digital orthoquad of the Willamette

Valley coupled with telemetry locations. Field size use was compared between Cacklers and Duskys with a two-sample t-test of mean field size (Proc TTEST, SAS version 9.1). Values are expressed as $\bar{x}$ ± SE with the associated minimum and maximum values.

Additionally, we used a log-linear analysis of categorical data based on saturated models (Proc GENMOD, SAS version 9.1) to compare habitat use between species (Erickson et al. 2001). We analyzed use based on three separate models: 1) use of all feeding habitats combined versus the roost for each species throughout the winter; 2) use of only feeding habitats (excluding the roost) for each species throughout the winter, with perennial grass habitats combined; and 3) use of public or private land throughout the winter and during hunting or non-hunting periods for each species.

Finally, using log-linear analysis, we compared habitat use by Cacklers and Duskys with habitat availability (Erickson et al. 2001). We defined availability by creating a circular area around the central roost at Finley NWR with a radius that contained a minimum of 75% of all fields used off-refuge for each species (10-km radius for Cacklers, 5-km radius for Duskys). We made comparisons based on a model for the entire winter, as well as separate models for each winter period. The offset variable was the natural log of the proportion of available habitat. Selection ratios with 95% confidence intervals were generated for each habitat type (Erickson et al. 2001). Selection ratio confidence intervals that were below 1 indicated avoidance, above 1 indicated preference, and overlapping 1 indicated no preference. We divided the values of two selection ratios to assess the comparative magnitude of preference or avoidance for one habitat over another (Erickson et al. 2001).

RESULTS

In year one of the study, 13 radio-tagged Cacklers were killed by either Bald Eagles (*Haliaeetus leucocephalus*) or hunters before contributing significantly to the data set; in year two 12 radio-tagged Cacklers were killed. Therefore, the sample for analysis was 22 Cacklers in year one and 21 Cacklers in year two. All surviving birds were socially independent. The sample size of surviving Duskys was three in year one and 17 in year two. The ability to locate geese differed between species. Over the duration of both study years, 33 ± 1% of Cacklers were located at least once per day versus 80 ± 3% of all Duskys. Over the two study years, we obtained 1,601 locations of Cacklers and 1,618 locations of Duskys.

Cacklers moved more frequently among roosting complexes than did Duskys. Over both study years combined, 74% of Cacklers changed their roost complex at some point during the season. In contrast, no Duskys changed their roost complex; however, in year two, one adult male Dusky tagged in year 1 returned to winter in a different geographic area than in year one (Sauvie Island Wildlife Management Area; 45°14′N, 122°48′W). Of those Cacklers that moved between roosts, 31% changed their roost complex once, 34.5% changed twice, and 34.5% changed three to five times. The percentage of total switches between roosting complexes that occurred during early winter was lower than expected (2.6% vs. 5.7%, n = 330 bird-days), during mid-winter was higher than expected (59.7% vs. 46%, n = 2,666 bird-days), and during late winter was lower than expected (37.7% vs. 48.3%, n = 2,795 bird-days; χ^2= 6.26, P = 0.044). During the mid-winter period, Cacklers switched roosts more than expected (63% vs. 45%) during the break between hunting periods (χ^2= 6.3, P = 0.01). During late winter, Cacklers switched roosts at a similar rate after the end of the hunting season (64%) compared with before (65%).

Cacklers commuted farther from roost sites to foraging areas than Duskys in general (5.2 ± 0.3 vs. 3.0 ± 0.4 km), but the pattern differed depending on whether birds were feeding on public or private lands ($F_{1,1886}$ = 63.3, P < 0.001). When geese foraged on public lands, commuting distance was similar between species (P = 0.12; Cacklers: 2.2 ± 0.3 km, n = 472 locations; Duskys: 1.2 ± 0.4 km, n = 668). When foraging on private lands, however, Cacklers commuted significantly farther and showed a wider range of movements (8.2 ± 0.3 km, range = 0.8 to 28.1 km, n = 506 locations) compared to Duskys (4.9 ± 0.4 km, range = 0.3 to 8.7 km, n = 325). Commuting distances decreased after early winter for both species ($F_{2,1886}$ = 2.03, P = 0.13; Fig. 3.2). Hunting influenced commuting distances differently between the two species ($F_{2,1886}$ = 6.37, P = 0.002; Fig. 3.2). Cacklers commuted farther during the hunting break, whereas Duskys had similar commuting distances during hunting and non-hunting periods.

Cacklers were less likely to be found on public lands than Duskys (57% vs. 74%; χ^2 = 46.9, P < 0.001). However, use of public lands by Duskys decreased more steeply across the winter (χ^2 = 123.9, P < 0.001), so that during late winter Cacklers and Duskys used public lands to a similar extent (Fig. 3.3). Each species' use of public lands during hunting vs. non-hunting periods differed ($\chi^2 = 164.5$, $P < 0.001$). Cacklers decreased their use of public lands during the hunting break, whereas Duskys increased their use of public lands during the hunting break. Cacklers used public lands equivalently during hunting and after the end of hunting, but Duskys used public lands less during hunting and decreased their use after the end of hunting (Fig. 3.3).

Over the entire winter period, Cacklers were found more often in grass foraging habitats (90%) compared to Duskys (60%; $\chi^2 = 46.9$, $P < 0.001$; Fig. 3.4). Individual Cacklers used an average of 16.4 ± 1.3 fields throughout a season, whereas individual Duskys used 9.1 ± 1.0 fields ($t_{39} = 2.02$, $P < 0.001$). Average field size used by Cacklers when off refuge (37.1 ± 2.4 ha; range: 1.1–176.8 ha) was not significantly different from that of Duskys (33.5 ± 5.6 ha; range: 1.0–100.4 ha; $t_{212} = 0.55$, $P = 0.56$). Cacklers always used the roost less than Duskys, especially during early winter (22% less) and mid-winter (44% less), but Duskys reduced their use of the roost more drastically from mid-winter to late winter ($\chi^2 = 23.8$, $P < 0.001$). Cacklers were found on the roost 9% of the time during early winter ($n = 119$ locations), 17% of the time during mid-winter ($n = 631$), and 5% of the time during late winter ($n = 851$). Duskys spent 31% of the time at the roost during early winter ($n = 29$ locations), 61% during mid-winter ($n = 965$), and 8% during late winter ($n = 624$).

Throughout the winter, Cacklers preferred young grass and either avoided or used in proportion to availability mature grass, pasture, and winter wheat (Table 3.1). In contrast, Duskys preferred both pasture and young grass and avoided mature grass and winter wheat (Table 3.1). The degree of selection varied among periods of the winter (Table 3.2). During early winter, the preference by Cacklers for young grass was only slight, and they used mature grass in proportion to its availability (Table 3.2). Cackler preference for young grass increased considerably by mid-winter (2–6 times more preferable than mature grass; 1.3–3.5 times more preferable than pasture) and late winter (1.5–2.7 times more preferable than mature grass; 1.2–2.4 times more preferable than pasture; Table 3.2). Cacklers avoided mature grass during mid- and late winter, and showed no preference for pasture during any winter period (Table 3.2). In early winter, Duskys showed no preference for any habitat type (Table 3.2). In mid-winter, Duskys preferred pasture relative to other habitat types (1.1–1.8 times more preferable than young grass; 3.2–3.5 times more preferable than mature grass; Table 3.2) and preferred young grass relative to mature grass (1.8–3.3 times more preferable than mature grass). In late winter, Duskys showed no relative preference for pasture or young grass (0.9–1.6 times; Table 3.2), but avoided mature grass (4.9–12.0 times less preferable) and winter wheat (2.1–4.3 times less preferable).

DISCUSSION

Movements

Cacklers and Duskys differed in roost site fidelity and commuting distances in agreement with *a priori* predictions, lending support to the hypothesis that body size influences movement patterns in wintering geese. Duskys were faithful to the original roost site where captured, whereas Cacklers frequently changed roost sites. Cacklers were more difficult to track off of public land and, as the total search area expanded with increasing distance from the roost, we were less likely to detect geese that made large daily commutes to foraging areas. Thus, the average commuting distance and average number of fields used by Cacklers is likely biased low and the true discrepancy between the two goose species larger than we report. The pattern with commuting distance and body size in our study fit the pattern observed for geese in general, summarized from other studies (Fig. 3.5).

Differences in commuting distances between goose species were consistent with our prediction based on the energetics of animal movements (Schmidt-Nielsen 1972, Calder 1984, Eisenberg 1990). The mass-specific energy costs of locomotion decline with increasing body size (Schmidt-Nielsen 1972); however, shorter flight distances of Duskys are disproportionately costly because energetically expensive activities (take-off, climbing, and the associated acceleration) comprise a larger proportion of total flight costs (Norberg 1996, Nudds and Bryant 2000, Powell and Engelhardt 2000). Because Cacklers can move around the foraging landscape at lower energetic cost and at greater distances from the roost, they are more likely to change foraging locations (van Gils and Tijsen 2007); Cacklers, which traveled farther from the roost to forage, also exploited a greater number of fields. In contrast to Cacklers, Duskys remained in small family groups that did not need to commute as far to find suitable feeding sites.

Physiological effects of body size were not likely the only body size related factor influencing movement patterns and contributing to differences between species. Cacklers are the focus of recreational waterfowl hunters, while Duskys are largely protected from harvest (Pacific Flyway Council 1998). Hunting generally results in movements back to refuge areas (Béchet et al. 2004) and shortens commuting distances (Humburg et al. 1985). An experimental ban on hunting in Denmark resulted in geese spreading out more (Madsen 1993); during the break in hunting in our study, Cacklers changed roost complexes more often, commuted greater distances, and were more likely to be found foraging on private lands off the refuge. In contrast to Cacklers, Dusky commuting distances did not change between hunting and non-hunting periods, and they used refuge areas less during the hunting season. The much strong sociality and larger group sizes of Cacklers likely makes it essential for them to range more widely and forage at more sites (Johnson and Raveling 1988). Additionally, larger flocks of Cacklers are likely hazed more frequently by farmers, which may have added to increased movements (Hamilton 1971).

Patterns in commuting distance may also be influenced by resource depletion (Vickery et al. 1995, Percival et al. 1996, Rowcliffe et al. 2001, Tinkler et al. 2009) or differential response to predation pressure. Food abundance on the refuge declined from early winter into mid-winter (Chapter 4), which may explain the decreased use of refuge fields from early winter to mid-winter by both Cacklers and Duskys. While use of refuge fields declined, Cacklers actually commuted shorter distances during mid-winter, which may reflect avoidance of hunters (Humburg et al. 1985, Béchet et al. 2004, Spragens 2010). However, once hunting pressure stopped during the hunting break, Cacklers commuted farther while Duskys were not affected. Alternatively, some Cacklers changed roost complexes, which could represent a strategy to capitalize on new food resources while avoiding high-risk habitats further from any single roost

(Inger et al. 2006). When food resources replenished during late winter (Chapter 4) and hunting ended, Cacklers commuted shorter distances.

Habitat use and selection

Consistent with predictions based on relatively higher mass-specific energy requirements, Cacklers spent more time in feeding fields. Cacklers never used the roost more than 17% of daylight hours during any winter period, whereas Duskys spent over 50% of the time on roosts during the early winter and mid-winter periods. Duskys may have foraged on alternative foods available at the roost (*e.g.*, tubers in marshes) to offset their reduced time spent grazing and, in conjunction, reduced flight costs to lower total daily energy expenditure (A. Mini, pers. obs.). By late winter, both Cacklers and Duskys increased the proportion of time spent in fields, most likely related to energy acquisition for pre-migratory tissue synthesis (Ebbinge et al. 1975, McWilliams and Raveling 2004, Black et al. 2007). During late winter, Cacklers required 11–14 hours of foraging time to satisfy their daily energy requirements (Appendix D) and Cacklers spent 95% of daylight time in fields. Duskys required 6–14 hours of foraging time per day during late winter, and spent a significant amount of time (92%) in fields, contrary findings for Greater White-fronted Geese (*Anser albifrons*; 2.2 kg; Ely 1992). However, Greater White-fronted Geese were using highly-digestible, energy-dense food resources [*e.g.*, rice (*Oryza sativa*) or potatoes (*Solanum* sp.)] to build pre-migratory fat reserves, whereas Duskys deposited pre-migratory fat reserves on a diet of green forage, which requires 6–14 hours of feeding, depending on intake rate (Appendix D).

Contrary to our prediction, the average size of fields used for foraging was similar between the two species. Historically, Duskys used smaller fields than Taverner's Cackling Geese (*B. h. taverni*; Havel and Jarvis 1988), a goose of intermediate body size, and anecdotal observations by neck-collar observers suggested that Duskys used smaller fields than Cacklers (USFWS, unpubl. data; ODFW, unpubl. data). Differences between our results and earlier observations may reflect changing conditions for geese in the Willamette Valley. Recreational hunting occurs over a longer period now than 30 years ago, and hazing is now a comparatively common practice by farmers on private lands. One response to increased levels of hazing disturbance may be reduced flock size, which decreases flock detectability. Hazing was associated with a reduction in the average size of fields used by foraging Pink-footed Geese (*A. brachyrhyncus*) from 50 ha to 17 ha (Jensen et al. 2008). Furthermore, an increasing number of Cacklers throughout the Willamette Valley are being observed in urban habitats (A. Mini, pers. obs.). The safe-habitat hypothesis suggests that predation risk, either anthropogenic or natural, is reduced in urban areas (Tomialojc 1982, Valcarcel and Fernández-Juricic 2009). We hypothesize that the combination of hunting, landowner disturbance, and predation risk from an increasing population of Bald Eagles (USFWS, unpubl. data) may be driving both a change in field size and in the use of urban habitats by Cacklers in the Willamette Valley during winter.

Habitat preferences by Cacklers were better defined than those of Duskys, confirming that Cacklers are more specialized grazers of short green forage (Johnson and Raveling 1988). Cacklers preferred foraging in fields of young grass during all periods of the winter. Cacklers avoided fields of mature grasses in all periods except early winter. During early winter, young grass was just beginning to emerge and many of the recently-planted fields were bare of vegetation (Chapter 4); these fields would be unsuitable for foraging Cacklers (Gill 1996), and this explains the similar preference for fields of mature grass during early winter. In contrast, Duskys showed changing preferences for particular foraging habitats across the periods of the winter, suggesting that Duskys are more flexible in their habitat use (Owen 1980, Ely and Raveling 2011). Duskys showed no preference for any habitat during early winter, preference for two habitats (pasture and young grass) during mid-winter, and preference for young grass in late winter. No previous study has specifically studied habitat use of three green forage options during winter, but other studies have compared habitat use of winter wheat vs. pasture (Therkildsen and Madsen 2000), clover vs. perennial ryegrass (van Liere et al. 2009), and grains vs. grasses (Ely and Raveling 2011). Our results are consistent with several previous studies reporting much higher habitat selectivity in geese smaller than 2.2 kg (Patton and Frame 1981, Summers and Grieve 1982, Markkola et al. 2003).

Nutrient content of food resources often influences selection of foraging fields by geese, but habitat preferences based on foraging efficiency may be a more important factor in our study (Durant et al. 2003, 2004; Therkildsen and Madsen 2000; Heuermann et al. 2011). Cacklers exhibited a strong preference for young grass, despite the fact that the protein content of mature grass was higher during late winter

(Appendix C). Digestibility was greater, however, for young grass (Appendix C), which implies lower crude fiber content, less tensile strength, and increased handling efficiency (Hassall et al. 2001). Cacklers forage most efficiently in swards with simple plant structure (grass at low standing crop biomass; Heuermann et al. 2011) and peck fastest in young grass (Chapter 2). Thus, Cacklers may have higher foraging efficiencies and intake rates in young grass (Black et al. 2007), as evidenced by the preference for this habitat during mid-winter and late winter. In contrast, Duskys preferred pasture during mid-winter, when forage biomass and height were reduced in grass seed fields, as their longer bills hamper foraging efficiency on short grass (Heuermann et al. 2011).

Farming on the refuge to produce the forage preferred by geese may attract geese to these protected areas. Ideally, a mixture of young grass and pasture would provide for the needs of both Cacklers and Duskys throughout the winter. However, ensuring that a sufficient supply of forage resources is provided to support geese in the refuges would be essential to reducing grazing pressure on private lands that surround the refuges. Estimating how many geese of different body sizes the refuges can support (*e.g.*, refuge carrying capacity) would be important to determine how farming different mixtures of habitat preference could support a wintering goose population.

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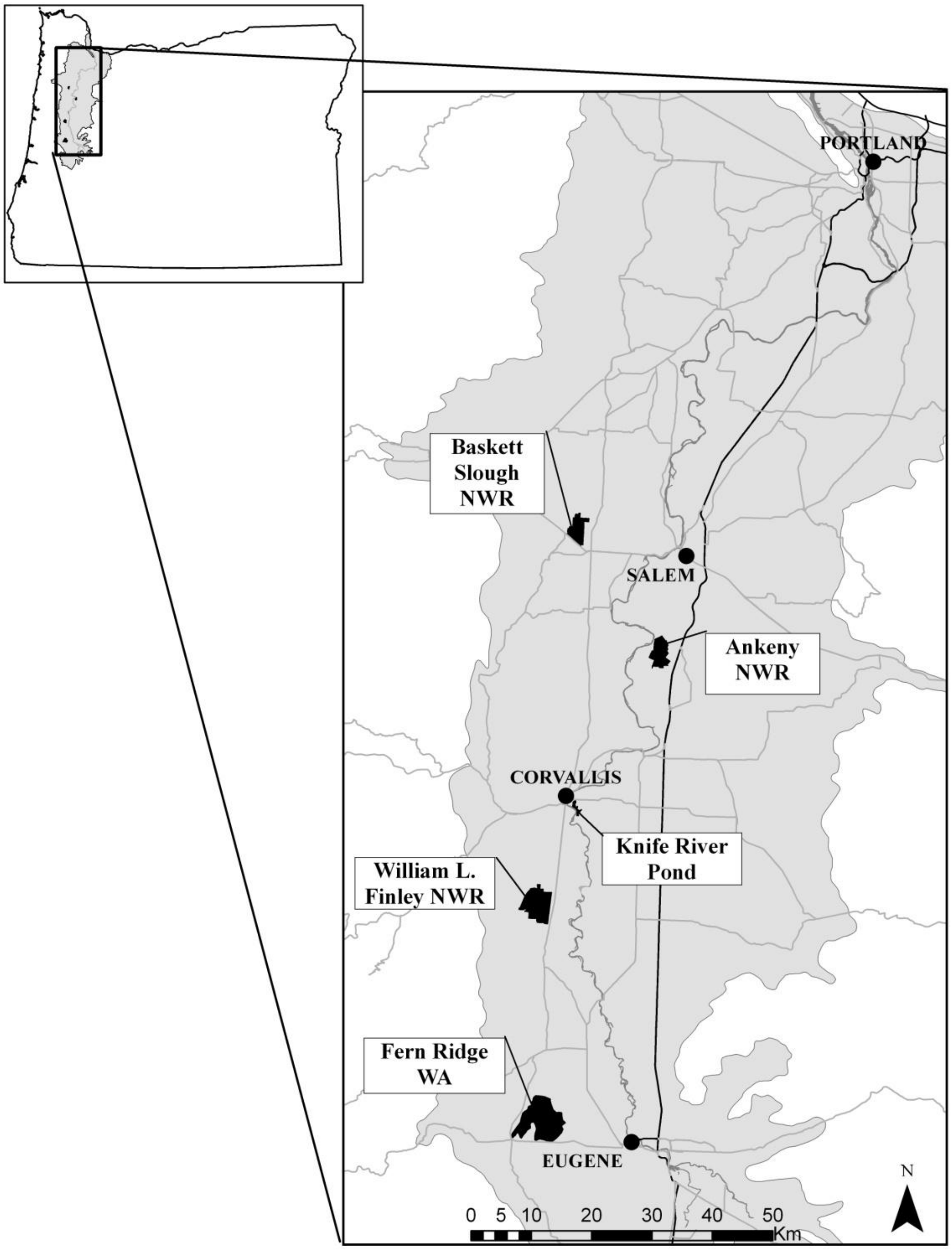

Figure 3.1. Map depicting goose roosting areas located on federal, state, and private lands during the study in the Willamette Valley of Oregon (light gray shaded area). Federal roosting areas include William L. Finley NWR, Ankeny NWR, and Baskett Slough NWR. The state roosting area is Fern Ridge WA. The private roosting area is Knife River Pond. Black circles label major Oregon cities in the study area.

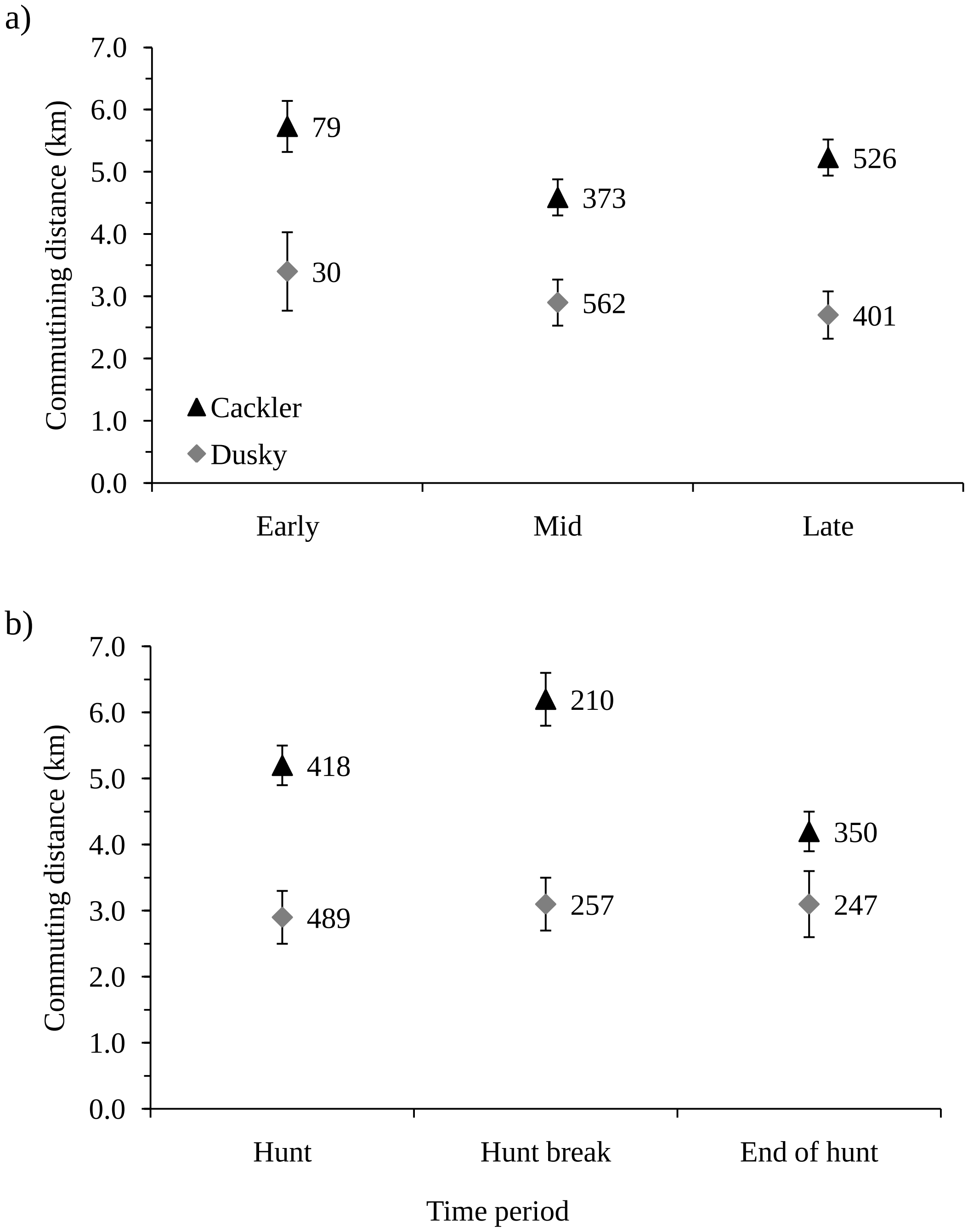

Figure 3.2. Commuting distance of Cackling Geese and Dusky Canada Geese during (a) early winter (30 November–14 December), mid-winter (15 December–14 February), and late winter (15 February–15 April) and (b) during hunting periods, hunting breaks, and after the end of hunting in the Willamette Valley, Oregon during the winters of 2007–2008 and 2008–2009. Values are least squares mean ± SE; *n* represents the number of locations.

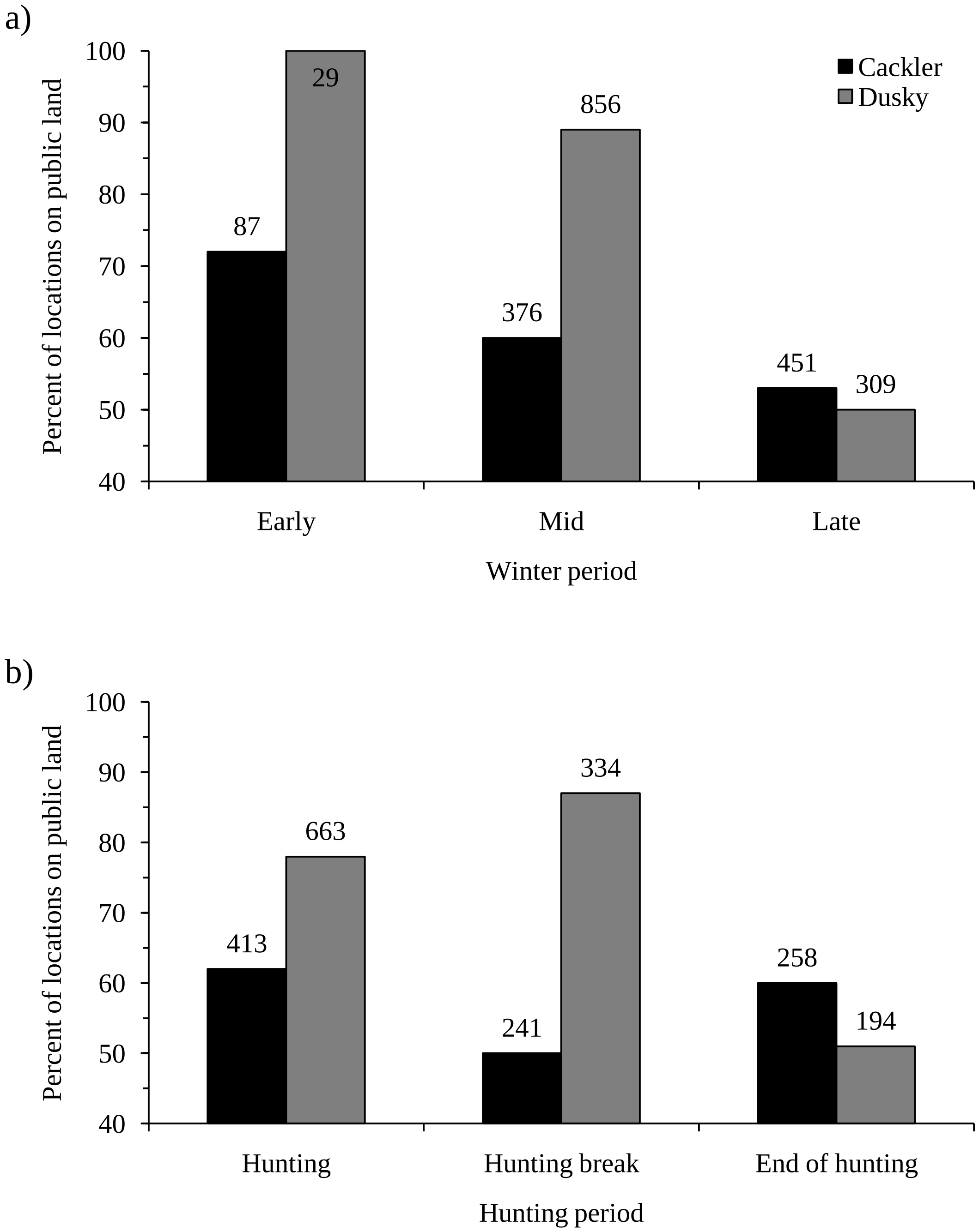

Figure 3.3. Use of public land compare to private lands (%) by Cackling Geese and Dusky Canada Geese wintering in the Willamette Valley, Oregon in the winters of 2007–2008 and 2008–2009 during (a) early winter (30 November–14 December), mid-winter (15 December–14 February), and late winter (15 February–15 April), and (b) during hunting periods, hunting breaks, and after the end of hunting. Values indicate sample sizes.

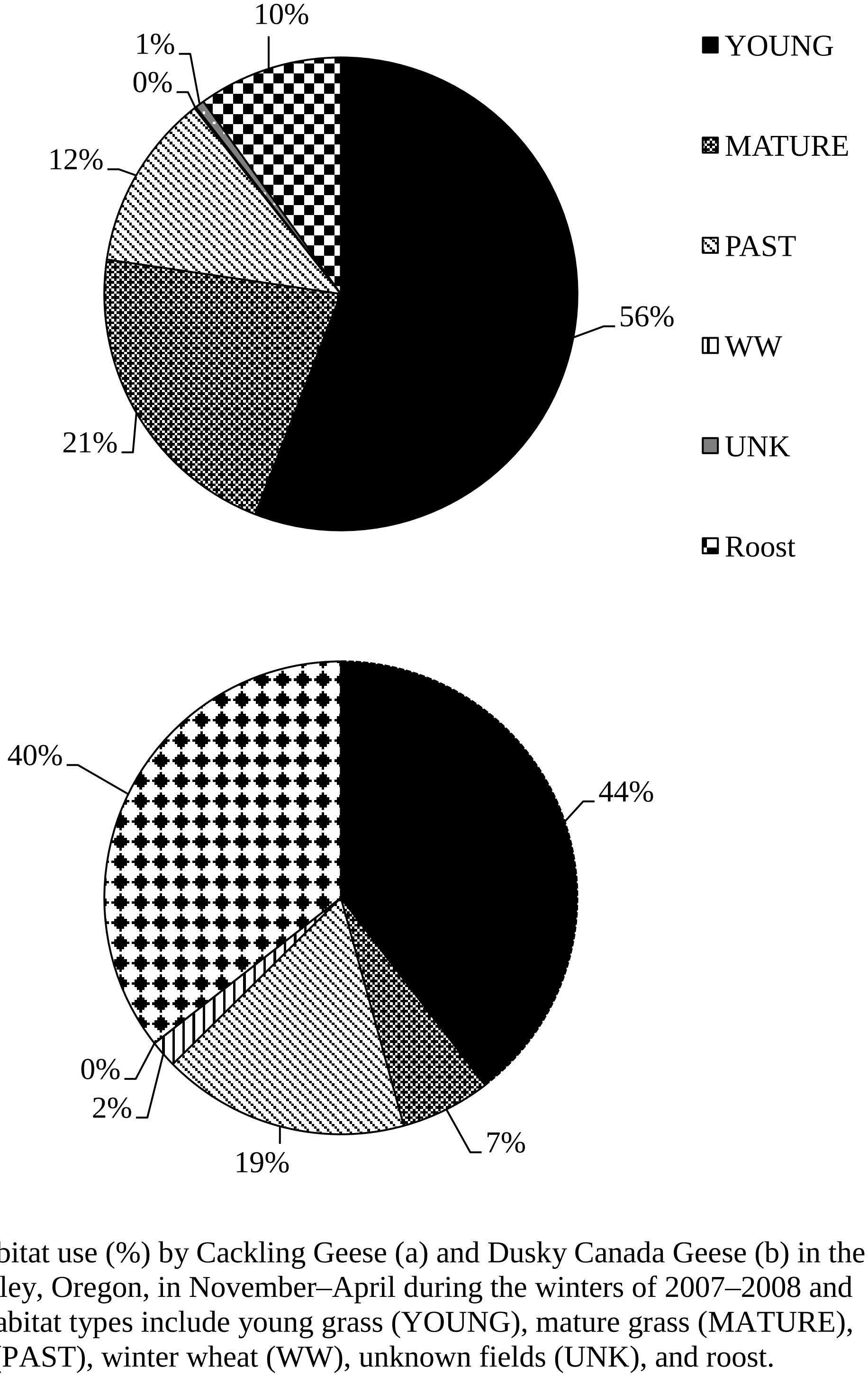

Figure 3.4. Habitat use (%) by Cackling Geese (a) and Dusky Canada Geese (b) in the Willamette Valley, Oregon, in November–April during the winters of 2007–2008 and 2008–2009. Habitat types include young grass (YOUNG), mature grass (MATURE), mixed pasture (PAST), winter wheat (WW), unknown fields (UNK), and roost.

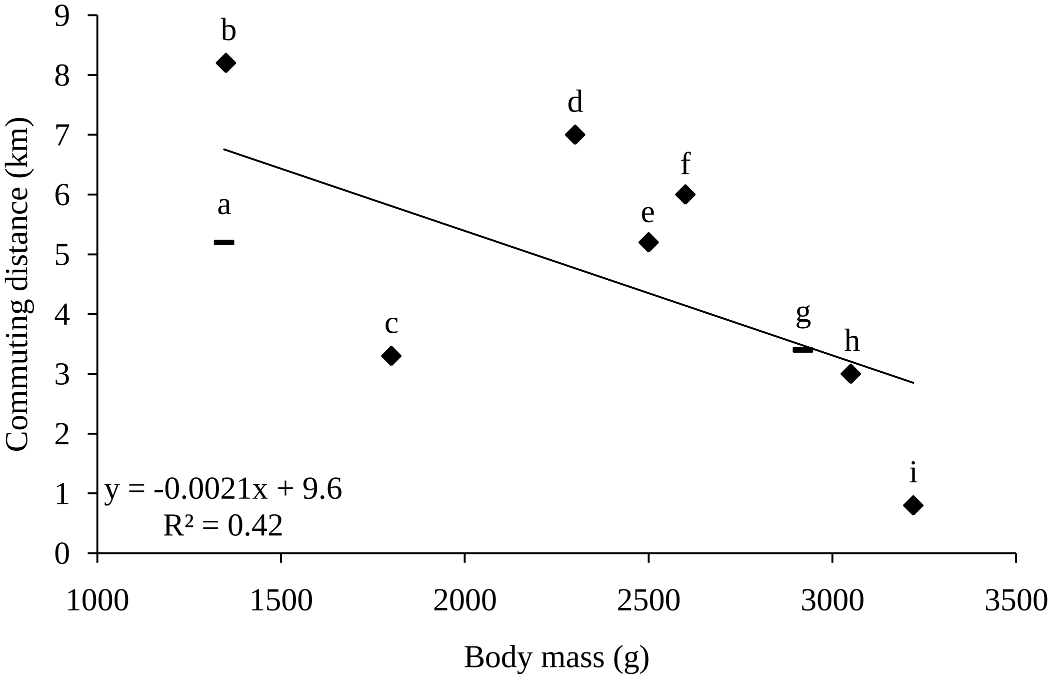

Figure 3.5. Commuting distance (km) between roosting sites and foraging areas as a function of body mass in nine different goose species and subspecies. Letters above symbols indicate species and study: a. Cackling Geese (*Branta hutchinsii minima*; this study); b. Brent Geese (*B. bernicla*; Summers and Critchley 1990); c. Barnacle Geese (*B. leucopsis*; Owen et al. 1987, Si et al. 2011); d. White-fronted Geese (*A. a. albifrons*; reviewed in Vickery and Gill 1999 [from Percival 1996, Hampson et al. 1996]); e. Pink-footed Geese (*A. brachyrhyncus*; Giroux and Patterson 1995, Gill 1996, Patterson et al. 1989); f. Greater Snow Geese (*Chen caerulescens atlantica*; Hill and Frederick 1997); g. Dusky Canada Geese (*B. canadensis occidentalis*; this study); h. Greylag Geese (*A. anser*; Patterson et al. 1989); i. Bean Geese (*A. fabalis*; reviewed in Vickery and Gill 1999 [from Smith et al. 1995]).

Table 3.1. Habitat selection by Cackling Geese (during the winters of 2007–2008 and 2008–2009) and Dusky Canada Geese (during the winter of 2008–2009 only) wintering in the Willamette Valley, Oregon. Use and availability values represent the percent of locations in young grass seed fields (Young), mature grass seed fields (Mature), pasture (PAST), and winter wheat (WW), versus the percent of available habitats within 10 km of Finley NWR for Cackling Geese and within 5 km of Finley NWR for Dusky Canada Geese. SR represents the Wald 95% confidence intervals for selection ratios. Intervals below 1 indicate avoidance, intervals including 1 indicate no preference, and intervals above 1 indicate preference.

	Cackling Geese						Dusky Canada Geese		
	Winter 2007-2008			Winter 2008-2009			Winter 2008-2009		
	Use	Availability	SR	Use	Availability	SR	Use	Availability	SR
Young	68.6	59.7	[1.13, 1.17]	75.2	47.9	[1.55, 1.59]	73.4	53.0	[1.37, 1.40]
Mature	24.4	21.4	[0.92, 1.42]	14.7	28.0	[0.41, 0.67]	8.8	22.1	[0.31, 0.51]
PAST	6.8	15.8	[0.30, 0.62]	9.9	9.2	[0.81, 1.43]	13.9	9.8	[1.16, 1.75]
WW	0.2	0.5	[0.05, 2.74]	0.0	13.4	[NS]	3.9	14.9	[0.19, 0.38]

Table 3.2. Habitat selection in young grass seed fields (Young), mature grass seed fields (Mature), pasture (PAST), and winter wheat (WW) within 10 km of Finley NWR for Cackling Geese averaged over the winters of 2007–2008 and 2008–2009 and within 5 km of Finley NWR for Dusky Canada Geese in the winter of 2008–2009 during early winter (30 November–14 December), mid-winter (15 December–14 February), and late winter (15 February–15 April). Bracketed values represent the averaged Wald 95% confidence intervals for selection ratios; intervals below 1 indicate avoidance, intervals including 1 indicate no preference, and intervals above 1 indicate preference. NS represents non-significant values due to no use. Early represents early winter, Mid represents mid-winter, and Late represents late winter.

	Cackling Geese				Dusky Canada Geese			
	Early	Mid	Late	Availability	Early	Mid	Late	Availability
Young	64.4 [1.02, 1.14]	72.5 [1.52, 1.56]	73.6 [1.37, 1.41]	53.8	40.0 [0.58, 0.97]	70.2 [1.30, 1.35]	77.1 [1.44, 1.47]	53.0
Mature	29.9 [0.83, 2.34]	20.6 [0.25, 0.64]	16.8 [0.51, 0.92]	24.7	60.0 [0.86, 8.57]	12.0 [0.39, 0.76]	4.2 [0.12, 0.30]	22.1
PAST	5.7 [0.14, 0.96]	6.9 [0.44, 1.19]	9.5 [0.57, 1.14]	12.5	0.0 [NS]	17.8 [1.36, 2.44]	11.5 [0.88, 1.59]	9.8
WW	0.0 [NS]	0.0 [NS]	0.1 [0.00, 0.04]	7.0	0.0 [NS]	0.0 [NS]	7.1 [0.33, 0.67]	14.9

The Role of Body Size in the Foraging Strategies and Management of Avian Herbivores: A Comparison of Dusky Canada Geese (*Branta canadensis occidentalis*) and Cackling Geese (*B. hutchinsii minima*) Wintering in the Willamette Valley of Oregon

Chapter 4

A BIOENERGETIC APPROACH TO THE CONSERVATION AND MANAGEMENT OF OVER-WINTERING GEESE IN THE WILLAMETTE VALLEY, OREGON

Anne E. Mini and Bruce D. Dugger

ABSTRACT

The abundance of Canada Geese (*Branta canadensis*) and Cackling Geese (*B. hutchinsii*) over-wintering in the Willamette Valley of Oregon has led to increasing conflicts with agriculture as geese graze on economically-valuable grass seed fields. Accordingly, the capacity of available public lands to support the energy requirements of existing over-winter populations of geese needs to be evaluated. We estimated carrying capacity of federal lands for Dusky Canada Geese (*Branta c. occidentalis*) and Cackling Geese (*B. h. minima*) using a daily ration approach during three winter periods (early winter, mid-winter, and late winter). We collected data regarding forage supply (available habitat acreages and forage biomass availability in each habitat) and food requirement (daily food requirement based on predictions of allometric equations and target population size for each goose species). Regrowth rates of grass declined from early to mid-winter, and increased from mid-winter to late winter ($F_{2,23} = 2.25$, $P = 0.14$). During mid-winter, the fewest geese (16,164 Cacklers; 11,066 Duskys) could be supported on currently-available public lands; during late winter, the greatest number of geese could be supported (34,509 Cacklers; 27,654 Duskys). Even with improvements to existing foraging habitat or providing alternative forages, our model predicts that a large area of additional public lands (14,691 ha) would be required to support the over-wintering population of geese (340,000 geese). Although the forage to support all these geese on public lands in the Willamette Valley is far from attainable, total availability of food energy in the Willamette Valley (on public and private lands) is not limiting.

INTRODUCTION

The distribution and abundance of geese wintering in the Willamette Valley of Oregon has changed significantly over the past decades (Pacific Flyway Council [PFC] 1998). The Willamette Valley, as part of the Pacific Flyway, has historically been an important wintering area for a small population (20,000–25,000) of Dusky Canada Geese (*Branta canadensis occidentalis*). Beginning in the 1970s, other populations of Canada and Cackling geese that primarily over-wintered in California became winter residents in the Willamette Valley (Simpson and Jarvis 1979, Raveling and Zezulak 1992, PFC 1998). Taverner's Cackling Geese (*B. hutchinsii taverni*) and Lesser Canada Geese (*B. c. parvipes*) increased in numbers in the 1970s after a series of four federal refuges, three in Oregon and one in Washington, were established *c.* 1965 to protect the small population of Dusky Canada Geese (hereafter Duskys; PFC 1998). Concurrently, a large Cackling Goose (*B. h. minima*; hereafter Cacklers) population that wintered in California was declined significantly from 400,000 to 26,000 individuals due to over-harvest and severe drought (1986–1992; PFC 1999). Coincidentally, as the Cackler population began to recover in the late 1990s, nearly the entire population relocated from California to the Willamette Valley during winter (PFC 1999). Currently, five subspecies of Canada and Cackling geese winter in the Willamette Valley and the over-wintering populations have increased significantly to a total of over 250,000 geese (PFC 1998, U.S. Fish and Wildlife Service 2011a).

The increased winter goose population in the Willamette Valley of Oregon has resulted in escalating complaints from farmers of agricultural depredation on grass seed crops (PFC 1998). Grass seed crops are the dominant agricultural commodity in the Willamette Valley (Oregon Seed Extension Program 2012). Specific characteristics of grass as an agricultural commodity and geese as foragers make the depredation situation especially problematic. As in most agricultural depredation situations, the spatial distribution of geese, the birds' migratory schedule, and the phenology of crops are all factors in the agricultural conflict (Owen 1990, Moser and Kalden 1992). Geese are central place foragers that feed most intensively within 5–10 km of their night-time roost (Vickery and Gill 1999, Baveco et al. 2011, Chapter 3); in the Willamette Valley, extensive areas of private grass seed fields (Mueller-Warrant et al. 2007) that are of high economic value (Oregon Seed Extension Program 2011) surround these roosting sites. As geese arrive in fall with depleted body reserves following breeding and migration, they forage to replenish reserves and then to maintain energy balance through winter (Owen 1980, Owen et al. 1992). Coinciding with goose arrival, new grass growth begins in the Willamette Valley (Jarvis and Cornely 1988), and young shoots are especially vulnerable to grazing damage (Kahl and Samson 1984, Flegler et al. 1987, Patterson et al. 1989). Although late winter grazing by sheep is a common practice for grass seed farmers, by late March producers remove sheep to reduce stress on grass, thereby allowing the necessary growth of vegetation to promote flowering and seed production (Young et al. 1996). However, during late February through April, in preparation for spring migration and breeding, geese become hyperphagic and increase their grazing intensity to increase body condition (Ankney and McInnes 1978, Owen 1980, McLandress and Raveling 1981a, Prop and Black 1998).

One management approach to alleviating farmer complaints is to assure that foraging geese have access to sufficient energy (*i.e.*, forage resources) on publicly owned lands to maintain body condition through winter and store sufficient reserves to complete spring migration (Vickery and Gill 1999, Black et al. 2007, Baveco et al. 2011). However, the present carrying capacity of public lands for geese in the Willamette Valley is currently unknown. Therefore, managers cannot determine how many geese of each subspecies the public lands can support, or how many additional hectares might be needed to meet over-winter energy requirements.

Agricultural depredation complaints are not leveled equally among all five subspecies of geese that over-winter in the Willamette Valley (PFC 1998). Therefore, differences between subspecies in total food demand, which is influenced by body size and population size, should be taken into account for conservation planning purposes (Baveco et al. 2011). Because total daily energy requirements increase with body size (Miller and Eadie 2006), providing for the energy needs of the population of one goose subspecies may not provide for the energy needs of the other four populations. Cackling Geese, primarily of the subspecies *B. h. minima*, congregate in dense foraging flocks (Johnson and Raveling 1988) that extensively graze on private grass seed fields while wintering in the Willamette Valley, and these geese are the main source of farmers’ complaints (PFC 1998). Larger-bodied Canada Geese (*B. canadensis* spp.) generally forage in smaller flocks (Raveling 1969) and are not as much a cause of concern for crop depredation in the Willamette Valley (Clark and Jarvis 1978). Cacklers and Duskys are of particular interest in the Willamette Valley because their body masses differ by a factor of two and have different conservation statuses (PFC 1999, 2008). Duskys are approximately twice as large as Cacklers (2.9 ± 2 kg *vs*. 1.4 ± 2 kg; Johnson et al. 1979), but are relatively uncommon, having a population objective about one-tenth that of Cacklers (10,000–20,000 *vs*. 250,000; PFC 1999, 2008).

In this chapter, we use a bioenergetic approach to estimate the amount of foraging habitat needed to support target populations of geese over-wintering in the Willamette Valley. Specifically, we use estimates of available acreage of foraging habitat, standing stock grass biomass, grass regrowth rates, and food needs of geese to quantify carrying capacity relative to specific management objectives. Our goal was to estimate how much land would be needed to support target populations of geese over-wintering in the Willamette Valley.

METHODS

Study site

Our study was conducted in the Willamette Valley of western Oregon (44º24′N, 123º20′W). We focused the majority of my data collection and bioenergetic modeling on William L. Finley National Wildlife Refuge (FNWR); however, we used information from Ankeny National Wildlife Refuge (ANWR) and Baskett Slough National Wildlife Refuge (BSNWR) to supplement data needs (Fig. 4.1). FNWR is a 2,155 ha federal refuge established in the 1960’s to provide habitat for over-wintering

Duskys. All three federally-owned refuges are cooperatively farmed to provide foraging habitat for geese. Based on flyoff counts, FNWR roosted up to 36,000 Cacklers and Duskys (average ~25,000; J. Beall, pers. comm.), ANWR roosted ~20,000 geese (M. Monroe, pers. comm.), and BSNWR roosted ~25,000 geese (M. Monroe, USFWS, pers. comm.).

Available foraging habitat types for geese in the Willamette Valley differ in the timing of seeding and their growth structure. The primary foraging habitats that geese use are annual ryegrass (*Lolium multiflorum*), perennial ryegrass (*L. perenne*), and perennial tall fescue (*Festuca arundinacea*). For this study, fields of first and second year annual ryegrass and all first year perennial grass fields were considered "young" grasses. Young grass is seeded in fall and forms dense, even stands (Hanaway et al. 1999a). Mature perennial grasses, which were classified as "mature" grass, are 2–15 years old, and form tufted stands with distinct, separated rows (Hanaway et al. 1999b, c). Approximately 767 ha of FNWR were farmed for grass seed production of which 580 ha are young grass and 187 ha are mature grass.

We defined the carrying capacity of our study area as the maximum number of geese that could be supported energetically during each period of the winter (Goss-Custard and Charman 1976, Goss-Custard 1985, Goss-Custard et al. 2002). We used a daily ration approach that took into account forage abundance and forage demand (*sensu* Goss-Custard et al. 2002, Stephens et al. 2003). We divided the over-wintering period into early winter (25 October–15 December), mid-winter (16 December–15 February), and late winter (16 February–1 April for Duskys; 16 February–30 April for

Cacklers) based on patterns observed in abdominal profile index scores (API; Owen 1981) and the different migration chronologies of Duskys and Cacklers. Early winter was defined as a period when API scores increased, mid-winter API scores decreased, and late winter API scores increased again (Appendix A). The majority of Duskys leave the Willamette Valley during the first week of April (Bromley and Jarvis 1993), while Cacklers are present through the end of April (A. Mini, pers. obs.).

Estimating food abundance

Food abundance, or the total biomass available for foraging (kg ha^{-1}), included measurements of standing stock biomass and regrowth rates of grass in grazed fields. We measured standing stock biomass (SSB) and regrowth rates of young and mature grass using a non-destructive sampling procedure during 1 November–15 April in 2005–2006 and 2008–2009. Typically, geese do not graze to the edge of each field due to road disturbances or risk of predation (Vickery and Gill 1999), so we stratified fields into an interior grazed section and an ungrazed border (approximately 10 m in width). We established five to six transects through the interior grazed section of a field and systematically marked out 20–30 1-m^2 plots. We randomly assigned half the plots as “grazed” and used these to measure SSB and assigned the other half of the plots to an “exclosure” treatment to measure regrowth rates of grass after grazing. Exclosures, which kept geese from grazing the plot, consisted of 30-cm tall dark green welded wire, zip-tied to stakes placed at the corner of each plot.

At each plot in a field, we measured SSB or regrowth using a combination of reflectance values collected from a spectroradiometer (FieldSpec Handheld Pro®, Analytical Spectral Devices, Inc., Boulder, Colorado, USA) and grass height (Summers 1990; n = 16 young; n = 16 mature fields). We took measurements between 10:00 and 14:00 PST, when the sun was highest in the sky, in the absence of heavy precipitation, and when cloud cover was $\leq 50\%$ (Summers 1990). After taking a reflectance reading, we measured grass height to the nearest 0.5 cm by sliding a polystyrene disc (area = 275 cm^2) with a hole in the center down a measuring stick flush with the ground (Ydenberg and Prins 1981, Summers 1990, Stewart et al. 2001).

We calibrated this non-destructive sampling procedure by destructively sampling 25 1-m^2 plots in a field (n = 2 young grass fields; n = 3 mature grass fields). After measuring reflectance and grass height, we clipped all of the above ground vegetation in the plot. In the lab, we weighed the clipped vegetation, removed all dead (non-green) material, reweighed the sample, dried the remaining material for 24 hrs at 60°C, and weighed the final dried biomass. We used multiple linear regression (Proc GLM, SAS version 9.1, SAS Institute, Inc., Cary, North Carolina, USA) to estimate a mathematical relationship between dry weight clipped biomass and infrared–red reflectance ratio plus grass height. We calculated a reflectance ratio for each plot sampled as the ratio of infrared (0.800 nm) and red (0.675 nm) wavelengths (Summers 1990). Dry biomass was significantly related to infrared–red reflectance ratios (IR/R) and grass height (ht) for young grass (dry mass = -2.89 + 0.83*IR/R + 0.81*ht, R^2 = 0.87, $F_{2,18} = 50.4$, $P < 0.001$) and mature grass (dry mass = -12.37 + 0.88*IR/R + 2.81*ht, R^2 = 0.89, $F_{2,36} = 139.9$, $P < 0.001$). The regression equations generated from that analysis were subsequently used to convert the reflectance ratio and measured grass height into estimates of SSB for each plot sampled non-destructively.

Daily regrowth rates were calculated as the difference in reflectance ratios of exclosures between first and second visit divided by the number of days since the first visit. We revisited exclosure plots every 14–30 days (*n* = 10 young grass; *n* = 4 mature grass) and subsequently moved exclosures to a different location. We used the median of daily regrowth rates estimated separately for each winter period. Daily regrowth estimates were multiplied by the number of days in a winter period (51 in early winter, 62 in mid-winter, and 50 & 80 in late winter) to obtain total regrowth biomass. We then added regrowth biomass to the SSB value measured at the beginning of each winter period to arrive at total available forage biomass for a field. Forage biomass values were averaged for each habitat type (young or mature) within each winter time. The mean (kg ha^{-1}) total forage biomass of young and mature grasses was multiplied by ha of each grass type on FNWR to arrive at total forage biomass.

Statistically, we compared SSB and regrowth rates between young and mature grass and among winter periods with a linear model (Proc GLM, SAS version 9.1). Specific differences were compared using least squares means (LSMEANS procedure in Proc GLM) with a Tukey-Kramer multiple comparison test. We assumed that regrowth rates of grass were not affected by the taxa of goose (*e.g.*, Duskys, Cacklers, or a mixed flock) that grazed the field.

Estimating goose food requirement

Food requirement, or the daily biomass of forage needed by an individual goose (kg day^{-1}), was obtained from the literature. Daily food demand was estimated for adult Cacklers or Duskys, not juveniles that can differ in body mass and thus food requirements (Raveling 1979). For Cacklers, we used a daily food demand of 0.129 kg day^{-1} in early winter and mid-winter and 0.205 kg day^{-1} in late winter based on captive feeding trials (McWilliams and Raveling 2004). There are no published studies that estimate daily food requirements for Duskys. Thus, we obtained daily food requirements for nine species of grazing waterfowl in winter [Eurasian Wigeon (*Anas penelope*) and eight geese] and four species of geese in spring over a range of body sizes (Table 4.1). We assumed that daily food requirements were similar in post-arrival and mid-winter, but increased in pre-departure. For Duskys, we used the equation generated by regressing food demands against body mass (kg) in winter to estimate values for post-arrival and mid-winter (0.201 kg day^{-1}). We then assumed a similar increase in food need for pre-departure (0.319 kg day^{-1}; Fig. 4.2) as that of Cacklers (8 x mid-winter estimate).

Modeling carrying capacity

We used estimates of food abundance and food requirement along with estimates for the number of ha in young and mature grasses on FNWR to answer a series of questions including: (1) what is the current energetic carrying capacity of FNWR for Cacklers or Duskys; (2) does habitat composition at FNWR influence energetic carrying capacity for Cacklers or Duskys; and (3) how much additional publicly owned land in grass seed production would be required to support target populations of Cacklers, Duskys, and other geese that winter in the Willamette Valley?

We estimated carrying capacity for Questions 1 and 2 from SSB (kg ha^{-1}) corrected for regrowth estimates from exclosures (kg ha^{-1}) and daily food demands of geese (kg day^{-1}) as:

$$1)\quad \text{No. of geese supported} = \frac{\text{Total available biomass } \left(\text{kg ha}^{-1}\right)}{\text{Goose daily food demand } \left(\text{kg day}^{-1}\right)} \times (\text{No. of days in winter period})^{-1}$$

We estimated land need (ha) for Question 3 as:

$$2)\quad \text{Land need (ha)} = \frac{\text{Target population} \times \text{No. days in winter period} \times \text{daily food demand}}{\text{Mean biomass (kg)}}, \text{ where:}$$

a. Target population represents the current target population goals of Cacklers (250,000), Duskys (15,000), and other geese (75,000)

b. Mean biomass (kg) = 0.76 (mean kg of Young) + 0.24 (mean kg Mature) from Table 1; Young = young grass; Mature = mature grass

1) What is the current energetic carrying capacity of FNWR for Cacklers or Duskys?— For this scenario, we modeled each species separately, assumed that all birds were ideal free foragers (Fretwell 1972), assumed no travel costs associated with traveling among foraging patches, and required that birds meet 100% of their daily energy needs by feeding on FNWR. Initially, we assumed that all 767 ha planted to grass seed were available to foraging geese (580 ha young; 187 ha mature). We did not include wetland or pasture habitats because Cacklers did not use wetlands for feeding, only roosting and loafing (A. Mini, pers. obs.), and pasture was a small percentage (~9%) of available foraging habitat on FNWR. This first model represents the maximum number of either subspecies that FNWR could support in the most ideal management situation.

Refuge surveys, however, indicate that foraging geese do not use all grass seed fields on FNWR (9% of grass seed fields are not used) and the entire area of a field is not grazed (M. Monroe, pers. comm.; A. Mini, pers. obs.). Accordingly, we ran a second model parameterized as above with the exception that 9% of available ha were classified as not available to geese and, depending on the field, 50–98% ($\bar{x}$ = 84 ± 3%) of available ha in a field were used. Geese may not feed to the edge of each field due to roads or risk of predation (Vickery and Gill 1999). This reduced the grazing lands available to geese by 20% (509 young, 109 mature).

2) Does habitat composition at FNWR influence energetic carrying capacity for Cacklers or Duskys? — Currently, of all fields farmed for grass seed on FNWR (767 ha), ~76% are young and 24% are mature grasses. Based on the habitat preferences of geese (Chapter 3), we calculated carrying capacity assuming that FNWR converted all usable farmed grass seed fields (618 ha from Question 1) to young grass. We assumed that 100% of energy needs were met on FNWR.

3) How much land in grass seed is needed to support target populations of Cacklers, Duskys and other geese in the Willamette Valley?—The Pacific Flyway Council has established population objectives of 250,000 for Cacklers, 10,000–20,000 Duskys (PFC 1999, 2008), and 75,000 for the other geese (Taverner's Cackling and Lesser Canada; PFC 1998). We modeled species additively and used a ratio of 76% young grasses to 24% mature grasses (based on current estimates) when estimating land needs. We required that 100% of goose energy needs be met on public land. We modeled two scenarios of habitat availability: one in which geese used 100% of available fields and biomass and a second in which geese used 70% of available fields and biomass (Summers and Stanfield 1991).

We compared our estimate of habitat needed from the model against an estimate of habitat currently available to quantify the habitat surplus or deficit. We calculated habitat currently available by summing the total hectares of public land on federal wildlife refuges and state wildlife area that were known to feed geese in the Willamette Valley. The public lands inventoried included four federal refuges (William L. Finley NWR, Ankeny NWR, Baskett Slough NWR, and Ridgefield NWR) and one state wildlife area (Sauvie Island WA; Fig. 1). Available acreages were obtained from conversations with refuge staff (M. Monroe and J. Beall, pers. comm.), Comprehensive Conservation Plans for NWRs (USFWS 2010a,b; 2011b) and a draft management plan for Sauvie Island (Oregon Department of Fish and Wildlife 2010). Ridgefield NWR and Sauvie Island WA are primarily pasture habitat. Although grass biomass was not measured directly for pasture in this study, biomass values of pasture from other studies show it to be similar to mature grasses (Arnold 1987, Vickery et al. 1994), so pasture was treated equal to mature grasses in our calculations.

RESULTS

Estimating food abundance

SSB was greater in mature grass fields than young grass ($F_{1,67} = 64.1$, $P < 0.001$). SSB was highest in the late winter period and similar between early winter and mid-winter periods for both young and mature grass ($F_{2,67} = 2.1$, $P = 0.13$; Table 4.2). Mature and young grass were similar in overall regrowth rates ($F_{1,23} = 3.4$, $P = 0.08$) and patterns of regrowth rate were similar over the winter periods with regrowth rates declining from early winter to mid-winter and increasing in late winter ($F_{2,23} = 2.25$, $P = 0.14$). Taking regrowth into account increased total forage biomass in early winter and late winter periods when regrowth rates were greater (Table 4.2).

Modeling carrying capacity

1) What is the current energetic carrying capacity of FNWR for Cacklers or Duskys?—Carrying capacity for geese varied among winter periods, but was consistently lowest in mid-winter (Table 4.3). For Cacklers, carrying capacity ranged from 22,998 to 44,621 while Duskys ranged from 15,744 to 41,980 geese (Table 4.3). Carrying capacity decreased by 51% from early winter to mid-winter, but nearly doubled during late winter (Table 4.3). When we placed constraints on the number of fields used and the percentage of a field that was available, carrying capacity was reduced approximately 30% (Table 4.3) and only 16,164 Cacklers or 11,066 Duskys could be supported in mid-winter.

2*) Does habitat composition at FNWR influence energetic carrying capacity for Cacklers or Duskys?*—Farming FWNR entirely as young grass reduced carrying capacity by an average of 51% for Cacklers and 49% for Duskys (Table 4.4). Looking at results by winter period, carrying capacity was reduced similarly for Cacklers and

Duskys in all winter periods (Table 4.4). The greatest reduction in carrying capacity occurs during mid-winter when only 9,976 Cacklers (62% reduction) or 6,402 Duskys (58% reduction) could be supported.

3) How much land in grass seed is needed to support target populations of Cacklers, Duskys and other geese?—There were 3,721 ha of grass seed fields grown on the five publicly owned properties included in our study. We currently lack the ability to manage for goose populations by subspecies, so the most realistic estimates to consider are those for all subspecies combined. Under those conditions and assuming that geese can consume 100% of the available forage grown on public lands, we estimated there is a current habitat deficit of between 1,781 ha during the late winter period to 9,168 ha during mid-winter. Making the more realistic assumption that geese remove only some percentage of the total biomass available (70%) increases the habitat deficit to 4,139 ha during late winter and 14,691 ha during mid-winter. Thus during mid-winter, geese require from between 2.2 to 3.6 times more foraging habitat on public lands than is currently available.

DISCUSSION

Forage availability

The total forage biomass available to geese on public lands in the Willamette Valley varied significantly with winter period. Few published studies in North America have quantified green browse biomass for geese in winter (green in ricefields, Manley et al. 2004, 2005; spring grazing, Bédard et al. 1986, Bédard and Lapointe 1991). Furthermore, few studies globally have measured green browse non-destructively (Summers 1990) or done so over specific time periods in the annual cycle. The non-destructive sampling method using the spectroradiometer was reliable in estimating total forage biomass and would have application to other geographic regions to assess carrying capacity of geese that forage on green browse. My study indicates that regrowth rates should be periodically estimated throughout fall, winter, and spring if accurate estimates of forage biomass are a desired outcome because growth rates are variable among winter periods.

Carrying capacity

Variation in body size and population size among the subspecies of Canada and Cackling Geese that winter in the Willamette Valley has important implications when estimating energetic carrying capacity. Using Equations 1 and 2, an individual Dusky may need 56% more habitat (0.076 ha per goose) to satisfy energy needs in mid-winter than an individual Cackler (0.048 ha per goose). However, because of the different target population sizes, the larger Cackler population requires 90% more habitat than the Dusky population. Currently, the Dusky population is rather small and therefore has relatively little impact on refuge carrying capacity for Cacklers. However, if Duskys recovered to historic levels of 25,000–50,000 geese, Cacklers and Duskys could compete in resource use on local refuges (Sutherland and Allport 1994, Baveco et al. 2011). A population of 50,000 Duskys would require one-third of the land that a 250,000 Cackler population needs in early winter and mid-winter, but Duskys likely will not return to historic population levels. Being intermediate in size, the daily energy demand for Taverner's and Lessers is in between that of Cacklers and

Duskys. A large uncertainty associated with including these subspecies in any bioenergetic model is that we currently lack a population estimate or a target population size for these taxa at any spatial scale in the Pacific Flyway (Pacific Flyway Council [PFC] 1998).

Habitat composition affects carrying capacity because carrying capacity is reduced approximately 50% if only young grass is farmed. Although converting all farmed lands on FNWR to mature grass would increase biomass available to foraging geese, from a management perspective that option does not appear feasible for two reasons. First, the federal refuge lands are cooperatively farmed and dictating crop types that cooperative farmers may grow would raise costs to farmers and reduce their growing options (USFWS 2011b). The cooperative agreements allow farmers to take a certain percentage of crop harvest to offset operating costs. Dictating crop types would most likely require that the refuge directly offset costs, which may not be feasible. Second, geese, particularly Cacklers, prefer to forage in young grass fields (Chapter 3). Given habitat preference, commuting distance, and the large extent (14,000 ha) of young grass fields that occur on private lands within a 10 km radius of FNWR (Mueller-Warrant et al. 2007), farming FNWR entirely for mature grass may actually encourage higher use of surrounding private lands (Owen et al. 1987, Meire and Kuijken 1991). This contrary result provides one caveat to solely using bioenergetics to dictate goose management strategies.

Methods exist to improve foraging conditions without changing the habitat composition (Vickery and Gill 1999). Because geese do not graze 100% of a field due to an edge effect, removing tree lines or hedge rows may increase the percentage of a field that is used; however, the habitat requirements of other wildlife may limit altering tree lines. The planting of young grasses coincides with goose arrival in fall (Jarvis and Cornely 1988), so the crop is in a rather sensitive growth stage when geese arrive (Kahl and Samson 1984, Flegler et al. 1987, Patterson et al. 1989, Percival and Houston 1992). Irrigating newly planted grasses can be effective at establishing grasses (Hanaway et al. 1999a, Blount et al. 2009) before geese arrive in large numbers in fall (Vickery and Gill 1999). Additionally, fertilizer application can influence goose patch choice (Bos et al. 2005), increase grazing intensity from 13–100% (Vickery and Gill 1999), and double the number of goose-days that an area can support (Riddington et al. 1997). However, cost, infrastructure, water cycles, and available labor may limit options for improving existing conditions.

Providing forage other than green browse can help increase the carrying capacity of public lands for geese. Duskys likely met an unknown portion of winter energy needs foraging in wetlands, which needs further study; Cacklers were never observed foraging in wetlands (A. Mini, pers. obs.). Both species will readily feed on corn (*Zea mays*), which has a much high energy density than green browse (Petrie et al. 1998). Consequently, corn crops can support higher bird use on the same amount of land. Federal refuges in the Willamette Valley have proposed to increase lands planted to corn from 0–32 ha currently to 169 ha (USFWS 2011b). Achieving a habitat objective of 169 ha of corn could lessen use of surrounding private lands (Amano et al. 2006a, Amano et al. 2007); however, a result could be refuge resources being depleted more quickly because of geese aggregating on FNWR from nearby roosts (Owen et al. 1987). Although agricultural crops provide a fairly limited range of values to only a few species (McLaughlin and Mineau 1995), corn would be superior to green browse during early winter and mid-winter if the objective was to increase energetic carrying capacity for geese on publicly owned lands like FNWR. Corn would not be used in late winter as geese switch feeding preference from grain to green browse (McLandress and Raveling 1981b), so corn only has value during a limited timeframe in winter.

Even if improvements to current habitat or alternative forages could be implemented, our modeling indicates that habitats currently available on public lands in green browse would likely not be sufficient to support target populations of wintering geese. The size of the habitat deficit is lower if we assume that geese can consume 100% of available energy, but such an assumption is unreasonable given the current habitat configuration on public lands. Geese will leave a foraging patch despite food still being present (Amano et al. 2006b, Nolet et al. 2006, van Gils and Tijsen 2007), and such factors need to be built into to estimates of carrying capacity. We lacked a detailed understanding of how such factors might reduce food availability for geese. Instead, we relied on observation of goose use in fields and the experience of refuge staff to adjust for these factors in aggregate.

Assuming geese consume only 70% of available food, and that the goal is to provide 100% of all goose foraging needs on public land, we estimate that 14,691 ha of additional public lands are needed to support a goose population of 340,000 geese for the Willamette Valley throughout the entire winter (an average of 0.04 ha per goose). The habitat deficit is considerably lower during early winter and late winter than mid-winter, so targeted seasonal management might reduce the overall habitat need. Options for increasing habitat in public ownership include additional land purchases within existing refuge acquisition boundaries, establishment of new refuges, or the creation of Alternative Feeding Areas (AFA) through easements on private lands where geese can feed undisturbed (Black et al. 2007, Mini et al. 2011). AFAs have been successfully used in Europe (Black et al. 2007, Baveco et al. 2011), but AFAs likely cannot eliminate goose use of other private lands (Amano et al. 2007, Baveco et al. 2011).

Finally, although food for geese may be limited on public lands in the Willamette Valley, total food energy is not limited. Greater than 20,000 ha of grass seed are grown within 10 km of FNWR (Mueller-Warrant et al. 2007) and that amount of habitat is likely sufficient to support the energy needs for all geese currently wintering in the Willamette Valley. If such estimates are expanded to include the entire Willamette Valley, the region has the forage capacity to support most of the geese that currently winter farther south in California. With an increase of late-season hunts and hazing efforts in the Pacific Flyway in areas such as northern California and southern Oregon, it is possible that other subspecies (*e.g.*, Aleutian Cackling Goose [*B. h. leucopareia*]) or species (*e.g.*, Greater White-fronted Goose [*Anser albifrons*]) could be pushed northward at an earlier time and change regional movements (Béchet et al. 2003). If other geese arrived in the Willamette Valley in spring, the conflict between goose energy needs and agricultural practices would increase considerably (Moser and Kalden 1992, Black et al. 2007).

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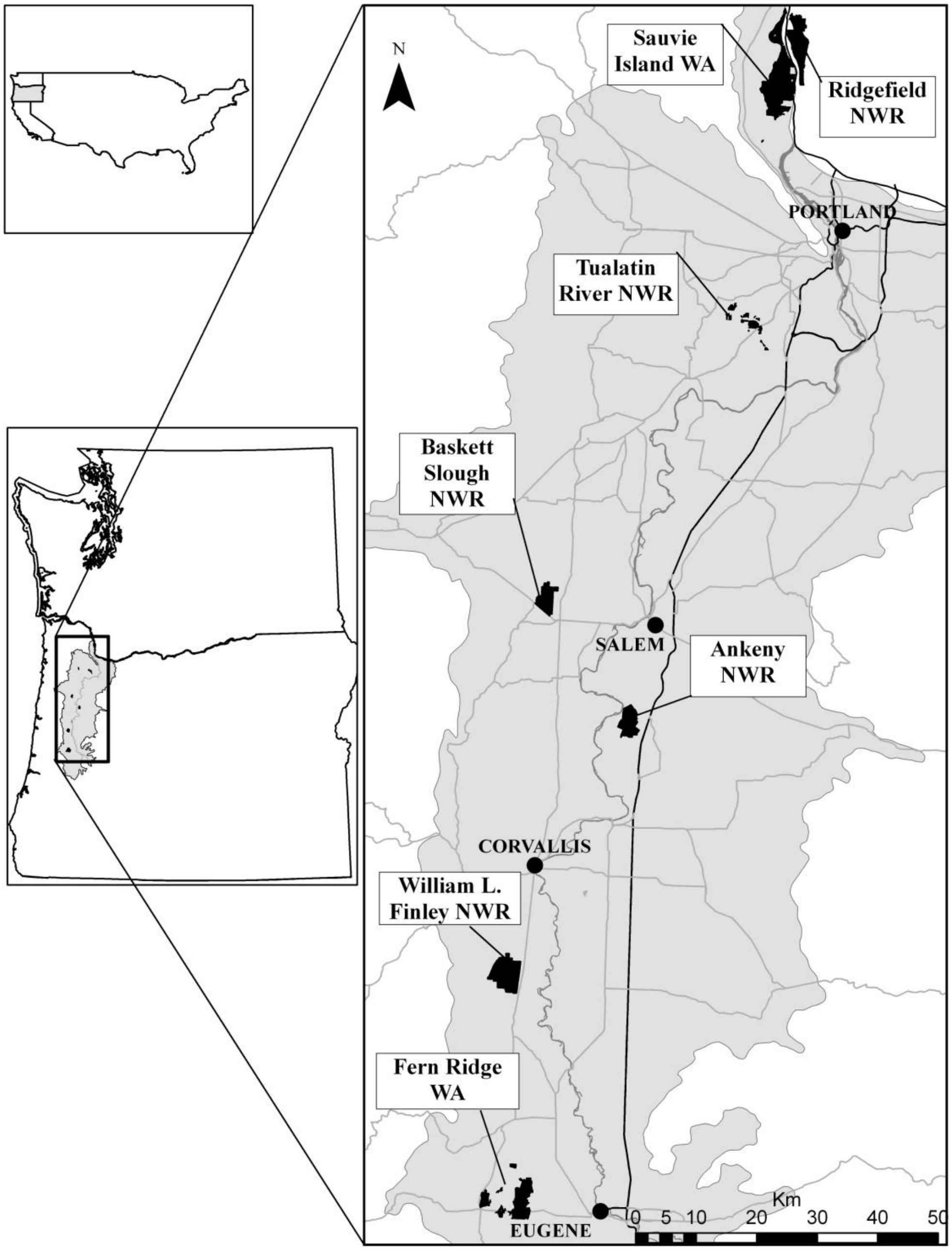

Figure 4.1. Map depicting federal and state roosting areas considered in the study in the Willamette Valley of Oregon (light gray shaded area). Federal roosting areas include William L. Finely NWR, Ankeny NWR, and Baskett Slough NWR. State roosting areas include Sauvie Island Wildlife Area (WA) and Fern Ridge WA. Black circles label major Oregon cities in the study area.

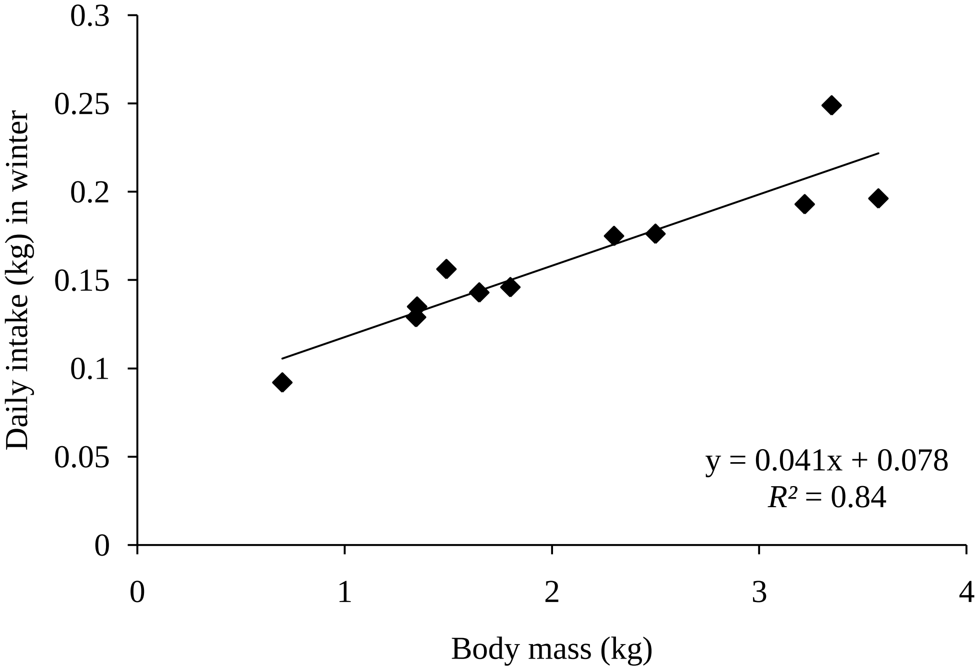

Figure 4.2. The relationship between body mass and daily food needs (kg day^{-1}) for nine species of waterfowl during winter taken from the literature. Daily intake rate values for Cackling Geese in winter are highlighted. Daily intake rate values for Dusky Canada Geese were estimated based on the regression equation generated from these data.

Table 4.1. Daily food requirements (kg day^{-1}) of nine waterfowl species of different body sizes obtained from a literature review of studies conducted in winter and four species in spring.

Species	Body mass (kg)	Season	Daily intake (kg day^{-1})
Eurasian Wigeon[a]	0.700	Winter	0.092
Cackling Goose[b]	1.345	Winter	0.129
Brent[c]	1.350	Winter	0.135
Brant[d]	1.492	Winter	0.156
Ruddy-headed Goose[e]	1.650	Winter	0.143
Barnacle Goose[f]	1.800	Winter	0.146
White-fronted Goose[g]	2.300	Winter	0.175
Pink-footed Goose[h,i]	2.500	Winter	0.176
Upland Goose[j]	3.350	Winter	0.249
Canada Goose (interior)[k]	3.575	Winter	0.196
Brent[l]	1.500	Spring	0.102
Cackling Goose[b]	1.560	Spring	0.205
Pink-footed Goose[m]	2.500	Spring	0.191
Greater snow Goose[n]	3.000	Spring	0.218

[a] Mayhew 1988; [b] McWilliams and Raveling 2004; [c] Drent et al. 1980; [d] Mason et al. 2006; [e] Summers and Grieve 1982; [f] Ebbinge et al. 1975; [g] Owen 1972; [h] Madsen 1985; [i] Therkildsen and Madsen 2000a,b; [j] Summers and Grieve 1982; [k] Gates et al. 2001; [l] Tinkler et al. 2009; [m] Therkildsen and Madsen 2000a,b; [n] Bedard and Gauthier 1989.

Table 4.2. Estimates of daily regrowth rates (median, [0.25 quartile,0.75 quartile]; kg ha^{-1} day^{-1}), standing stock biomass (SSB; $\bar{x}$ ± SE; kg ha^{-1}) and total biomass ($\bar{x}$ ± SE; kg ha^{-1}) of young and mature grass in the Willamette Valley, Oregon during three winter periods from October–April in 2005–2006 and 2008–2009. Early winter from breeding grounds was 25 October–15 December, mid-winter was 16 December–15 February, and late winter to breeding grounds was 16 February–1 April for Dusky Canada Geese and 30 April for Cackling Geese.

	Habitat type					
	Young grass			Mature grass		
Period	Regrowth	SSB	Total biomass	Regrowth	SSB	Total biomass
Early winter	0.37 [0.33, 0.41]	82 ± 21	129 ± 36	0.87 [0.85, 0.90]	578 ± 61	1,023 ± 61
Mid-winter	0.05 [0.03, 0.05]	101 ± 24	176 ± 24	0.11 [0.08, 0.13]	516 ± 89	583 ± 77
Late winter	0.23 [0.03, 1.05]	167 ± 61	353 ± 61	3.34 [2.17, 4.51]	922 ± 254	3,597 ± 254

Table 4.3. Carrying capacity of FNWR in the Willamette Valley, Oregon for either small-bodied Cackling Geese or large-bodied Dusky Canada Geese during early winter (25 October–15 December), mid-winter (16 December–15 February), and late winter (16 February–1 April for Duskys; 16 February–30 April for Cacklers) periods based on consuming 100% of current ha of farmed grass crops and based on restrictions to ha of farmed grass, in which 70% of current ha are consumed. 95% CI = 95% confidence interval.

	Species			
	Cacklers		Duskys	
Period	Mean	95% CI	Mean	95% CI
<u>100% biomass</u>				
Early winter	44,621	[34,792–54,450]	30,959	[24,139–37,779]
Mid-winter	22,998	[15,925–30,071]	15,744	[10,902–20,586]
Late winter	42,738	[52,882–63,025]	41,980	[31,053–52,907]
<u>70% biomass</u>				
Early winter	30,588	[22,992–38,184]	21,222	[15,952–26,493]
Mid-winter	16,164	[11,021–21,308]	11,066	[7,545–14,587]
Late winter	34,509	[27,315–41,702]	27,654	[19,905–35,403]

Table 4.4. Carrying capacity of FNWR in the Willamette Valley, Oregon for either small-bodied Cackling Geese or large-bodied Dusky Canada Geese during early winter (25 October–15 December), mid-winter (16 December–15 February), and late winter (16 February–1 April for Duskys; 16 February–30 April for Cacklers) periods based on 100% of grass seed fields on FWNR (618 ha) farmed as young grass. 95% CI = 95% confidence interval.

	Species			
	Cacklers		Duskys	
Period	Mean	95% CI	Mean	95% CI
Early winter	16,555	[9,807–23,304]	10,625	[6,294–14,956]
Mid-winter	9,976	[6,286–13,665]	6,402	[4,034–8,770]
Late winter	13,323	[8,692–17,954]	10,985	[6,226–15,745]

Table 4.5. Public land (ha) needed to support target populations of Cackling Geese (250,000), Dusky Canada Geese (15,000), and other populations of Lesser Canada and Taverner's Cackling Geese (other geese; 75,000) during early winter (25 October–15 December), mid-winter (16 December–15 February), and late winter (16 February–1 April for Duskys; 16 February–30 April for Cacklers) periods. Species were modeled additively. Land need was represented with two situations: the first in which 100% of fields and biomass are used on public land and the second in which 70% of fields and biomass are used on public land. Values in brackets indicate upper and lower confidence limits based on 95% confidence intervals of total available biomass estimates.

	Species		
Winter period	Cacklers	Cacklers + Duskys	Cacklers + Duskys + Other
100% biomass			
Early winter	4,333 [3,547–5,567]	4,745 [3,879–6,088]	6,650 [5,438–8,534]
Mid-winter	8,399 [6,419–12,137]	9,198 [7,019–13,271]	12,889 [9,840–18,605]
Late winter	3,666 [3,072–4,539]	3,882 [3,251–4,804]	5,502 [4,609–6,809]
70% biomass			
Early winter	6,190 [5,067–7,953]	6,779 [5,541–8,697]	9,500 [7,767–12,191]
Mid-winter	11,999 [9,170–17,339]	13,140 [10,027–18,959]	18,412 [14,057–26,578]
Late winter	5,237 [4,388–6,484]	5,545 [4,644–6,683]	7,860 [6,584–9,727]

The Role of Body Size in the Foraging Strategies and Management of Avian Herbivores: A Comparison of Dusky Canada Geese (*Branta canadensis occidentalis*) and Cackling Geese (*B. hutchinsii minima*) Wintering in the Willamette Valley of Oregon

Chapter 5

GENERAL CONCLUSIONS

Anne E. Mini

Body size is an important factor influencing the life history traits, behavior, foraging strategies, and management of avian herbivores (Peters 1983, Schmidt-Nielsen 1984, Owen-Smith 1988, Belovsky 1997). My study demonstrates how two taxa of geese that differ by a factor of two in body size, Dusky Canada Geese and Cackling Geese, have evolved unique adaptations in their foraging behavior and habitat use while coexisting in a similar foraging environment during winter (Chapters 2 and 3). Potentially, Duskys, Cacklers, and other geese could compete for resources on local refuges (Chapter 4), but strong allometric relationships exist between body size and percent time foraging, peck rates, and commuting distances (Chapters 2 and 3) that may serve to reduce competition. Ultimately, however, population size affects the ability of the landscape to support a population (Chapter 4), so management goals and habitat objectives for avian herbivores should be established in consideration of the influence on body size on the a suite of life history traits of a species.

Based on my results, I could predict how intermediate-sized Cackling Geese (Taverner’s, 2.1 kg) and Canada Geese (Lesser, 2.4 kg) would behave in the same foraging environment during winter and what impact they may have on management. Taverner’s and Lessers should demonstrate foraging behaviors (percent time foraging and peck rates) and movements (commuting distances) within the range of Cacklers and Duskys. I would predict habitat selection for young grass that was demonstrated by both Cacklers and Duskys, but due to larger body size (> 2 kg), Taverner’s and Lessers would also prefer pasture like Duskys. Four subspecies preferring the same habitat of young grass could lead to intense competition for the same resource.

However, if time and digestive capacity limited food intake, then an intermediate body size could be advantageous and result in greater foraging efficiency (Belovsky 1997). I would also predict that Taverner's and Lessers would generally commute < 5 km from roost sites, which would significantly heighten depredation concerns on private lands immediately surrounding roosting areas.

Hazing is often used as a means of trying to alleviate depredation, but disturbances may disproportionately affect Cacklers because their relatively higher energy needs require higher foraging effort (Giroux and Patterson 1995; Gill 1996; Bos and Stahl 2003; Béchet et al. 2003, 2004; Tombre et al. 2005). Intensive hazing may spread Cacklers among a larger number of fields and deter geese from heavily depredating any single field (Béchet et al. 2004). However, hazing is not always effective (Black et al. 2007) and could disperse Cacklers farther and to unwanted areas (*e.g.*, areas not currently used by geese). Cacklers are observed feeding in very urban areas such as a cemetery in Eugene and median strips of freeways/highways (A. Mini, pers. obs.) and this may be a response to disturbance. Additionally, intensive hazing during late winter may affect the ability of Cacklers to acquire sufficient reserves for migration and breeding (Black et al. 2007, Mini and Black 2009). Experimental manipulation of the hunting season would give further insight into the magnitude of the effect that hunting or other disturbance has on the distribution of geese and have potential for controlling the timing of use of private lands by geese (Humburg et al. 1985; Madsen 1993; Gates et al. 2001; Béchet et al. 2003, 2004; Spragens 2010). For example, given Cacklers forage closer to the roost, during the hunting season a continuous hunting season (*i.e.*, eliminate the split seasons) may be more effective at discouraging goose use of private lands (Humburg et al. 1985) as young grass grows during the early winter period. By late winter, young grass on private land may be tall enough that grazing damage would be reduced (Vickery and Gill 1999). Alternatively, a break in hunting could be taken earlier in the season (December through January) when geese are in relatively good body condition (Appendix A). Geese would be more likely to spread out at the beginning of mid-winter, which may conserve food resources on public lands (Young et al. 1996).

Although hazing and hunting may be used to scare geese from private land, an essential component to alleviating depredation is attracting geese to public land. Availability of resources during critical periods in winter is thus an important factor affecting the distribution of geese (Prins and Ydenberg 1985, Vickery et al. 1995, Percival et al. 1996, Si et al. 2011), but may affect small and large bodied geese differently. Cacklers may be more sensitive to changes in food availability (*i.e.*, habitat composition) around their roosts and respond to changes by changing roost sites. Duskys appear be more reluctant to change roosts, instead they hedge their bets to conserve energy until better habitat conditions arise (Chapter 3) or switch habitat types close to or at the roost (Chapter 3). However, making pasture more available on refuge may change the distribution of Duskys within local refuges and immediate surrounding areas.

Alternately, changing the distribution of crops on and around a refuge could help alleviate depredation (Amano et al. 2007). For example, planting more grains on public lands and redistributing sensitive crops further from roost sites when possible could help (Amano et al. 2007). However, such strategies require considerable cooperation and collaboration between wildlife managers and farmers. Furthermore, the distribution patterns of land ownership may constrain the possibilities for such an option. Ultimately, public land managers may be able to address carrying capacity and agricultural depredation conflicts through long-term strategic management in the form of conservation easements that are focused on the movement patterns, commuting distances, and habitat preferences of Cacklers and Duskys. Commuting distances reported in my dissertation provide a basis for establishing management zones for conservation easements (Owen 1990, McKay et al. 2001) and the creation of alternative feeding areas for geese (Owen 1990, Vickery et al. 1994, Black 1998, Amano et al. 2007, Black et al. 2007). Cacklers commuted an average of 8.2 km off of public land and the majority (75%) of observed commutes was within 10 km. Duskys commuted 4.9 km off of public land and all movements were within 10 km. Thus, at a minimum, lands within a 5 km radius of federal refuges or state wildlife areas could be offered as safe feeding zones (Owen 1990, Vickery et al. 1994). Within the safe feeding zone, farmers would be monetarily compensated for allowing geese to feed on their land. Likely Duskys would remain within this safe feeding area. Outside the core feeding zone and protected area, geese could be hunted intensively (Owen 1990, Vickery et al. 1994).

Future changes in the distributions of other goose species and subspecies in the Pacific Flyway are possible and would significantly impact the ability of public lands in the Willamette Valley to support a wintering goose population. As my study demonstrates, the magnitude of effect of other goose species is contingent on body size and population size. A small population (10,000–15,000) of large geese (> 2 kg) would not be problematic to public land need. However, a large population (400,000) of larger-bodied geese [*e.g*., Greater White-fronted Geese (*Anser albifrons*), 2.2 kg] would greatly increase grazing pressure on public and private lands.

With most populations of geese in North America increasing in abundance, combined with the potential positive effects of global warming on breeding conditions in the arctic, managers must plan for goose populations continuing to grow and agricultural conflicts intensifying in the future. We should embrace and develop creative approaches to managing abundant populations of geese (Ankney 1996). Appropriate management goals for Duskys, Cacklers, and other wintering Canada and Cackling Geese in all flyways should represent the current target population needs, as well as future habitat requirements of these subspecies on the wintering grounds. Based on the behavior and movements of Cacklers and Duskys and given the potential of future changes in goose distributions, we should focus conservation efforts on acquiring large, single plots of land surrounding current public lands that would, in the long-run, be more beneficial to addressing agricultural conflicts than creating multiple small refuges. We should build predictive models that can analyze future changes in goose distribution and then implement management plans either to accommodate for these changes or to minimize the possibility of distribution changes. Otherwise, crop depredation issues, such as that in the Willamette Valley, will continue to be repeated in other regions of the Pacific Flyway and other flyways. By considering body size and how it relates to foraging behavior and habitat use, appropriate strategic plans can be implemented to reduce the economic impacts of geese on the wintering grounds while promoting the conservation of geese in the future.

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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

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The Role of Body Size in the Foraging Strategies and Management of Avian
Herbivores: A Comparison of Dusky Canada Geese (*Branta canadensis occidentalis*)
and Cackling Geese (*B. hutchinsii minima*) Wintering in the Willamette Valley of
Oregon

APPENDICES

APPENDIX A

Abdominal Profile Indices

INTRODUCTION

Body condition in geese varies in a predictable cycle (Owen 1980). Geese are generally depleted upon arrival and put on some reserves until mid-winter (Owen et al. 1992). In mid-winter, body condition declines (Owen et al. 1992). In spring, geese become hyperphagic in an attempt to prepare for future migration and breeding (Owen et al. 1992).

Abdominal profile indices (API) are commonly used to assess body condition in geese (Owen 1981). API scores are correlated with fat reserves (Owen 1981). I used API scores to monitor the body condition of geese. I used changes in API scores to determine three winter periods (early winter, mid-winter, and late winter) in the annual cycle of Dusky Canada (*Branta canadensis occidentalis*; hereafter Duskys) and Cackling Geese (*B. hutchinsii minima*; hereafter Cacklers).

METHODS

I examined the patterns of reserve acquisition (*i.e.*, fat) to describe the annual cycle for Duskys and Cacklers. API scores were taken opportunistically during the 2007–2008 and 2009–2010. API scores were not taken during early January due to the logistics of capturing geese and acquiring volunteers. Dusky profiles were not taken after 1 April because of their migration chronology; most Duskys leave 15 April and finding flocks after 1 April was difficult. I took a minimum of 100 individual scores during each winter period. Scores were rated 1–4, with half scores, based on the degree of fatness and sagging in the abdomen, where 0 represented a lean bird and 4 a fat bird (Owen 1981).

RESULTS

Abdominal profiles were consistent with other previously described annual cycles for Cacklers (Raveling 1979), Duskys (Chapman 1970, Bromley and Jarvis 1993), and other geese (Owen and Black 1990). Cacklers and Duskys were depleted upon arrival from breeding grounds, replenished reserves until mid-winter, lost reserves through mid-winter, and then increased reserves substantially during spring/late winter (Fig. A1).

DISCUSSION

The annual cycle of Cacklers and Duskys is similar and shows a decrease in abdominal fatness (API scores) during mid-winter, which represents an energetic bottleneck for geese. During mid-winter, protein levels are slightly lower, although digestibility appears to increase slightly, and regrowth of grass is least. Behaviorally, Cacklers and Duskys exhibit reduced peck rates during mid-winter (Chapter 2). However, if grasses are more digestible, geese may be processing the material faster through their digestive system (Black et al. 2007). Duskys leave the Willamette Valley around 1–15 April (Bromley and Jarvis 1993; A. Mini, pers. obs.) and arrive on the Copper River Delta approximately 15–30 April (Bromley and Jarvis 1993). This short migration window implies a rather direct migration and would not leave time to lay additional reserves along the way. However, Duskys gain mass during pre-laying and use exogenous reserves to supplement the pre-laying period (Bromley and Jarvis 1993). Cacklers typically arrive on the breeding grounds 12–13 May and food on the breeding grounds also appears important during pre-laying (Raveling 1979).

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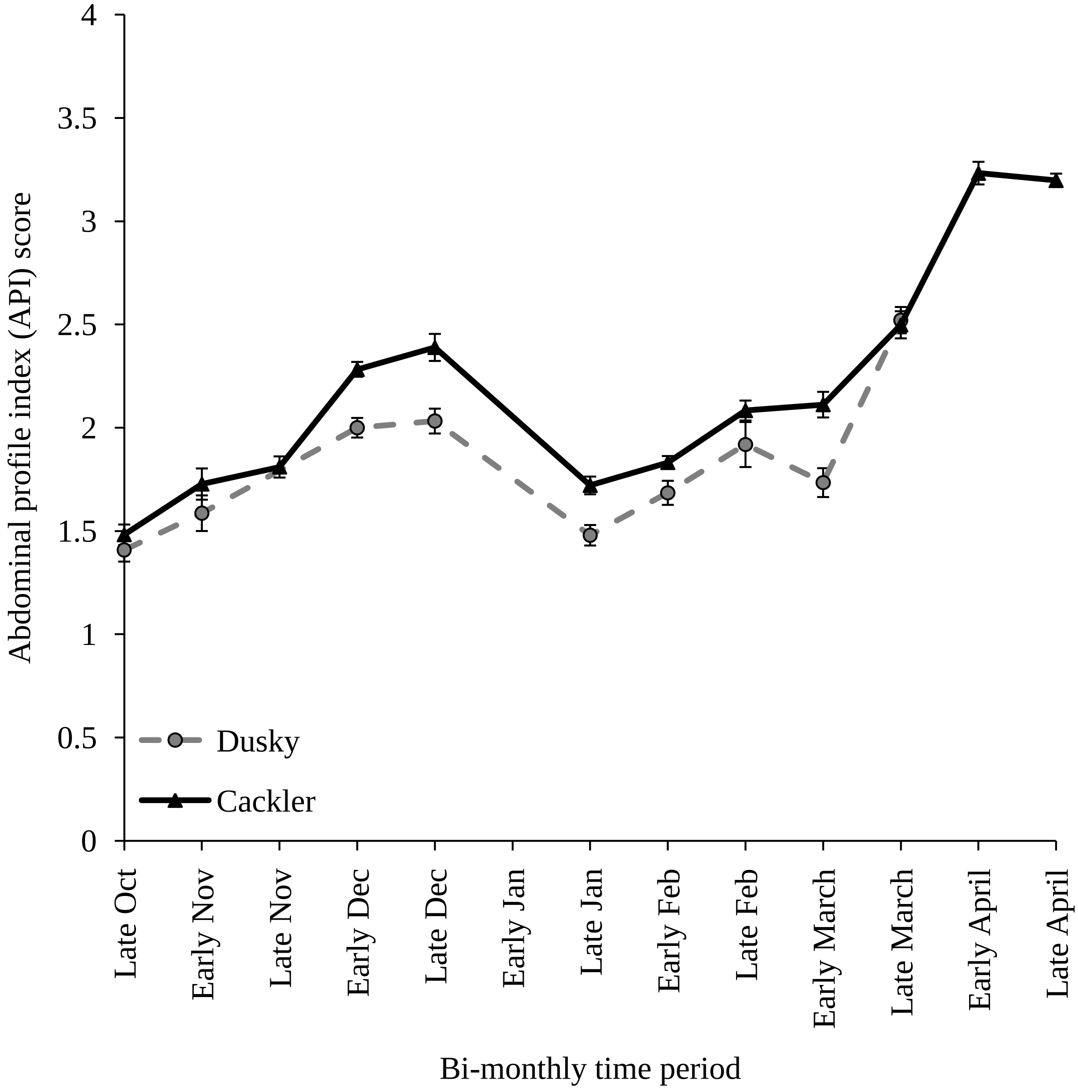

Figure A1. Abdominal profile index (API) scores of Dusky Canada Geese (grey circles) from late October to early April and Cackling Geese (black triangles) from late October to late April based on bi-monthly (early and late) time periods.

APPENDIX B

Alert Behavior in Cackling Geese

INTRODUCTION

An extension of body size relationships and the body size hypothesis is that vigilance levels will increase with small body size (Jónsson and Afton 2009) because small geese may be more vulnerable to predation (McWilliams et al. 1994). Consequently, small geese may spend more time alert or raise their heads up from feeding more frequently (Jónsson and Afton 2009). Alternatively, the “many eyes” hypothesis predicts that smaller geese may not spend more time alert because per-individual vigilance decreases in larger groups (Pulliam 1973, Powell 1974). Predation risk is high in the Willamette Valley based on observations of Bald Eagle (*Haliaeetus leucocephalus*) attacks on Cackling Geese (*Branta hutchinsii minima*; hereafter Cacklers) in the area, especially in early winter and mid-winter periods (A. Mini, pers. obs.). McWilliams et al. (1994) noted that, in the Klamath Basin during spring, Bald Eagle activity and predation on Cacklers was highest during mid-day (as opposed to morning or evening). We tested whether vigilance in Cacklers was related to winter period and time of day, predicting that vigilance would be higher in early winter and mid-winter as well as during mid-day.

METHODS

I used instantaneous scan sampling (Altmann 1974, Bart et al. 1998) to characterize the diurnal activity patterns of Cacklers from arrival in fall to departure in spring. Behaviors were classified as: 1) feeding, 2) alert, 3) locomotion (walking, swimming, or flying), 4) resting, or 5) comfort (a variety of behaviors including preening, wing flapping, and bathing). The response variable for this time activitybudget analysis was percent time alert. To achieve normality, constant variance, and eliminate zeros from the data set, the percent time alert was logit x+0.01 transformed prior to analysis. I divided winter into early winter (25 October–15 December), mid-winter (16 December–15 February), and late winter (16 February–15 April for Cacklers) periods based on patterns observed in abdominal profile indices (API; Owen 1981). Time of day included three time periods (morning [1 h after sunrise–1100], mid-day [1100–1400] and evening [1500–1 h before sunset]). I compared the mean percent time alert using a linear mixed model (Proc MIXED, SAS version 9.1, SAS Institute, Inc., Cary, North Carolina, USA). I included fixed effects of winter period and time of day; year was included as a random effect. I report values as $\bar{x}$ ± SE.

RESULTS

Alert behavior was significantly different among early winter, mid-winter and late winter periods ($F_{2,803} = 7.0$, $P = 0.001$) and among morning, mid-day, and evening ($F_{2,803} = 7.7$, $P = 0.001$). Alert behavior was similar in early winter (8.7 ± 0.4) and mid-winter (7.8 ± 0.3; $P = 0.71$), but lower in late winter (6.5 ± 0.3; $P = 0.01$). Alert behavior was higher in mid-day (8.5 ± 0.4; $P = 0.002$) than morning (7.1 ± 0.3) or evening (7.2 ± 0.3; $P = 0.92$).

DISCUSSION

Cacklers differed in alert behavior according to winter period and time of day as predicted. Bald Eagle presence may be an important factor contributing to vigilance levels in Cacklers and thus also impacting their habitat use. Bald Eagles reach highest densities in early winter and mid-winter, coinciding with lambing seasons in the Willamette Valley. Bald Eagle activity is typically higher in mid-day (McWilliams et al. 1994), which is when Cacklers were more alert.

Because of the “many eyes” hypothesis, the percent of time alert was a small difference between winter periods or time of day. If average flock sizes are 1,000 birds, a 2% difference between early winter and late winter represents 20 more individuals that are vigilant on average. If 70 are usually vigilant (average of 7% vigilance), then 20 additional individuals represents a 30% increase in the number of individuals that are vigilant.

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Appendix C

Nutritional Quality of Foraging Habitats

INTRODUCTION

Forage quality can be an important determinant of habitat use (Vickery and Gill 1999). Protein content and digestibility are the two components of forage quality to which geese respond (Owen et al. 1977). Accordingly, I tested for nutritional quality among grass types, including young grass [annual ryegrass (*Lolium multiflorum*); ≤ 1 yr perennial ryegrass (*L. perenne*); ≤ 1 yr perennial tall fescue (*Festuca arundinacea*)] and mature grass (≥ 2 yr *L. perenne* and *F. arundinacea*).

METHODS

To test for differences in nutritional quality among grass types and between ownerships, I collected 10 samples of grass types (*n* = 3–4 samples each of young grass, perennial ryegrass and perennial tall fescue from 11–12 public fields and 2–7 private fields) once per month in fields used by foraging geese. I sampled in the middle of the month from 15 October 2006–15 April 2007. Geese do not feed in every available grass field; thus, I wanted ensure representation of forage from fields that geese were actively choosing to use (field held ≥ 500 geese). I collected samples in the grazed portion of the field and additionally along the ungrazed borders of fields as a baseline idea of quality without grazing. I collected a minimum sample to achieve 4 g dry weight and limited collection to the top portion of grass shoots. Clipped samples were dried at 60^{o}C for 24 h and later analyzed for crude protein and fiber (acid detergent fiber; ADF), which are important determinants of nutritional quality for geese (Owen et al. 1977). Lower ADF values indicate better digestibility (Durant 2003).

The response variables for food quality were percent crude protein and ADF on an ash-free basis. The explanatory variables were grass type (young grass or mature grass), whether the grass was grazed or ungrazed, and month. I did not include nutritional quality measurements of pasture. No difference in nutritional quality existed between public and private land ($t_{309,0.05} = 1.55$, $P = 0.12$), so I combined these groups for statistical analysis. I compared percent crude protein and ADF with a linear model (Proc GLM, SAS version 9.1, SAS Institute, Inc., Cary, North Carolina, USA). I included two-way interactions of grass type and month and grass type and grazed or ungrazed. Differences among grass types were assessed using the LSMEANS procedure in Proc GLM with a Tukey-Kramer multiple comparison test.

RESULTS

Overall, grass types had no nutritional difference in crude protein ($F_{1,310} = 1.28$, $P = 0.26$), but crude protein was different among months for each grass ($F_{5,310} = 8.4$, $P < 0.001$). Young grass had consistent protein levels across all months ($P > 0.001$; Fig. D1). Mature grass had 5% more protein in February ($P < 0.001$) and March ($P < 0.001$) than young grass (Fig. D1). Whether a grass type was grazed or ungrazed did not affect crude protein ($F_{1,310} = 0.32$, $P = 0.57$).

ADF was significantly different among grasses ($F_{1,310} = 13.43$, $P < 0.001$). Young grass had better digestibility than mature grass (Young = 18.7 ± 0.3; Mature = 19.9; $P < 0.001$; Fig. D2). The effect of month ($F_{5,310} = 1.99$, $P = 0.08$) or grazing ($F_{1,310} = 1.79$, $P = 0.18$) was not significant.

DISCUSSION

Public lands in the Willamette Valley are of sufficient protein and digestibility to support the wintering goose population. Protein levels > 18% should provide sufficient nutrition for the geese, as protein levels < 15% are considered insufficient for protein uptake (Prop and Deerenberg 1991). Young grass in the Willamette Valley exhibits similar trends to annual ryegrass experiments in Texas with protein decreasing and ADF increasing from December–April (Lippke and Ellis 1997). Similar trends in other geographic areas are seen with perennial tall fescue, with a 6% increase from November–April and then a sharp decline (Pendlum et al. 1980). Digestibility levels of < 22% are within levels of what are generally described in other studies (Prop and Vulink 1992). Generally, forage quality increases and maturation delays with increasing latitude (Lippke and Ellis 1997), which may be advantageous to small-bodied Cacklers that should be selecting for high quality forage. However, Cacklers may face a tradeoff with the shortened daylight now that Cacklers winter farther north than historically in the 1980s.

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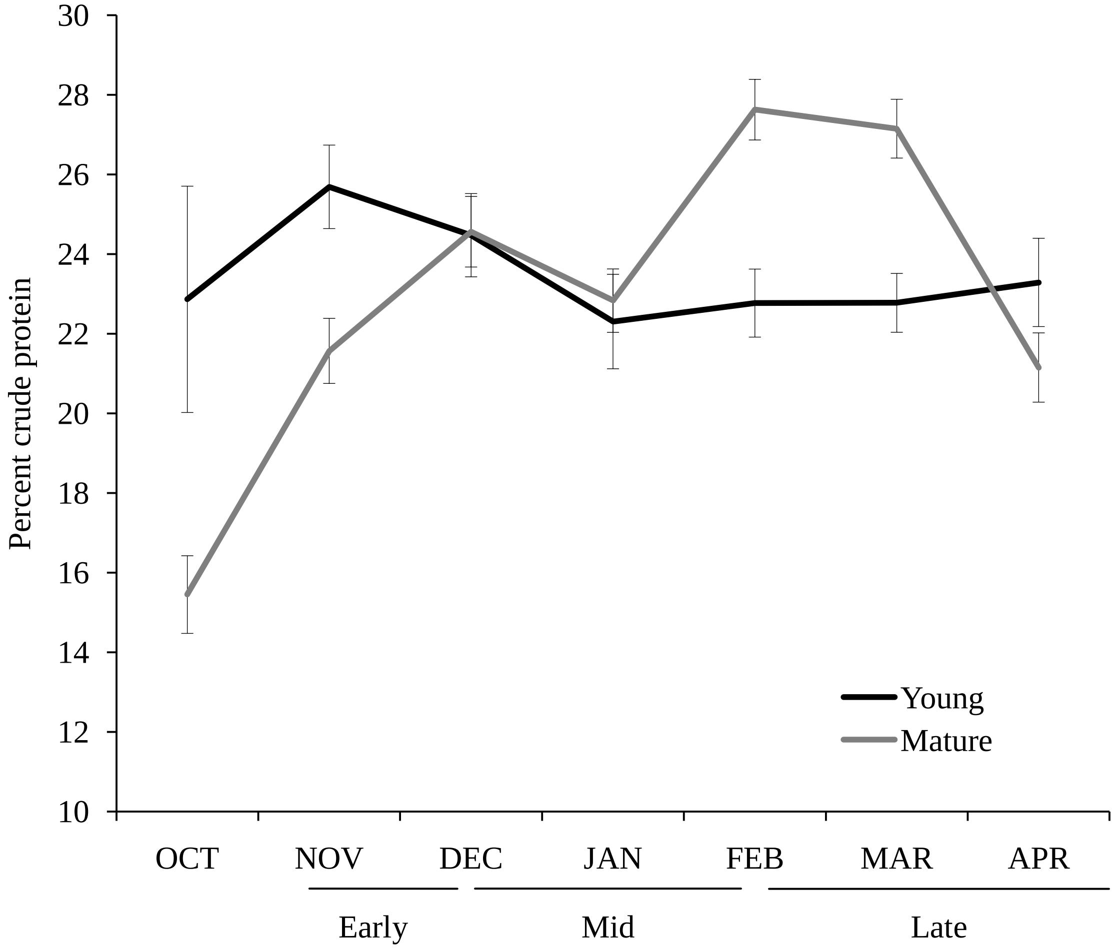

Figure C1. Percent of crude protein (ash-free) contained in two grass types, young and mature grass, in the Willamette Valley, Oregon from October through April in 2006–2007. Winter periods included early winter (30 November–14 December), mid-winter (15 December–14 February), and late winter (15 February–15 April).

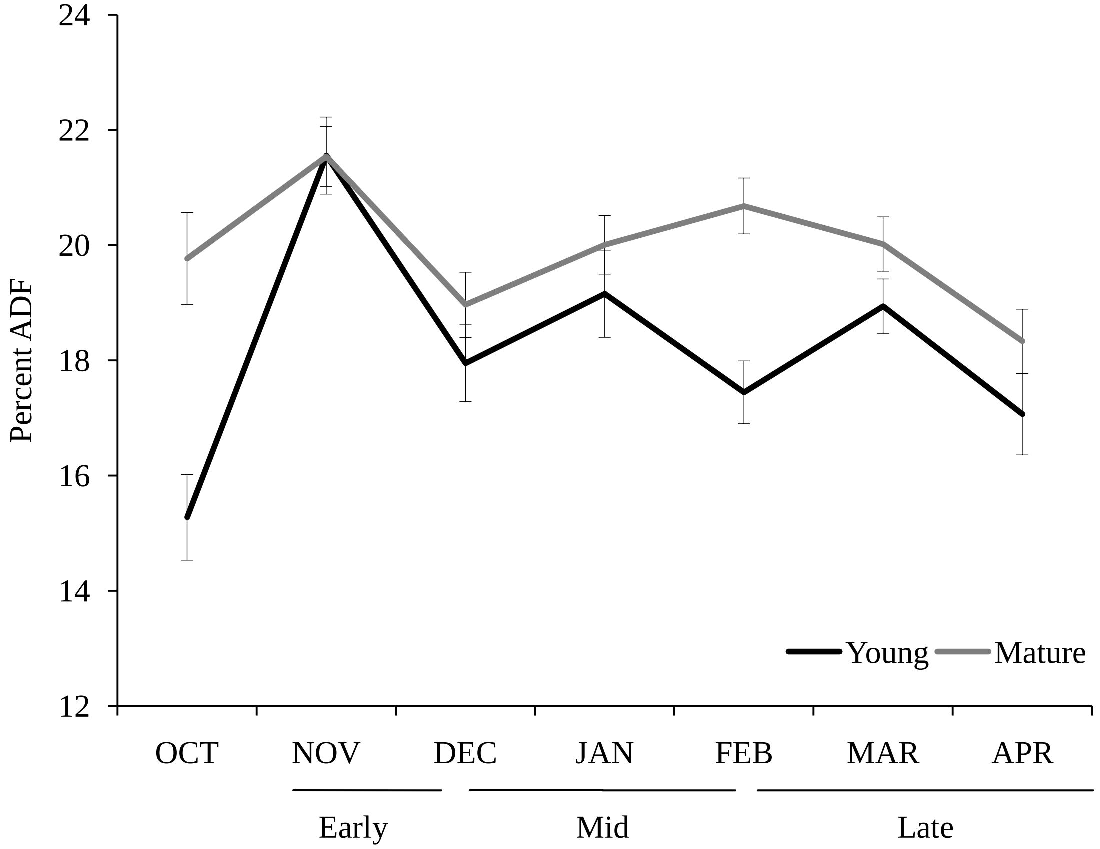

Figure C2. Percent acid detergent fiber (ADF; ash-free) contained in two grass types, young and mature grass, in the Willamette Valley, Oregon from October through April in 2006–2007. Winter periods included early winter (30 November–14 December), mid-winter (15 December–14 February), and late winter (15 February–15 April).

APPENDIX D

Foraging Time to Satisfy Food Demands

INTRODUCTION

Geese require a certain amount of total food (kg) per day; however, intake rates of an individual can differ based on a number of factors (*e.g.*, time of day or habitat type) to satisfy the ultimate amount of food needed per day (McWilliams and Raveling 2004). Increasing food demand requires increasing the number of hours needed to forage. Based on the idea that intake rates can differ, I used different hourly intake rates from daily food needs (Chapter 4) to predict a range of foraging times that would be needed to satisfy total food demands for Cackling Geese (*Branta hutchinsii minima*; hereafter Cacklers) and Dusky Canada Geese (*B. canadensis occidnetalis*; hereafter Duskys).

METHODS

Following McWilliams and Raveling (2004), I calculated a range of uninterrupted foraging times (FT) that individual Cacklers and Duskys would need to maintain a neutral energy balance mid-winter and build reserves in late winter as:

$$\text{FT} = \text{DEE}*(\text{AME}*\text{intake rate})^{-1}$$

where DEE was the estimate of daily energy expenditure, AME was the apparent metabolizable energy of grass, and intake rate was kg of grass consumed per h of foraging (dry weight; McWilliams and Raveling 2004). Methods for calculating the components of DEE, AME, and intake rates were:

1) DEE for Cacklers and Duskys was calculated following McWilliams and Raveling (2004) where DEE (kJ day^{-1}) equaled Field Metabolic Rate (FMR; kJ day^{-1}) plus the cost of tissue synthesis (kJ kg^{-1}).

FMR = $8.47W^{0.704}$ (Williams et al. 1993), where W = mass (g).

The cost of tissue synthesis included the energy content of lipid (0.03954 kJ kg^{-1}) and protein (0.01799 kJ kg^{-1}; Ricklefs 1974) multiplied by the kg of lipid and protein gained per day and then multiplied by an energy conversion coefficient of 1.43 (King 1973). I obtained body mass values for mid-winter and late winter from published literature (Dusky: Bromley and Jarvis 1993; Cackler: McWilliams and Raveling 2004) and hunter-donated Duskys and Cacklers (A. Mini, unpubl. data). Tissue synthesis costs for Cacklers and Duskys were assumed to be negligible during mid-winter, since abdominal profiles did not increase (Appendix A). Tissue synthesis costs during the late winter period were taken from McWilliams and Raveling (2004) for Cacklers and were assumed to be similar for Duskys. Based on values in McWilliams and Raveling (2004), lipid gain was 1.3 g and protein gain was 0.08 g in mid-winter and lipid gain was 12.95 g and protein gain was 1.325 g in mid-winter.

2) AME was ~0.0098 kJ kg^{-1} in mid-winter (Oct–Feb: Gates et al. 2001) and 0.0106 kJ kg^{-1} in late winter (Mar–Apr: Gates et al. 2001; Apr: McWilliams and Raveling 2004).

3) Hourly intake rate (kg h^{-1}) for Cacklers was based on the average of intake values from published literature for Cacklers (Raveling 1979, McWilliams and Raveling 2004) and instantaneous intake rates (kg min^{-1}) of Barnacle Geese ([*B. leucopsis*], ~2.0 kg body mass; Durant et al. 2004). For Duskys, hourly intake rates were estimated from instantaneous intake rates (kg min^{-1}) of Greylag Geese ([*Anser anser*], ~3.5 kg body mass; Durant et al. 2004). I used the same value for hourly

intake rates for all winter periods because specific data was not available for each winter period. I provided a range of values (minimum, mean, and maximum hourly intake rates) to demonstrate potential minimum, mean, and maximum foraging times that might be necessary to satisfy food demands.

RESULTS

During mid-winter, total DEE for Cacklers was 1,458 kJ day^{-1} and 2,556 kJ day^{-1} for Duskys, representing a 1.75 greater total DEE for Duskys (Table D1). During late winter, total DEE for Cacklers increased to 2,265 kJ day^{-1} and 3,388 kJ day^{-1} for Duskys, meaning that total DEE increase proportionately more for Cacklers than Duskys (Table D1).

Predicted feeding time (h) increased from mid-winter to late winter (Table D2). The value of hourly intake rates (kg h^{-1}) used for Duskys were variable (Table D2) because foraging efficiency of similar sized geese was greater in grass ≥ 5 cm tall (Durant et al. 2003). However, based on the higher intake rates of larger geese, less foraging time was needed for Duskys than Cacklers to satisfy food requirements (Table D2). Cacklers needed an additional four hrs of feeding time in late winter compared to mid-winter, whereas Duskys needed an additional 1.5 h (Table D2).

DISCUSSION

Foraging time for Cacklers and Duskys may be most limited in mid-winter when only 8.5–9 h of daylight are available in the Willamette Valley (National Oceanic and Atmospheric Administration 2012). During late winter, energetic requirements and predicted foraging time for Cacklers increased significantly compared to Duskys. Late winter may provide enough daylight for Cacklers to satisfy energetic requirements; however, redistribution of Cacklers further north in the winter would probably approach some critical day light threshold. In circumstances where the amount of day light is limited, Cacklers may opt to rely on some form of nocturnal foraging to make up the difference in foraging time.

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Table D1. Daily energy expenditure (DEE) of Cackling Geese and Dusky Canada Geese during mid-winter (16 December–15 February) and late winter (16 February–1 - 30 April) in the Willamette Valley, Oregon, based on estimated field metabolic rate (FMR) and the cost of lipid and protein synthesis following McWilliams and Raveling (2004). DEE during early winter was assumed to be similar to DEE in mid-winter. Based on values in McWilliams and Raveling (2004), lipid gain was 1.3 g and protein gain was 0.08 g in mid-winter and lipid gain was 12.95 g and protein gain was 1.325 g in mid-winter.

Species	Period	Mass (g)	FMR (kJ)	DEE (kJ day^{-1})
Cackler	Mid-winter	1,296	1,383	1,458
Dusky	Mid-winter	3,055	2,480	2,556
Cackler	Late winter	1,560	1,499	2,265
Dusky	Late winter	3,512	2,654	3,388

Table D2. Predicted feeding time (FT; h) of Cackling Geese and Dusky Canada Geese during mid-winter (16 December–15 February) and late winter (16 February– 30 April) in the Willamette Valley, Oregon, based on daily energy expenditure (DEE; kJ day^{-1}), apparent metabolizable energy (AME) of grass (kJ kg^{-1}), and hourly intake rates (kg h^{-1} ± SE) following McWilliams and Raveling (2004). 95% confidence intervals (CI) of FT are included.

Species	Period	DEE (kJ day^{-1})	AME (kJ kg^{-1})	Intake rate (kg h^{-1})	FT (h [95% CI])
Cackler	Mid-winter	1,458	0.00982	0.0168 ± 0.001	8.8 [8.1–9.8]
	Late winter	2,265	0.01064		12.7 [11.6–14.1]
Dusky	Mid-winter	2,556	0.00982	0.0357 ± 0.001	7.3 [5.2–12.1]
	Late winter	3,388	0.01064		8.9 [6.4–14.7]