Aleutian Cackling Goose *Branta hutchinsii leucopareia* use of pastures in relation to livestock management

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Abstract

The recovered Aleutian Cackling Goose *Branta hutchinsii leucopareia* population nowadays relies during spring on livestock-grazed pastures along the coast of Humboldt and Del Norte Counties, northern California, USA. Selection of these foraging sites has however put geese in direct competition with livestock, which in turn has led to increased actions to reduce economic impacts to local farmers. We assessed forage characteristics between the two primary livestock grazing regimes that shape this landscape of beef cattle ranches and dairy cow farms. Peak counts and densities of Aleutian Cackling Geese were associated with the chronology of highest crude protein concentrations and low forage heights, but the timing did not coincide with greatest spatial distribution of use across this staging area. Grass crude protein concentrations peaked in February and were generally higher in dairy pastures than in beef pastures. However, use of dairy pastures was not observed until a month after staging commenced in this region. We encourage wildlife land managers to provide a successional range of short sward high protein pasture, by improving areas subject to invasion by salt tolerant plants, low in digestibility, in the coastal region and by irrigation in the uplands. These two mechanisms are likely to deliver more grassland of better quality for Aleutian Geese, and to encompass temporal and spatial shifts that occur on this landscape throughout the spring staging period.

Key words: Aleutian Cackling Goose, *Branta hutchinsii leucopareia*, foraging, grassland, grazing, livestock, pastures, spring staging.

During spring, migrant goose populations shift to a protein-rich herbivorous diet at a series of progressively northern staging sites (Owen 1980; van der Graaf *et al.* 2006). These spring staging sites provide geese with the opportunity to acquire nutrient stores, both protein and lipids, important in fuelling migration to the breeding grounds, egg production, and incubation (Ryder 1970; Ankney & MacInnes 1978; McLandress & Raveling 1981). Many goose populations rely on spring staging sites as an opportunity to optimise protein and lipid acquisition by maximising nutrient uptake while minimising time spent foraging (Fretwell & Lucas 1970; Klaasen *et al.* 2006). Although the gradient between capital (*i.e.* fully reliant upon nutrient stores) and income (*i.e.* fully dependent upon additional nutrient acquisitions) breeding strategies may dictate the level of importance that food intake at a spring staging site plays in determining the birds' productivity (Schmutz *et al.* 2006), meeting a threshold of nutrient acquisition and balance at spring staging sites has been shown to influence the probability of successful reproduction in several species of geese, particularly small-bodied populations (Prop & Black 1998; McWilliams & Raveling 2004).

Historically, spring staging geese relied on coastal and seasonal marshes where receding freshwater and increasing temperatures generated conditions favourable for vegetative growth (Owen 1980; Hughes & Green 2005). Today, most goose populations take advantage of foraging sites created by farming activity (Owen 1971, 1975, 1980; Bedard & Gauthier 1989; Black *et al.* 1991; Owen & Black 1991; Black *et al.* 1994; van Eerden *et al.* 1996; Vickery & Gill 1999; Cope *et al.* 2003; Fox *et al.* 2005; Gauthier *et al.* 2005; Drent *et al.* 2007). Food plants that geese acquire from agricultural lands vary in quality and quantity, however, due to different stocking intensity and other farming practices (*sensu* McLandress & Raveling 1981; Bos & Stahl 2003). Wild herbivores are thought to track the nutrient value and digestibility of the vegetation, returning at regular intervals to optimise the availability of forage abundance and quality (McNaughton 1983; Prins *et al.* 1980; Prop & Vulink 1992; Bos & Stahl 2003). Geese, in particular, have been shown to track habitat quality at a landscape scale, particularly protein concentrations (Ydenberg & Prins 1981; Owen *et al.* 1987), including selection of livestock-grazed pastures in winter (Owen *et al.* 1987; Vickery & Gill 1999) and during spring migration (Black *et al.* 1991; McWilliams & Raveling 2004; Drent *et al.* 2007).

The Aleutian Cackling Goose *Branta hutchinsii leucopareia*, hereafter referred to as the Aleutian Goose, was removed from the endangered species list after recovering from a global population of only 790 geese in 1974 to *c.* 100,000 birds in 2007 (USFWS 2001; Trost & Sanders 2008). As population levels increased, lands owned by livestock grazers at the traditional spring staging site, near Crescent City, Del Norte County, California, USA became the primary foraging habitat for the geese, prompting complaints of economic loss (Mini *et al.* 2011). With permission from the United States Fish and Wildlife Service (USFWS), private landowners near Crescent City began an active hazing programme in the mid-1990s to deter geese from using their pastures (Mini *et al.* 2011). The number of Aleutian Geese in the Humboldt Bay, California region, 150 km to the south, consequently began to grow in the subsequent years (Black *et al.* 2004; Mini & Black 2009), prompting concern from livestock producers there as well. The Humboldt Bay spring staging region now supports the majority of this goose population from January–April (Trost & Sanders 2008; Mini *et al.* 2011). To help shift goose foraging away from privately owned pastures and on to public (state-owned) wildlife areas, managed to sustain wildlife and also for recreational use, a late season hunt period was established from 24 February–10 March beginning in 2007, which closed public wildlife areas and encouraged hunting pressure on the private farm pastures (Mini *et al.* 2011). Management of grass swards in wildlife areas and at other sites intended as feeding areas for Aleutian Geese would also help to ease pressure on private pastures, but for this to be effective it is vital to understand the conditions selected by the geese on their spring staging grounds.

In the Humboldt Bay region of California, two types of grazing dominate the pasture landscape: beef cattle ranches and dairy cow farms. Beef ranches have seasonal variation in stocking rates, with higher rates during the summer months in relation to biomass availability (when multiple pastures may be occupied by the beef herds on any given day), and grazing for beef cattle is supplemented by use of land outside of the Arcata Bottoms during winter (Conroy 1987). Dairy farms have relatively stable stocking rates, but rotate the entire herd through particular pastures on particular days to streamline logistics of returning cows to the milking stalls. Rotation intervals are regulated by the number of livestock and pasture area, in order to increase pasture grass production and nutritional quality of the sward (Conroy 1987; Barr 1993), so that generally there is an increased number of cattle on the land corresponding to rapid increases in plant biomass on the pastures in March (Conroy 1987). As such, a major differentiation between these two main types of cattle farming is that the year-round milking of dairy cattle forces dairy farmers to locate livestock to slightly higher elevations directly adjacent to the reclaimed tidal lands of the Arcata Bottoms (where drainage is poorer and the soil can rapidly become saturated), whereas managers of the beef ranches and public wildlife area lands of the Arcata Bottoms rarely need to irrigate their pastures which typically flood rapidly following prolonged periods of precipitation. The differences in these two practices have direct implications for goose foraging patterns during winter and spring, as they create seemingly homogeneous pastures upon the landscape, but in terms of forage nutrition may in fact create heterogeneous availability.

This study therefore aims to identify characteristics of pastures used by geese in the Humboldt Bay region, with emphasis on examining the effects of the different livestock types and management on the landscape. As beef cattle ranches and dairy cow farms are the two dominant land practices yielding short sward pastures in the area, determining the relationship between these livestock grazing regimes and goose feeding distribution is of particular importance for advising on the future management of Aleutian Goose habitats at this spring staging site.

Methods

Study area

The Arcata bottomland (a.k.a. Arcata Bottoms) is approximately 2,500 ha of coastal grazed grasslands located near Arcata, Humboldt County, California (40°46'N, 124°12'W; Fig. 1). These pasturelands are the result of deposits from historic floods from the Mad River, clearing of former Sitka Spruce *Picea sitchensis* forest, and reclamation of historic Humboldt Bay tidal lands in the late 1800s (Hoff 1979). Approximately 50% of this landscape was formerly salt marsh habitat along the shore of Humboldt Bay and the Mad River Slough, now largely dominated by beef ranches and public wildlife areas, with the Arcata Bottoms also extending into low-lying inland areas (the former forested regions), now largely dominated by dairy farms. Agricultural lands surrounding the Mad River Slough levees and bordering the North Humboldt Bay still show remnant scars of these historic tidal channels and allow accumulation of freshwater during periods of heavy rainfall to form numerous semi-permanent and seasonal water bodies (Hoff 1979; Colwell & Dodd 1995).

Today, the Arcata Bottoms consists of livestock-grazed pasturelands dominated by beef cattle and dairy cows *Bos taurus*. All grazed pasturelands use some variation of time-controlled grazing (*i.e.* the "Savory grazing method") in which livestock are rotated through pastures created by subdivision of the larger farm or ranch for units of time (Savory & Parsons 1980). The Humboldt Bay region of California has a moderate climate; on average, 90% of annual precipitation occurs between October and April, permitting the growth of pasture grasses throughout the year (Diamond 1990). The typical grass complex of pasture in the region is comprised of Velvet Grass *Holcus lanatus*, Marsh Grass *Heleochloa schoenoides*, Rye Grass *Lolium perenne*, Tall Fescue *Festuca arundinacea*, White Clover *Trifolium repens*, Meadow Grass *Poa* sp., Bent grass *Agrostis* sp., and Buttercup *Ranunculus* sp. (Verhey 1992; Long 1993). Other goose foraging studies have confirmed that these grasses commonly occur across pastures used by the Aleutian Geese (Bachman 2008; Mini & Black 2009).

Goose surveys

Surveys to record the presence and abundance of geese in the 529 pastures associated with the Arcata Bottoms were conducted by the same observer from a vehicle following a 56-km set route between 1 January and 20 April 2007. Surveys were conducted on a minimum of four days per week. Starting times were alternated (morning, afternoon, evening) and starting locations (north, south) of each survey were also alternated to minimise observational biases. A supplementary count was conducted on a small number of days only if the first count was deemed to have had poor detection levels, due to poor weather conditions reducing visibility or to major disturbances flushing geese from the pastures. All surveys were divided into six survey periods encompassing the winter and spring staging season: 1–19 January (Period 1), 20 January–3 February (Period 2), 4–23 February (Period 3), 24 February–9 March (Period 4), 10–31 March (Period 5), 1–20

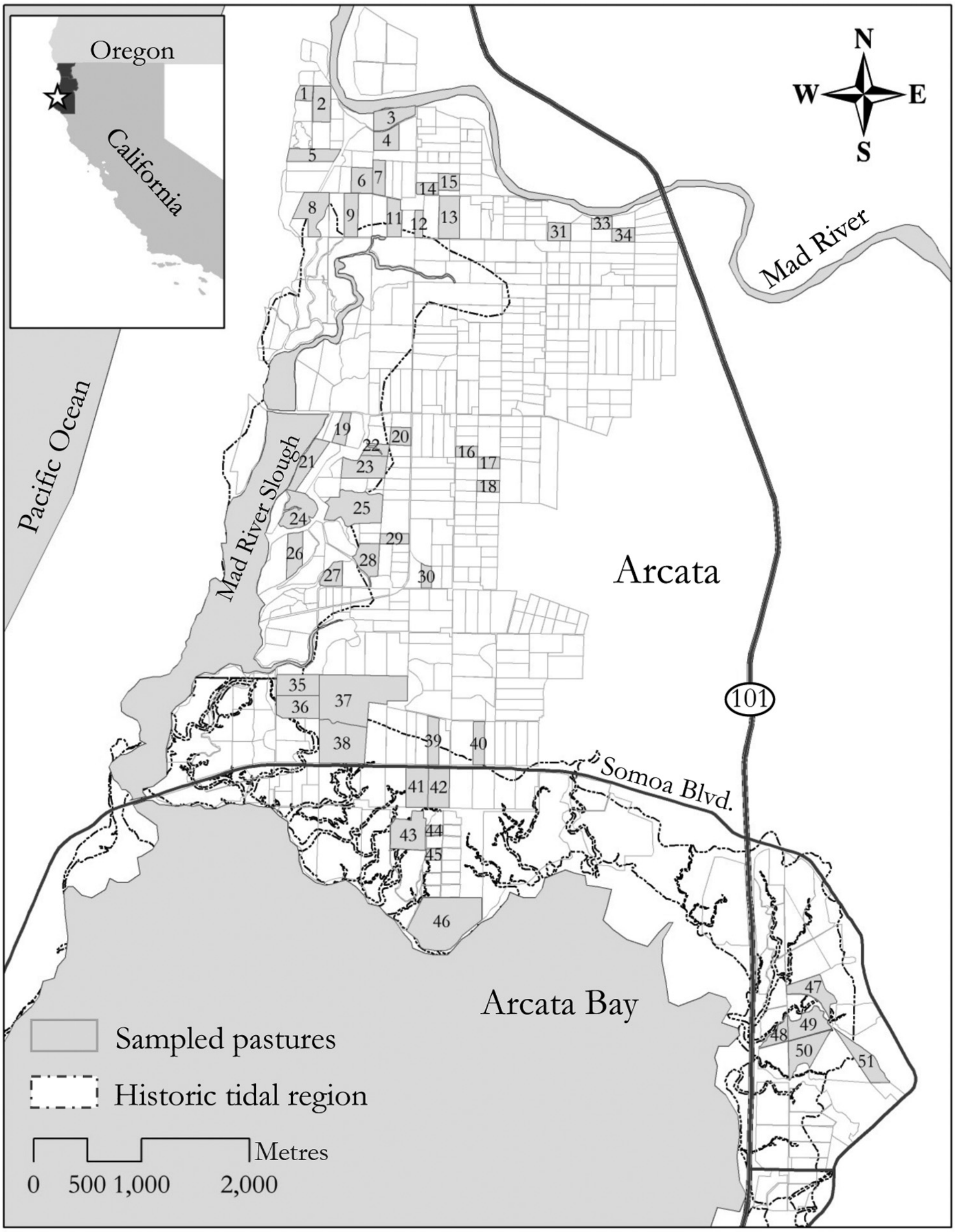

Figure 1. Map of pastures sampled for grass quality characteristics in the Arcata Bottoms (star) during spring 2007. Pastures 1–30 = beef pastures, 31–42 = dairy pastures, and 43–51 = public wildlife area pastures. Dashed line indicates the extent of former tidal salt marsh (historic marshland zone) habitat in this region.

April (Period 6), in order to assess seasonal changes in use of pasture types. The number of pastures used repeatedly (*i.e.* on more than one occasion) was summarised. Use of pastures by the geese was measured as "goose-days", in which each goose observed on a pasture was equal to one goose-day. Goose use of the Arcata Bottoms on days when no surveys were undertaken was estimated as being the mean of numbers counted in all pastures immediately before and after the missing days, and the total number of goose-days for pastures in the Arcata Bottoms was then calculated as the sum of the observed and imputed counts over the study period (Owen *et al.* 1987). The cumulative number of goose-days occurring within the region of historic tidal marsh was derived by joining the pasture-specific counts and intersecting this layer with the extent of historic marsh in a Geographic Information System (GIS) (Fig. 1). All GIS analyses were conducted using ArcGIS 9.3 (Environmental Systems Research Institute 2009).

Farm type

During summer and autumn 2006, grass pastures were categorised by land practice or farming regime as: 1) grazed by beef cattle on privately owned lands (beef: n = 21 ranches, 273 pastures); 2) grazed by dairy cows on privately owned lands (dairy: n = 9 farms, 174 pastures); 3) managed wildlife area pastures ("public": n = 2 wildlife areas, 48 pastures); 4) grazed by sheep on privately owned lands (sheep: n = 1 farm, 17 pastures), and 5) other non-grazed agriculture (NGA: total n = 34 total pastures), including pasture mown for silage or hay (n = 15), flower bulb meadows (n = 11), and recently ploughed crop fields (n = 8). The two public wildlife areas were similar in total area, but differed in that one was open to hunting from October–January inclusive and was managed with low grazing densities, whereas at the other there was no public access throughout the year and the land was managed with higher stocking densities similar to a beef ranch. Both wildlife areas served as closed zones (*i.e.* no hunting and no public access) during the late season hunt from 24 February to 10 March 2007. Management practices of these pastures were similar to beef cattle grazing practices, with a small number of cattle rotated through a series of pastures after several days in each. For two of the farm type categories – sheep and NGA – the frequency of goose use was comparatively low and the overall area of land managed in this manner was limited. These two categories therefore were excluded from analysis of grass swards at the sites.

Grass characteristics

Grass characteristics were measured from a subset of pastures during spring 2007 (Fig. 1). Fifty-one pastures representing four beef ranches, two dairy farms, and two public areas were included in three sampling periods (16–23 February, 10–17 March, 1–8 April, corresponding to goose survey periods 3, 5 and 6, respectively) to capture the heterogeneity typical upon this landscape while geese are present. These pastures were selected at random from farms and ranches where landowner permission could be obtained, and sampling of a particular pasture occurred only when cattle were no longer present to minimise disturbance to livestock. Five random 4 m^2 goose dropping plots were surveyed per pasture during each pasture visit, as a verification of the goose surveys, to confirm that selected pastures were used by geese during each of the three grass sampling intervals (Owen 1971).

Grass height was measured with a sward stick at 20 random sites within each pasture (Summers & Critchley 1990). Grass clippings were taken during each sampling period along randomised transects, clipping the top third to half of sward, representing the portion of grass targeted by grazing geese (Prop & Black 1998), at a minimum of 50 sites per pasture at intervals no closer than 20 m apart. A minimum of 50 clippings, dependent upon pasture size, were taken for each pasture per period, with the only constraint being that subsequent transects could not overlap to prevent re-sampling of previously clipped areas. Clippings from the same pasture were mixed together to estimate average pasture forage values.

Grass samples were sorted for live matter and dried in an oven at 60°C for 24–48 h. Samples were analysed for percent crude protein (derived from total Nitrogen × 6.25; see Van Soest 1994), which is a measure of forage quality, and also for percent acid-detergent fibre (ADF), an index of digestibility (see Prop & Vulink 1992). All values were calculated on an ash-free basis.

Statistical analysis

The comparisons of used to unused pastures with respect to grass height, protein and fibre were conducted using parametric one-way analysis of variance (ANOVA). A dichotomous pasture categorisation was chosen as the response variable because the details of each ranch and farm management practice during the intervening sampling periods could not be collected at a time-interval relevant to the goose surveys, particularly in relation to their possible influences on grass-related values. Comparisons across farm types and sampling periods were conducted using ANOVA, with *post hoc* Tukey-Kramer multiple-comparison tests used to identify the direction of statistical differences between farm types and periods. All analyses use significance level of $P < 0.05$ and were conducted using Program R (R Core Team 2015). Selection ratios were derived for each of the six survey periods where the proportion of goose-days that occurred on each of the pasture types was the observed proportion used, and the total area of pasture for each type was the proportion available during the respective survey period. These values were calculated for beef ranches, dairy farms and managed wildlife area pastures where higher selection ratio values indicate selection of a pasture type above expected proportional availability of that type on the landscape (*i.e.* > 1.0). Standard errors (s.e. values) were calculated for selection ratios in accordance with Manly *et al.* (2002).

Results

Seventy-five surveys of goose distribution were conducted between 1 January and 20 April 2007. Aleutian Geese were present in the Arcata Bottoms staging site for a minimum of 109 days, during which the counts recorded 466,101 observed goose-days, and total goose-days was estimated at 667,485 days (Fig. 2a). Numbers of Aleutian Geese in the study area peaked at 17,882

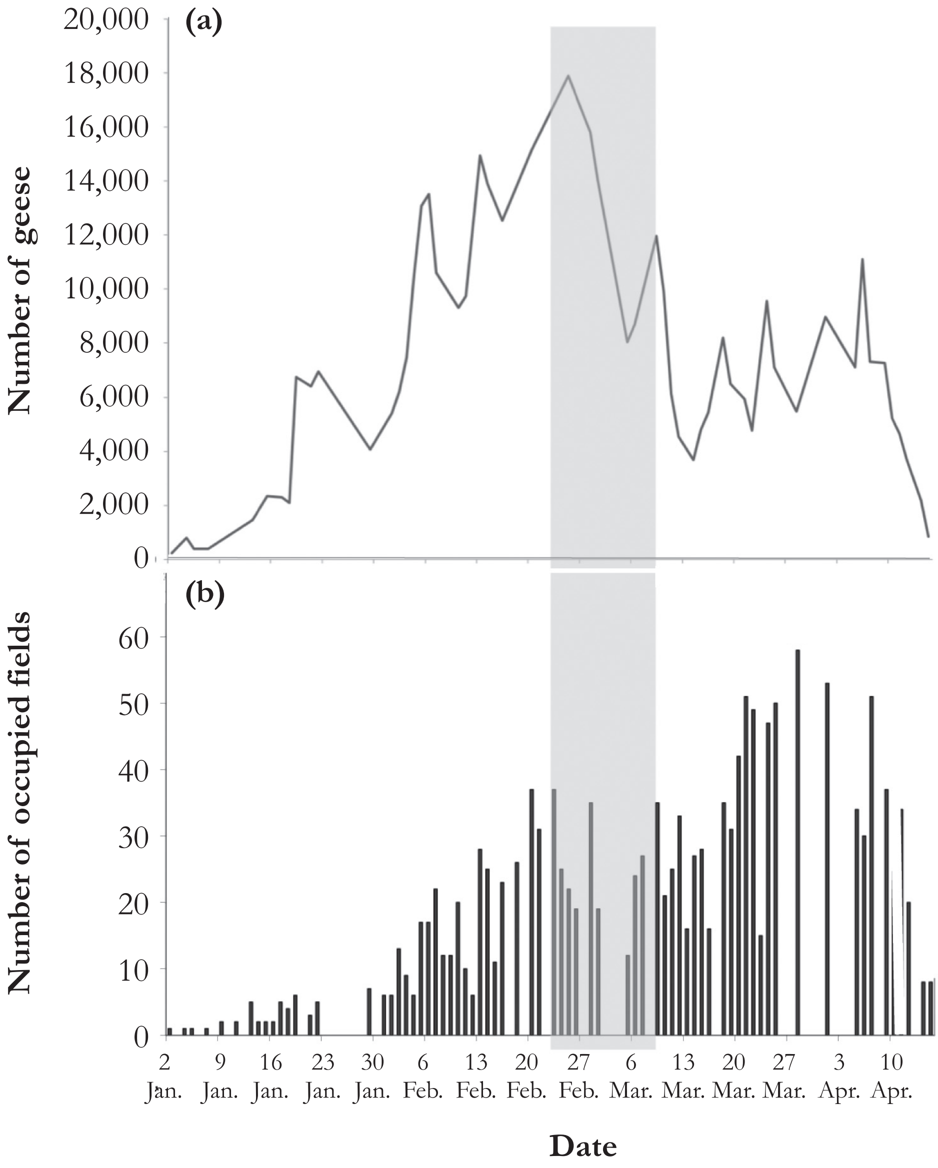

Figure 2. (a) Aleutian Goose abundance on the Arcata Bottoms study area during spring 2007. Shaded area represents the timing of the late season hunt, which is designed to displace the geese from privately owned lands on to public wildlife areas. The peak spring count occurred on 25 February 2007. (b) Number of pastures utilised by the geese during the spring surveys. The maximum number of pastures used on a single day was on 28 March 2007, whereas peak numbers were recorded on 25 February 2007.

birds on 25 February, after which there was a dramatic decline, by *c.* 10,000 geese, coinciding with the late season hunt from 24 February to 10 March (Fig. 2a), but at a rate earlier than previously described (Mini *et al.* 2011).

Geese used particular farm and ranch pastures with higher frequency than others on the landscape. Twenty-seven farms were visited by geese; however, nine farms accounted for 77% of the total number of goose-days during the study. Aleutian Geese were recorded on 258 of the 529 pastures, 28 (the top 10%) of which received 40% of total goose-days attributed to the study area. The number of pastures used in a single day increased over the majority of spring, reaching a maximum of 58 pastures on 28 March 2007, despite the decrease in overall goose numbers during this same period (Fig. 2b). This relationship was also reflected in the highest densities, 171 goose-days per ha, being recorded during Period 2, pre-peak counts, the lowest densities, 64 goose-days per ha, recorded during Period 5, but 0.51 of all goose-days occurred during Periods 3 and 4 (Table 1). Several pastures were used repeatedly throughout the spring, varying with respect to farm type and seasonality (all types = 40–167 different pastures, beef = 32–76, dairy = 1–70, public = 0–22) (Table 2). The highest frequency of pasture revisits was observed in late March, when a single beef pasture was revisited a minimum of 12 times and a single dairy pasture was revisited a minimum of 15 times (Table 2).

Farm type

Aleutian Geese used each of the five farm types during spring 2007; however, privately

Table 1. Summary of goose use of the Arcata Bottoms spring staging area during spring 2007, for all five land types. The area of land used in each period is compared to the number of observed goose-days recorded. Relative densities of geese in each period permit an assessment of changes in land use during the study. Period 1 = 1–19 January, Period 2 = 20 January–3 February, Period 3 = 4–23 February, Period 4 = 24 February–9 March, Period 5 = 10–31 March, Period 6 = 1–20 April.

Period	Total pasture area used (ha)	Goose-days (relative proportions)	Goose-days/ha
1	177	28,706 (0.08)	162
2	363	61,878 (0.17)	171
3	583	95,056 (0.25)	163
4	740	95,882 (0.26)	130
5	761	46,893 (0.13)	62
6	544	45,816 (0.12)	84

Table 2. Summary of foraging pasture visits for the total number (*n*) of pastures in the Arcata Bottoms within each farm type, including fields not visited by the geese. The number of pastures used by the geese and the number of occasions on which geese were found to have revisited pastures is given for each goose survey period in spring 2007, with the observed maximum number of revisits to one pasture (*i.e.* 1 = pasture visited twice), for each type, in parentheses. Further information on the different farm types is provided in the text.

Farm type	*n*	**No. of pastures visited**						**No. of pasture revisited**					
		Late Jan.	Early Feb.	Mid-Feb.	24 Feb.–10 Mar.	Late Mar.	Early Apr.	Late Jan.	Early Feb.	Mid-Feb.	24 Feb.–10 Mar.	Late Mar.	Early Apr.
NGA	27	1	0	1	8	3	2	1 (1)	0 (0)	1 (1)	16 (3)	4 (2)	3 (2)
BEEF	273	32	52	66	74	76	61	47 (5)	83 (5)	144 (7)	150 (7)	238 (12)	159 (9)
DAIRY	174	1	22	48	44	70	54	1 (1)	37 (4)	78 (5)	78 (7)	245 (15)	152 (8)
PUBLIC	48	4	10	6	22	7	0	4 (1)	10 (1)	11 (4)	45 (6)	10 (2)	0 (0)
SHEEP	17	2	3	8	4	11	3	8 (5)	4 (2)	18 (4)	8 (4)	26 (6)	7 (3)
Totals	529	40	87	129	152	167	120	61	134	252	297	523	321

owned pastures cumulatively accounted for 90% of goose-days during the 109-day Arcata Bottoms staging period. Seventy-two percent of all observed goose-days occurred on pastures within the historic marshland zone, accounting for 50% of the study area. The composition of used pastures changed over the course of spring staging. Geese decreased their use of beef-grazed pastures from January to April (from 62–55%; Fig. 3), while increasing their use of dairy-grazed pastures (from 0–41%; Fig 3). Public wildlife area pastures were utilised in the early spring survey periods with the largest percentage of use coinciding with the late season hunt (from 5–25%; Fig. 3); however, during the final two weeks of spring no geese were observed on public pastures. Selection ratios indicated that Aleutian Geese favoured beef ranch pastures through the time of peak goose numbers, Period 3 (Fig. 4), but then shifted towards dairy farm pastures in much higher proportional use compared to availability during the last 6 weeks of spring, in Periods 5 and 6 (Fig. 4). Wildlife area pastures showed use in proportion with availability only during the late season hunt, Period 4 (Fig. 4).

Grass characteristics

The period of spring staging by Aleutian Geese corresponded with rapid grass growth, with grass height nearly doubling between January and April (ANOVA: $F_{3,110} = 6.72$, $P < 0.001$; Fig. 5). Grass height in pastures used by the geese was consistently shorter compared to unused pastures, regardless of farm type (ANOVA; pasture status: $F_{1,96} = 33.12$, $P < 0.001$; farm type: $F_{2,96} = 3.90$, $P = 0.20$, n.s.; interaction: $F_{2,96} = 1.40$, $P = 0.25$, n.s.; Fig. 6a).

Crude protein percentage varied among months, farm types, and their interaction; the highest values were achieved on dairy

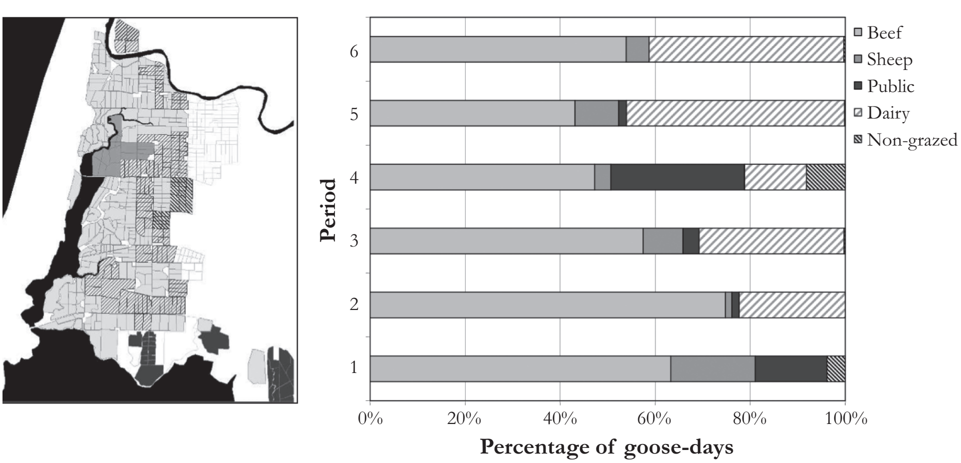

Figure 3. Composition of goose-days by pasture type for each of the six survey periods on the Arcata Bottoms during spring 2007. Period 1 = 1–19 January, Period 2 = 20 January–3 February, Period 3 = 4–23 February, Period 4 = 24 February–9 March, Period 5 = 10–31 March, Period 6 = 1–20 April.

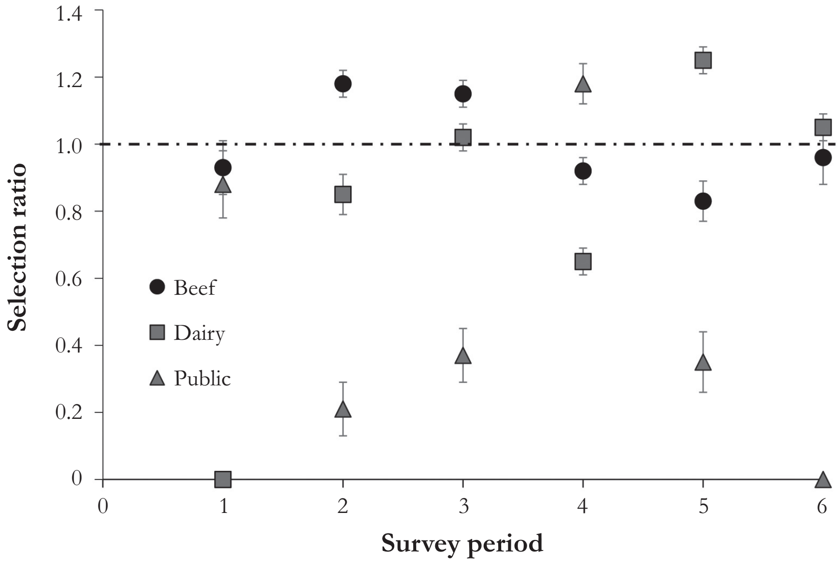

Figure 4. Selection ratio (± s.e.) comparisons between proportional goose-days recorded by available pasture area for beef ranch, dairy farm and public wildlife area pastures during each of the six spring survey periods.

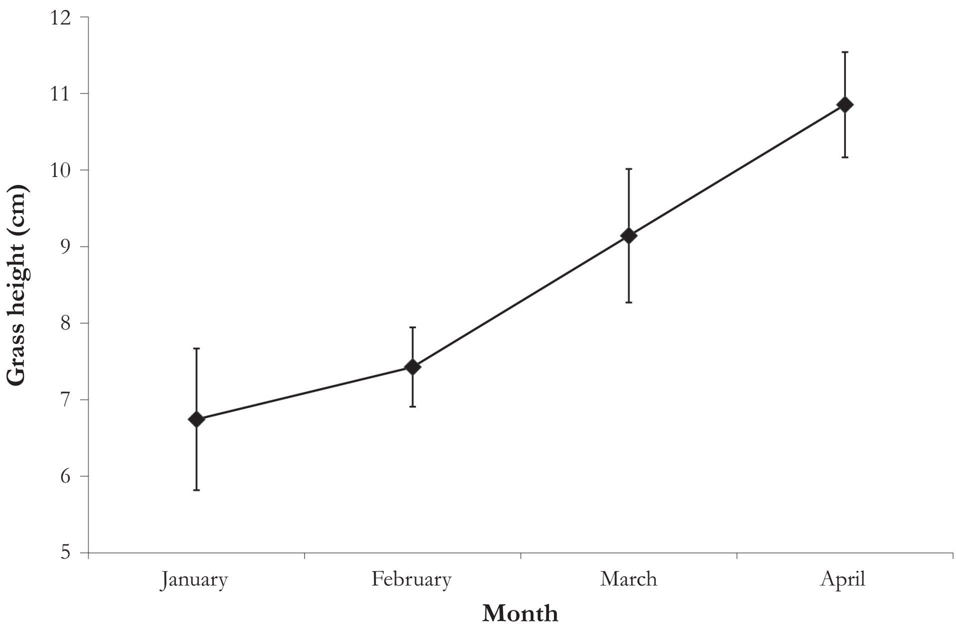

Figure 5. Monthly trends in average grass height (± s.e.) measured in January–April 2007 (n = 16, 51, 18 and 29 fields sampled in each month, respectively) on pastures in the Arcata Bottoms study area.

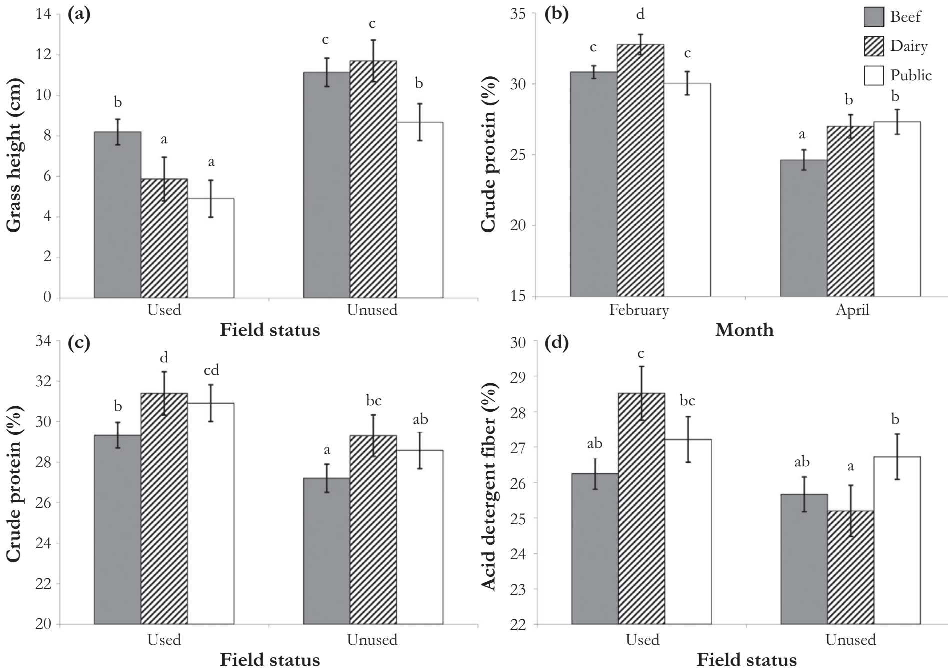

Figure 6. (a) Pasture status (*i.e.* pastures used *versus* unused by the geese) and farm type (*i.e.* beef, dairy, or public land) in relation to average (± s.e.) grass height (used: n = 29, 10, 14; unused: n = 24, 11, 14). (b) Comparison of average (± s.e.) crude protein values on sampled beef, dairy and public pastures during February (n = 30, 12, 9) and April 2007 (n = 12, 9, 8). (c) Pasture status and farm type with average (± s.e.) crude protein (used: n = 29, 10, 14; unused: n = 24, 11, 14). (d) Pasture status and farm type with average (± s.e.) percent acid detergent fibre (used: n = 29, 10, 14; unused: n = 24, 11, 14) on sampled pastures of the Arcata Bottoms spring staging site during spring 2007. Bars that do not share the same letter are significantly different (P < 0.05) from each other.

farms in February and the lowest on beef ranches in April (ANOVA; month: $F_{1,74}$ = 64.58, P < 0.001; type: $F_{2,74}$ = 4.20, P < 0.02; interaction: $F_{2,74}$ = 3.20, P < 0.05; Fig. 6b). Crude protein percentages were significantly higher in pastures used by Aleutian Geese than unused pastures for each of the three farm types, and tended to be lowest on beef pastures (ANOVA; pasture status: $F_{1,96}$ = 9.05, P = 0.003; type: $F_{2,96}$ = 278.14, P = 0.004; interaction: $F_{2,96}$ = 0.01, P = 0.99, n.s.; Fig. 6c). Grass from private dairy farms had higher crude protein (31.4%, range = 25.1–36.7%) than grass from beef pastures (29.3%, range = 20.6–34.9%), but similar to sampled public wildlife areas (30.3%, range = 26.1–34.5%).

Acid detergent fibre (ADF) in pastures used by Aleutian Geese had consistently higher values compared to unused pastures, especially for dairy pastures (ANOVA; pasture status: $F_{1,96}$ = 8.18, P = 0.005; farm type: $F_{2,96}$ = 0.48, P = 0.676, n.s., interaction: $F_{2,96}$ = 3.27, $P < 0.05$; Figure 6d). Although crude protein and acid detergent fibre values are typically negatively correlated (Ydenberg & Prins 1981), they were positively correlated in this study (R^2_{113} = 0.37, $P < 0.001$).

Discussion

Variations in implementation of livestock grazing practices that exist between different farming regimes may influence the availability and condition of forage available to geese from late winter through spring. Peak densities of Aleutian Cackling Geese aligned with the chronology of highest crude protein concentrations and lowest forage heights. Grass crude protein concentrations peaked in February and were generally higher in dairy pastures than in beef pastures. However, there were relatively little use of dairy pastures by the geese until a month after staging initiated in this region. An observed shift away from beef pastures to dairy pastures, as indicated by selection ratios, suggests that forage quality and availability, influenced in part by a disparity in the two types management practices, may ultimately drive goose distribution in late spring, when high protein forage is at a premium prior to departure for breeding areas (Ankney & MacInnes 1978; McLandress & Raveling 1981; Prop & Black 1998).

Aleutian Geese in the Humboldt Bay region used all five farm types (non-grazed agriculture, beef, dairy, public, and sheep) on the landscape throughout spring, but the majority of goose foraging occurred on just 285 of 529 pastures, belonging to nine of 35 privately owned lands. The typical range of grass height (5–9 cm) in pastures grazed by Aleutian Geese was similar to preferred heights reported for other small goose species in spring, including Brent *Branta bernicla bernicla* (4–10 cm, Summers & Critchley 1990; McKay *et al.* 1996) and Barnacle Geese *Branta leucopsis* (2–10 cm, see Black *et al.* 1991; Prop *et al.* 1998; Vickery & Gill 1999). We detected that pastures used by the geese were significantly shorter than unused pasture, a finding that was consistent across farm types. The overall range of crude protein values on used pastures (25.1–36.7%) are comparable to those described in Helgeland, Norway for spring-staging Barnacle Geese visiting traditionally managed and agricultural pastures (Prop & Black 1998).

Diamond (1990) demonstrated increases in protein production of both grasses and clovers through irrigation treatments on dairy pastures in the Arcata Bottoms. This seasonally consistent source of water, required for year-round milking of dairy cattle, forces dairy farms to locate to higher elevations and away from poorer drainage of the historic tidal lands to avoid rapid saturation of their soils. Thus, dairy farms tend to be slightly farther from the reclaimed regions of the Arcata Bottoms than the beef ranches and public lands, which rarely irrigate their pastures. However, during spring 2007, cumulatively, 72% of observed foraging geese occurred within the region of historic marshland zone in the Arcata Bottoms, where historic flooding events would have occurred, which seems at odds with the supposed increased protein concentrations offered by clovers (Bachman 2008), and the irrigated dairy pastures (Conroy 1987; Diamond 1990). This region, which is primarily grazed by beef cattle, showed high proportional use and selection ratios by the geese until late-February, after which they seemingly shifted further inland to pastures with grasses higher in protein (typically dairy pastures) during the final month of spring. While the pattern of this shift would seem to suggest geese were seeking optimal food plants by searching more widely, a view supported by selection ratios favouring of dairy pastures in late spring, Aleutian Geese were counter-intuitively found in higher densities upon beef pastures during the period of highest available protein concentrations upon dairy pastures. Perhaps in an attempt to seek a nutritional balance between protein and lipids concentrations (McWilliams & Raveling 2004), geese were forced into limited regions of optimal forage early in staging and an environmental release broadened the availability of profitable locations across pastures. This may also help to explain the discrepancy between higher ADF concentrations recorded on used, compared to unused, dairy pastures, as geese may have been seeking a more profitable protein to lipid composition found within sward of dairy pastures in late spring.

Ydenberg & Prins (1981) suggested that frequency, rather than the intensity, of visits to a pasture may encourage higher rates of forage production and increasing the likelihood of geese returning to forage. In our study, 80% of the 258 pastures used by the geese were visited more than once. Repeat visits were most common on beef and dairy pastures compared to the other three farm types, especially during the final month of spring, whereas only one public pasture was revisited during the final month. Interestingly, though sheep-grazed fields were the most limited on the Arcata Bottoms landscape, with only 17 pastures, these pastures showed the most consistent pattern of revisits throughout the entire study period. This limited management practice may generate a continually short and even sward that may be very attractive to and perhaps nutritionally beneficial to geese. Further investigation is warranted because the consistent but lower flock densities of foraging geese may be less economically burdensome to the sheep grazing industry.

While agricultural expansion and intensification has created large food resources for migratory geese that never historically existed on the landscape (Owen 1980; Ankney 1996; Jefferies *et al.* 2003), agricultural policy and livestock management practices have led to heterogeneous sward heights and foraging qualities upon which goose flocks have distributed (McKay *et al.* 2001; Bos & Stahl 2003; Cope *et al.* 2003; Fox *et al.* 2005). Given that the highest number of pastures used on any one day was recorded approximately a month after the peak goose count, Aleutian Geese may have expanded their foraging range during the final month of spring because previously high densities depleted forage on many pastures, whereas forage recovery and higher profitability were maintained with repeat visits on the best beef and dairy pastures. While underlying variation in forage characteristics seems to differentiate the pasture types and may provide the mechanism behind goose foraging patterns observed in the Arcata

Bottoms in spring, other features within the landscape that influence site selection should be explored to provide further understanding of goose use of the region. In particular, distance from night roosts, field size, distance to roads and structures, availability of water and other geospatial attributes of particular pastures interacting with forage characteristics, shaped by the various farm types, may provide a more robust description of pasture availability as a foraging site for Aleutian Geese in this landscape.

Conservation and habitat management implications

Our results identified differences in pasture characteristics, shaped by the predominate livestock management regimes on the Arcata Bottoms landscape, which can inform future habitat management targeted for Aleutian Geese. The three month period of spring staging must accommodate anticipated seasonal and environmental influences such as precipitation, cattle stocking densities, peak numbers of geese, landscape disturbance, and increased demands for protein-rich but also nutritionally balanced (protein and lipids) forage. Pastures intended to be attractive as goose feeding areas should occur along the habitat gradient created by short grass salt-tolerant pastures in regions of historic marshland early in staging (*e.g.* current beef and public wildlife areas) to more intensely managed pastures later in spring (*e.g.* current dairy) that provide grass higher in protein content. Focussing management of sites only to those located on one side of the current habitat gradient would ignore the seasonal movement of geese that follow shifts of nutrient profitability and changes in pasture availability across the landscape. If population growth continues at particular spring sites, increased expansion will likely occur into grassland habitats of lower quality and spread perceived impacts to a larger number of farmers. Therefore, the development of a habitat-based approach, such as the provision of alternative feeding areas (Owen 1990; Vickery & Gill 1999), incorporating concepts of energetic needs and availability (*e.g.* carrying capacity), is needed to advise effectively on management actions required to achieve stated objectives (USFWS 2001; Mini *et al.* 2011).

A profitability gradient may be created by the different pasture management strategies implemented by each farm type. However, if public lands intended to provide foraging habitat for geese are to offset economic loss to farmers on private lands, then those located within areas of high use and high flock densities in the historic marsh region should be most useful in early spring, whereas habitat located upslope should offer higher protein forage in late spring and accommodate the apparent tendency of lower flock densities across a larger area, to encompass the full range of seasonal and energetic requirements displayed by this population. Future studies should investigate the composition of grass and clover species targeted by Aleutian Geese, the nutritive quality of primary species, and the response of these species to repeated grazing (and fertilising) by geese or other forms of livestock grazing (*e.g.* sheep), in order to provide a better understanding of specific habitat management strategies that will attract these birds to protected public lands and address the question of goose foraging carrying capacity across this mosaic landscape.

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Photograph: Aleutian Cackling Geese foraging on pasture in the Arcata Bottoms, California, by Kyle Spragens.