Management and Conservation Article

Expensive Traditions: Energy Expenditure of Aleutian Geese in Traditional and Recently Colonized Habitats

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ABSTRACT In an effort to reduce goose depredation at a traditional spring migratory stopover site, private landowners implemented a coordinated hazing plan to scare Aleutian cackling geese (*Branta hutchinsii leucopareia*) from private lands to adjacent public pastures that were cultivated and set aside specifically for geese. Coincidentally, some Aleutian geese began using a new stopover site 150 km farther south in their spring migratory range; numbers at the new site continue to increase. We tested the idea that when their ability to acquire resources deteriorates geese are likely to seek improved foraging conditions, especially during spring migration when individuals strive to maximize nutrient stores and minimize energy expenditure. We quantified measures of goose foraging performance in traditional and new spring staging sites by calculating foraging opportunity, foraging effort, body condition, and daily energy expenditure. Geese staging at the site with higher levels of human disturbance had less foraging opportunity and, despite increased foraging effort and more nutritious food-plants at the site, birds there experienced an elevated energy expenditure and poorer body condition than birds at the new stopover site. Reduced foraging time and increased energy expenditure at the traditional spring staging site may have triggered the colonization process. Suitability assessment of habitat for migratory geese should include measures of foraging opportunity, disturbance risks, and daily energy expenditure in addition to quantity and quality of foods. (JOURNAL OF WILDLIFE MANAGEMENT 73(3):385–391; 2009)

Northern-nesting geese (e.g., *Anser, Branta, Chen* spp.) spend substantial time and effort each spring obtaining nutrients in preparation for migration and breeding and should optimize opportunities to acquire resources (Newton 1977, Owen 1980, Black et al. 1991). In addition to visiting profitable foraging patches (Prop and Black 1998, Prop et al. 2003), northern geese may optimize foraging performance by selecting nearby habitats with limited predation risk, disturbance, and other interference. Overall, foraging performance within habitats should influence how individuals are spatially and temporally distributed (sensu Sutherland et al. 2002, Black et al. 2007).

Aleutian cackling geese (*Branta hutchinsii leucopareia*), like many other northern-breeding geese, stop during spring migration (i.e., spring stage), to replenish lost nutrient stores from winter and to maximize nutrient stores before breeding. Aleutian cackling geese (hereafter Aleutian geese) winter in the San Joaquin and Sacramento valleys of California, USA, feeding primarily on corn and grain stubble. Around January, Aleutian geese migrate to the northwest coast of California, staying for 3 months before heading north to the southern coast of Oregon, USA, for 2–3 weeks and then onto Alaska, USA. Springer and Lowe (1998) reported that the primary spring staging area for Aleutian geese was on dairy and cattle pastures of Del Norte County, California. However, beginning in 1997, small numbers of geese began using pastures adjacent to 2 new roost sites north and south of Humboldt Bay, Humboldt County, California (Black et al. 2004). Although pasture habitat in both locations is quite similar, the newly

discovered sites are 100–150 km south of the traditional spring staging location (Springer and Lowe 1998, Black et al. 2004). Aleutian geese are of particular interest because in 2001 the subspecies was removed from endangered species classification due to its dramatic population increase (United States Fish and Wildlife Service [USFWS] 2001). This remarkable recovery, however, has been tainted because many birds consume spring forage that is valuable to the local dairy and ranching community. To reduce grazing impacts in traditional staging sites, landowners at the traditional site implemented a coordinated hazing plan to move geese from private land to an area of adjacent public pastures that were cultivated specifically for geese.

Using the Aleutian goose population as a model, we explored an energy-based foraging model, which states that migratory geese are likely to seek improved conditions when foraging performance deteriorates due to any one of a variety of limiting factors (sensu Sutherland and Parker 1982, Sutherland et al. 2002, Black et al. 2007). To compensate for reduced foraging performance, geese may feed at different times of day or at night (Kahlert et al. 1996, Lane and Hassall 1996, Percival and Evans 1997) or shift to alternative habitats or locations (Black et al. 1991, Prop et al. 1998, Madsen 2001). During our study, Aleutian goose numbers were declining at the traditional site and increasing at the new site, indicating pursuit of the latter solution, that Aleutian geese were in process of colonizing a new staging location. This provided us with an ideal natural experiment to test for disparities in foraging performance between the sites. We predicted that birds at the traditional hazed site would not perform as well in terms of foraging opportunity, foraging effort, daily energy expenditure, and body condition compared to birds at the newly colonized site, which

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did not have an active hazing program. We also quantified goose diet and forage quality in the 2 sites to examine potential mechanisms that influence colonization events.

STUDY AREA

Our study took place from February to April of 2003 and 2004 in 2 geographic areas of northwestern California: the traditional site near Crescent City, California (41°52′N, 124°08′W) and new site around Humboldt Bay, California, which included North Humboldt Bay (40°59′N, 124°06′W) and South Humboldt Bay (40°53′N, 124°06′W). Each of these geographic areas included major Aleutian goose roosting sites, a 6-ha oceanic island 3.2 km from shore at the traditional site (Springer et al. 1978), and several freshwater ponds at the new Humboldt Bay sites (Black et al. 2004). Geese fed in dairy and beef cattle pastures or mowed and hayed pastures in both regions (Stabins et al. 2002, Black et al. 2004). The most common pasture plant species included velvetgrass (*Holcus lanatus*), bentgrass (*Agrostis* sp.), Italian ryegrass (*Lolium mulliforum*), orchardgrass (*Dactylis glomerata*), clover (*Trifolium* sp.), and buttercup (*Ranunculus* sp.; Long 1993).

METHODS

We estimated goose numbers, usually once per week, by counting geese as they departed from roost sites on the way to pastures. We compared our counts with similar unpublished estimates made in previous years (D. B. Bachman, USFWS, unpublished report; Pacific Flyway Council 1999; USFWS 2005).

To calculate average amount of time geese were present in pastures, we recorded time geese arrived at and departed from pastures. We recorded duration of early morning and late evening roost flights that geese made in traditional and new sites. During daily observations while geese were in pastures we recorded occurrences of observable disturbance flights. We considered likely cause for disturbance flights when ≥50% of a flock took flight. We categorized likely causes of disturbance events (after Black et al. 2004): 1) automobiles, such as cars and trucks; 2) all-terrain vehicles; 3) farming activity, such as plowing, mowing, and moving cattle; 4) aerial sources, such as helicopters, airplanes, and ultralight aircraft; 5) hazing noises, such as cracker shells; 6) avian sources, such as raptors; 7) people, such as individuals walking into a pasture with geese; and 8) unknown sources. An ultralight aircraft was used at the traditional site to scare geese away from private lands.

We quantified time (in sec) and counted geese when disturbed (i.e., flushed into the air) in each hour of observation (continuous behavior sampling, Martin and Bateson 1993). We expressed this as mean number of geese disturbed per hour in an observation area multiplied by total minutes of disturbance, divided by total number of geese in the observation area. Not every disturbance event flushed all flocks, thus number of geese disturbed often differed from total number of geese in an observation area. We defined an

observation area as a geographic area ($\bar{x} \pm$ SE $= 2.70 \pm 0.35$ km^2) in which we counted all flocks.

We defined foraging opportunity as time geese spent in pastures minus disturbance time expressed on a monthly basis. Geese routinely returned to roosts soon after dark; we assumed feeding at roost sites was negligible and return to pastures after dark was rare.

We derived foraging effort from the proportion of flock members that were feeding when in pastures. To determine effort, we performed instantaneous flock scans and calculated daily activity budgets. We attempted to obtain ≥10 flock scan samples per daylight hour during each 2-week period but limited sampling to ≤3 scans per flock within a 1-hour period and waited ≥10 minutes between scans (Black and Owen 1988). We scanned flocks of >100 birds because smaller flocks behave differently than larger flocks (sensu Inglis and Lazarus 1981). We sampled similar flock sizes at both sites ($\bar{x} \pm$ SE; traditional $= 1047 \pm 69$, $n = 205$; new $= 926 \pm 38$, $n = 392$) and scanned a similar number of geese per flock (traditional $= 186 \pm 3$; new $= 178 \pm 3$). In each scan, we categorized behaviors as 1) feeding; 2) drinking; 3) resting; 4) walking, not feeding; 5) vigilant, head up; 6) preening; and 7) interacting, including aggressive encounters.

We calculated daily energy expenditure as expended energy (kJ) per goose in a 24-hour period. We summed energetic costs of daily activities (from activity scans), disturbance flights, and and roost flights. We calculated energetic costs of activities using multiples of metabolic rate based on values for behavioral parameters (foraging, 1.7; alert, 1.7; preening, 1.8; resting, 1.6; walking, 1.9; interacting, 1.9; drinking, 1.7) that were derived for semi-captive brent geese (*Branta bernicla bernicla)* fitted with noninvasive heart rate loggers and calibrated inside a respirometer chamber (Stahl 2001). We calculated basal metabolic rate (BMR) using values from brent geese (mean mass $= 1,564$ g) adjusted to Aleutian geese (mean mass $= 1,600$ g Aleutian, mean derived from 40 hunter-killed birds measured in Feb; K. Ross, Humboldt State University, personal communication). Basal metabolic rate was 20.7 kJ/hour. We calculated flight costs (14 × BMR) from P$_{flight}$ (kJ) $= 189.36$ m$^{2.66}$ (Butler and Bishop 2000).

We estimated duration of roost flights by following flocks in a vehicle after flyoffs to and from feeding pastures and timed flights to the nearest minute. With Geographic Information Systems, we additionally calculated distance between roosts and pastures where most birds arrived and divided this distance by the flight speed of an Aleutian goose ($\bar{x} = 62$ km/hr, $n = 5$ flocks; A. E. Mini and J. M. Black, Humboldt State University, unpublished data). We calculated flight speed from 2 observers using reference points at known distances from each other, recording the exact time at which flocks flew over reference points en route to feeding pastures. Flight speed equaled distance between reference points divided by minutes of flight between points.

We indexed body condition of 20–250 geese ($\bar{x} = 115$) per week in 2003 and 50–250 geese ($\bar{x} = 105$) per week in 2004
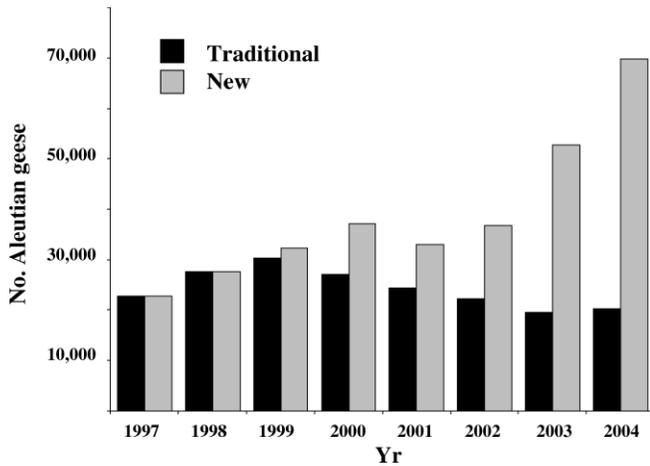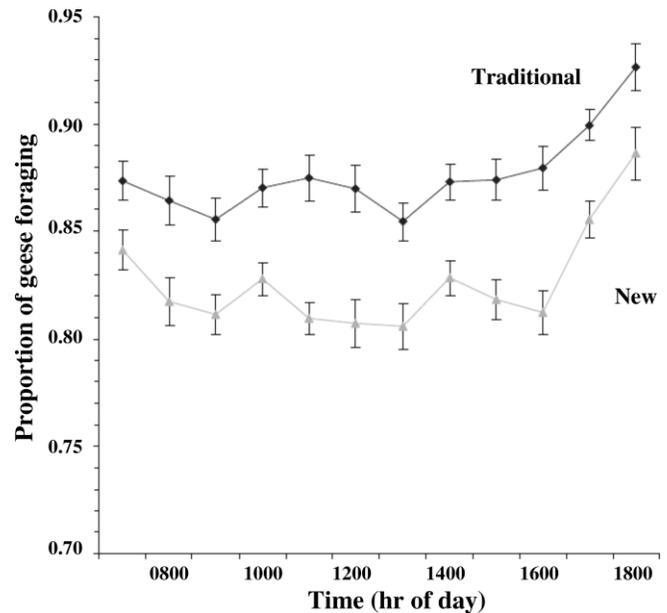
Figure 1. Change in Aleutian cackling goose numbers in the traditional (Del Norte County, CA, USA) and new spring staging area (Humboldt County, CA) from 1997 to 2004. Difference between the 2 bars represents increase of goose numbers at new site.

Figure 2. Foraging effort of Aleutian cackling geese in the traditional (Del Norte County, CA, USA) and new spring staging area (Humboldt County, CA), represented as a function of time of day averaged across months in 2003–2004. Values are means ± standard error; each data point represents 20–90 scans ($\bar{x} = 44$ scans).

using an abdominal profile field index (API) following Owen (1981). Studies in other goose species showed that API classes (similar to ours) were linearly related to fat stores (Boyd et al. 1998, Zillich and Black 2002, Féret et al. 2005, Madsen and Klaassen 2006). We assume this holds for Aleutian geese. The index was 1 (lean) to 4 (fat). We only opportunistically recorded abdominal profiles for geese with heads down and bodies perpendicular to the observer and parallel to the ground. We began scoring geese >1 hour after their arrival on the feeding pastures, allowing time for the digestive system to be filled with plant material (Owen 1981). We selected individuals from middle and edges of flocks to ensure wide representation of individuals, not strictly one age, sex, or dominance type. We averaged API scores over weekly periods.

We examined diet in 2004 by collecting fresh fecal droppings from pastures that contained large goose flocks (>750 birds) for ≥1 hour. We oven-dried droppings at 60° C for 24 hour, then blended them. We analyzed 68 bags (traditional $n = 28$; new $n = 40$) of 10 droppings for plant species content using plant epidermal fragment identification (Owen 1975, Prop and Deerenberg 1991). Using a microscope, we conducted ocular transects (2 mm apart) across a wet-mount slide of thinly spread plant fragments, identifying cell wall characteristics every 2 mm until we obtained 50 plant identification points (sensu Prop and Deerenberg 1991, Summers and Stansfield 1991). We used reference pictures of cell walls taken from known plants to aid species identification.

We collected a mix of 2 dominant grass species in the diet; samples consisted of ≥4 g dry weight of approximately 66% *Lolium* sp. and 33% *H. lanatus*. We collected 4–8 samples per month in each site. To sample portions of plants likely to be consumed by geese, we limited grass collection to the top third to half of grass shoots. We initially dried samples at 60° C and later analyzed them for total nitrogen, ash, and acid detergent fiber (ADF). Additionally, in 2004 we analyzed grass samples for caloric content, or gross energy,

with bomb calorimetry (Van Soest 1994). We estimated crude protein values as total nitrogen multiplied by 6.25 (Van Soest 1994). We used ADF as an index of crude fiber, which has been negatively correlated with digestibility (Sedinger et al. 1989, Prop et al. 2005). We subtracted ash from crude protein and ADF values prior to calculating composition value.

We used the NCSS statistical package (Hintze 2001) and for all tests $\alpha = 0.05$. We report values as mean ± standard error. We assessed trends in maximum number of geese with Spearman rank correlation. We assessed variation in foraging opportunity (time in pastures), foraging effort (proportion of flocks foraging), energy expenditure (kJ), and forage quality (protein, ADF, and gross energy content) using analysis of variance (ANOVA). Independent variables for analyses included 1) site, including traditional (Del Norte) and new (Humboldt) sites, and 2) month, including February, March, and April. When appropriate, we used a post hoc Fisher's least significant difference test (Fisher's LSD) to detect statistical differences of comparisons. We assessed difference in rate of disturbances between sites with Mann–Whitney U tests. We assessed difference in frequency of disturbance types using chi-square contingency tables. We assessed variation in body condition (API) in relation to time (weeks) and site (as above) using nonparametric Kruskal–Wallis ANOVA.

RESULTS

Mean number of geese counted in 2003 and 2004 was 19,875 geese in the traditional site and 37,675 in the new site. Numbers using the traditional site decreased over time from 1997 to 2004 ($r_s = -0.714$, $n = 8$, $P = 0.01$), whereas

Table 1. Proportion of observations ($\bar{x} \pm$ SE) that Aleutian cackling geese in the traditional (Del Norte County, CA, USA) and new spring staging area (Humboldt County, CA) spent in 7 behavior categories during daylight hours across dates in 2003 and 2004.

	Traditional area								New area							
	Feb		Mar		Apr		Overall		Feb		Mar		Apr		Overall	
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Foraging	86.6	0.7	87.5	0.4	88.7	0.4	87.7	0.3	78.4	0.5	84.1	0.4	85.0	0.5	82.6	0.2
Vigilance	6.7	0.4	5.3	0.2	4.3	0.2	5.5	0.2	10.2	0.3	6.9	0.2	6.2	0.3	8.0	0.2
Preening	1.7	0.2	1.6	0.1	1.9	0.2	1.7	0.1	4.6	0.2	3.2	0.2	3.3	0.3	3.7	0.1
Walking	3.7	0.3	4.4	0.2	3.3	0.2	4.0	0.2	3.5	0.2	3.5	0.1	3.1	0.2	3.4	0.1
Resting	0.9	0.1	0.8	0.1	1.6	0.3	1.0	0.0	2.8	0.2	2.0	0.2	2.0	0.3	2.3	0.1
Drinking	0.2	0.0	0.2	0.0	0.1	0.0	0.2	0.0	0.3	0.0	0.2	0.0	0.1	0.0	0.2	0.0
Interaction	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.2	0.0	0.1	0.0
No. of scans	94		209		70		373		290		364		134		788	

number of geese increased at the new site ($r_s = 0.929$, $n = 8$, $P = 0.01$; Fig. 1). During the 2 years of our study, there was an 18% increase in use of the new site from an annual peak of 34,560 birds to 40,790 birds.

Foraging opportunity varied as a function of month and site (ANOVA; month: $F_{2,29} = 18.86$, $P \leq 0.001$; site: $F_{1,29} = 5.23$, $P = 0.03$). Geese in the traditional site had less foraging opportunity (min spent in pastures without being disturbed) than did geese in the new site in April (Fisher's LSD: $t = 3.63$, df = 4, $P < 0.05$). At both sites, geese spent more hours in pastures as daylight increased from month to month, with approximately 11 hours in February ($n = 15$), 12 hours in March ($n = 15$), and 13 hours in April ($n = 5$).

The proportion of individuals foraging was consistently less at the new site compared with the traditional site (Fig. 2). Overall, activity budgets varied as a function of month and site (multivariate ANOVA; month: $F_{14,2298} = 8.97$, $P \leq 0.001$; site: $F_{7,1149} = 22.40$, $P \leq 0.001$; interaction: $F_{14,2298} = 2.93$, $P \leq 0.001$). Foraging effort in both sites increased

Figure 3. Proportion of known disturbances to Aleutian cackling geese associated with 7 disturbance categories in the traditional (Del Norte County, CA, USA) and new spring staging area (Humboldt County, CA) in 2003–2004. Aerial disturbance included helicopters, planes, and an ultralight aircraft. Avian disturbance included raptors, herons, and egrets. People represented individuals walking out into or near pastures with geese. Hazing noises included cracker shells and other loud sounds. Values in legend indicate sample sizes.
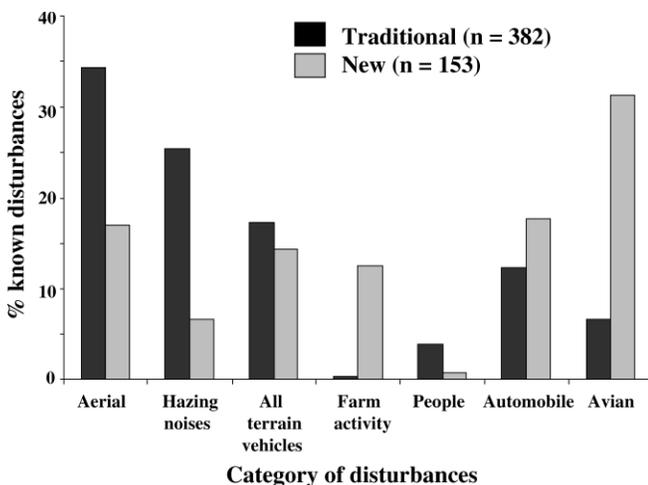
from February to April. Mean foraging effort in the traditional site (88% of day) was greater than in the new site (83% of day; analysis of covariance [ANCOVA] Fisher's LSD: $t = 13.08$, df = 1153, $P \leq 0.001$; Table 1). Additionally, hour of day (ANCOVA; hr: $F_{1,1153} = 32.93$, $P \leq 0.001$) and yr (ANCOVA; yr: $F_{1,1153} = 47.44$, $P \leq 0.001$) were significant covariates of foraging effort.

Daily flights from roosts to foraging areas were 15–16 km (15 min) for birds at the traditional site compared to only 6–8 km (6–8 min) for those at the new site. Geese were disturbed more often at the traditional site (traditional = 211 ± 34 sec/hr, $n = 66$) than at the new site (new = 65 ± 13 sec/hr, $n = 87$; Mann–Whitney test: $z = 4.94$, df = 152, $P \leq 0.001$). Frequency of 7 disturbance types differed between sites ($\chi^2 = 165.2$, df = 6, $P \leq 0.001$). The traditional site had more disturbances from aerial sources, mainly ultralight aircraft, and also noises, such as shell crackers, whereas the new site had more disturbances from avian sources, such as raptors (Fig. 3).

Daily energy expenditure (as calculated from activity budgets, disturbance min, and roost flight time) was a function of site, but not month (ANOVA; site: $F_{1,3} = 47.88$, $P = 0.006$; month: $F_{1,3} = 0.48$, $P = 0.66$). Energy expenditure was greater in the traditional (1,095 ± 14 kJ/ 24 hr, $n = 3$) than the new site (931 ± 11 kJ/24 hr, $n = 6$; Fisher's LSD: $t = 6.92$, df = 2, $P \leq 0.001$; Table 2). In both staging sites, geese spent the greatest percentage of total energy budget performing foraging (traditional 60%, new 71%) and flight (traditional 31%, new 12%) activities.

In both years, body condition, as assessed from birds' abdominal profile scores, varied as a function of week (Kruskal–Wallis ANOVA; 2003: $\chi^2_{8,2788} = 1,157$, $P \leq 0.001$; 2004: $\chi^2_{10,3751} = 2,095$, $P \leq 0.001$) and site (Kruskal–Wallis ANOVA; 2003: $\chi^2_{1,2795} = 35.6$, $P \leq 0.001$; 2004: $\chi^2_{1,3173} = 67.3$, $P \leq 0.001$). Body condition increased throughout the season at both sites (Fig. 4) but was consistently lower in the traditional site from week 6 through week 10 prior to departure (Fisher's LSD; $P < 0.05$).

Traditional and new site droppings contained ryegrass (*Lolium* sp.), clover (*Trifolium* sp.), velvetgrass, fescue (*Festuca* sp.), and bentgrass. Crude protein in vegetation

Table 2. Daily energy expenditure of Aleutian cackling geese staging in the traditional (Del Norte County, CA, USA) and new spring staging area (Humboldt County, CA) in 2004, represented on a second per hour basis, extrapolated to hourly energy expenditure and daily energy expenditure, or the energy expended in 24 hours.

Variable	Units	Behavior	Staging area	
			Traditional	New
Time budgets	sec/hr	Foraging	2,926	2,871
		Vigilance	203	307
		Preening	65	138
		Resting	38	80
		Walking	146	126
		Social	3	6
		Drinking	8	7
		Flight	211	65
Hourly energy expenditure	kJ/hr	Foraging	29	28
		Vigilance	2	3
		Preening	0.7	1.4
		Resting	0.4	0.7
		Walking	1.6	1.4
		Social	0.0	0.1
		Drinking	0.1	0.1
		Flight	15.1	4.8
Energy expenditure in pastures	kJ/hr		580	475
Energetic cost of commute	kJ/hr		134	67
Energetic cost of roosting	kJ/hr		381	389
Daily energy expenditure[a]	kJ/24 hr		1,095	931

[a] Energy expenditure was a function of the site but not month (see text).

samples increased from February to April in both staging areas, whereas gross energy and ADF did not (Table 3). Differences in crude protein and gross energy were marginally significant between sites (ANOVA; site: $F_{1,40}$ = 4.37, P = 0.043, month: $F_{2,40}$ = 0.65, P = 0.53; site: $F_{1,24}$ = 4.58, P = 0.046, month: $F_{2,24}$ = 3.19, P = 0.06, respectively). Differences in ADF were not different between traditional and new sites (ANOVA; site: $F_{1,40}$ = 0.10, P = 0.75; month: $F_{2,40}$ = 0.11, P = 0.90).

DISCUSSION

Our data support an energy-based redistribution model (Black et al. 2007, sensu Sutherland and Parker 1982, Sutherland et al. 2002), which predicts that individuals will abandon less-suitable sites to search for improved foraging opportunities. Geese residing in the traditional site, where farmers intensively hazed, had less foraging opportunity during the day and experienced elevated energy expenditure, contributing to a poorer body condition index (i.e., API) compared to geese in the newly colonized site. Movement away from the traditional site took place even though primary food-plants were apparently higher in nutritive and energetic value at this site. Population size, which was increasing, probably accelerated decisions to look for alternative staging areas, similar to dispersal decisions in other goose species (Black et al. 2007). The amount of reserves a goose obtains directly influences reproductive success (Ankney and MacInnes 1978). Geese departing spring staging sites in poorer body condition have reduced breeding success, returning the next autumn with fewer goslings (Prop and Black 1998, Prop et al. 2003). Therefore, selection would favor exploratory behavior when conditions at traditional sites deteriorate (Black et al. 2007).

Similar studies have shown differences in energy expendi-
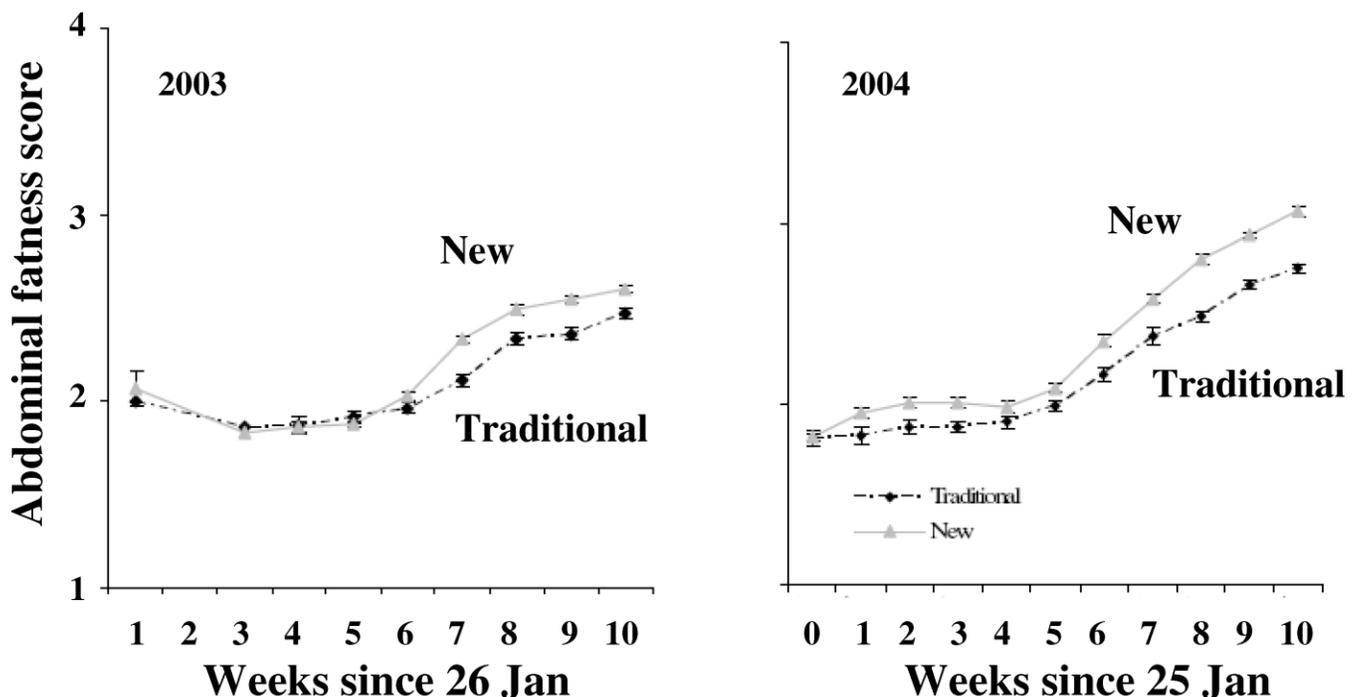
Figure 4. Abdominal fatness scores of Aleutian cackling geese spring staging in the traditional (Del Norte County, CA, USA) and new spring staging area (Humboldt County, CA) in 2003 and 2004. Abdominal profiles ranged from 1 (lean) to 4 (fat). Values are means ± standard errors. In 2003, each data point represented from 20 to 250 scores ($\bar{x}$ = 115 scores); in 2004, each data point represented from 50 to 250 abdominal profile field index scores ($\bar{x}$ = 105 scores).

Table 3. Mean ± SE protein, acid detergent fiber (ADF), and gross energy values of forage collected from Aleutian cackling geese feeding in pastures in traditional (Del Norte County, CA, USA) and new spring staging area (Humboldt County, CA) in 2003–2004.

	Traditional area								New area							
	Feb		Mar		Apr		Overall		Feb		Mar		Apr		Overall	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Protein	23.1	0.0	24.6	0.0	25.9	0.1	24.3	0.0	22.4	0.0	22.9	0.0	22.0	0.03	22.5	0.0
ADF	21.3	0.0	20.1	0.0	20.1	0.0	20.8	0.0	20.1	0.0	21.2	0.0	20.0	0.00	20.6	0.0
Gross energy	18.5	0.2	18.8	0.1	18.8	0.0	18.7	0.1	18.2	0.1	18.6	0.1	18.6	0.10	18.5	0.1

ture due to disturbances (Madsen 1985, Stock and Hofeditz 1997) and differences in habitat quality (Gauthier et al. 1984, Black et al. 1991, Prop and Black 1998, Prop et al. 1998). In barnacle geese (*Branta leucopsis*), older birds remained while younger birds were more likely to move to new spring staging areas when traditional sites deteriorated in quality (Black et al. 1991, 2007). Few studies have been able to relate differences in energy expenditure to changes in distribution (Fredrick et al. 1987, Béchet et al. 2004, Klaassen et al. 2006). During our study, there was a continual increase in bird use of the new site, demonstrating the colonization process. Although migration at this time of year is to the north, we observed large Aleutian goose flocks flying directly south from the traditional roost site in the early morning, presumably initiating the 150-km flight south to the new site. We also recorded collar observations of individuals first seen in the traditional site returning to the new site at a later date (A. E. Mini and J. M. Black, unpublished data). These observations suggested habitat movements or distribution changes within a year, but frequency and duration of such movements is unknown.

Reduced foraging time and increased energy expenditure may have triggered the colonization process. Hazing efforts that we observed in the traditional site increased during March and April, which coincided with thinner abdominal profiles recorded at the traditional site indicating birds' inability to acquire adequate food. Féret et al. (2003) suggested that hunting disturbances in greater snow geese (*Chen caerulescens atlanticus*) affected nutrient storage due to decreased feeding opportunity and increased flights. Féret et al. (2003) found that rate of increase of greater snow goose abdominal profile indices was lower in hunting years, which had more disturbance than nonhunting years.

Although derived from a different methodology than ours, Stabins et al. (2002) found that in 1992, before the coordinated hazing program began, Aleutian geese in the traditional site spent 79% of daylight hours feeding. During our study, 10 years after the Stabins et al. (2002) study and 7 years after the hazing program was implemented, Aleutian geese using the traditional site spent 88% of daylight feeding, potentially representing a 9% increase in foraging effort. However, despite an increase in foraging effort, individuals at the traditional site were unable to gain the same body stores as individuals at the new site. An increased foraging effort due to reduced foraging opportunities is a common response in goose flocks (Gauthier et al. 1984, Madsen 1985, Black et al. 1991, Owen et al. 1992).

MANAGEMENT IMPLICATIONS

Our study suggests that functionality of wildlife areas should be assessed in terms of foraging opportunity and energy expenditure, which may limit individuals' ability to achieve nutrient and energy needs. When implementing hazing programs, managers should ensure that adequate habitat is provided within a staging area or geese may be pushed to another region. Future studies should attempt to identify sociopolitical and economic costs and benefits to society (sensu Owen 1990, Vickery et al. 1994) for maintaining migratory goose populations at traditional staging areas versus at multiple new sites within migratory routes.

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