A RETURN TO THE STAGING GROUNDS: REASSESSMENT OF ALEUTIAN CACKLING GOOSE SPRING DISTRIBUTION IN NORTH HUMBOLDT BAY

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ABSTRACT

A RETURN TO THE STAGING GROUNDS: A REASSESSMENT OF ALEUTIAN CACKLING GOOSE SPRING STAGING DISTRIBUTION IN NORTH HUMBOLDT BAY

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After a 15-year interval in research, spatial and temporal patterns of the Aleutian cackling goose during spring staging was assessed again in 2022. During my study, 3,389 goose flocks were recorded in Arcata Bottoms staging site, 1 January to 21 April 2022, amounting to an estimated total of 2,248,512 goosedays, which was 336.8% higher than 2007 estimates of 667,485 goosedays. Geese continued to use pastures with a wide range of landscape characteristics primarily represented by livestock grazing practices. Goose use was greater than availability on beef-cattle fields early in the season and dairy-cow fields later in the season. Human disturbances were infrequent throughout the study, but more often during the late-season-hunt. Goose use on land managed by State and City agencies (aka Alternative Foraging Areas; AFAs) was less than predicted, based on availability, except when geese arrived in early January, which coincided with opening of the waterfowl hunting season. AFA fields contained 9% of all observed goosedays, 90% of which were located within the City of Arcata's Jacoby Creek – Gannon Slough Wildlife Area, which was managed with livestock and closed to hunting. The late-season-hunt shifted few geese onto AFAs as seen in 2007 when disturbance of flocks was more frequent and intense (Spragens et al. 2015). Goose flocks were closer to roads and structures in 2022 compared to 2007. In 2022, large field size, short distance to roads, and presence of disturbance were important characteristics in predicting goose presence and flock size. In 2022, rate of fat accumulation (determined by a field index of the birds' abdominal profiles) was lower than previously determined in 2004, likely due to increased goose numbers and competition. Management efforts could focus on enhancing existing AFAs to provide disturbance-free habitat that supports the bird's shifting requirements for food while avoiding disturbances.

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INTRODUCTION

Before the breeding season, Arctic-nesting geese accumulate body reserves at progressively northern stop over points along their migration route until they arrive at their staging grounds (Owen 1980, McLandress and Raveling 1981, van der Graaf et al. 2006). Staging grounds are a vital last-stop-shop for obtaining nutrients needed for migration and reproduction that cannot be obtained in harsh artic breeding habitats (Ankney and MacInnes 1978; Prop and Black 1998; Drent et al. 2003, 2007). Many migratory species match their timing of migration with the flush of nutrient availability at stop over (known as the Green Wave hypothesis, Drent 1978, Owen 1980) and staging sites, however some have fallen out of sync due to climate change.

Although goose species have shown flexibility to environmental change (Sutherland 1998), differing levels of anthropogenic disturbance at these sites illustrate a gradient of sensitivity regarding the rate at which fat stores can be accumulated (Tombre et al. 2005, Klaasen et al. 2006, Mini and Black 2009). These fat stores are used for demanding migration flights and reproduction that begins upon arrival at the breeding area (Prop and Black 1998; Prop et al. 1998, Black et al. 2014). Over the last 60 years wild goose populations have grown from improved foraging conditions in winter and spring staging seasons via managed agricultural land (Ankney 1996, Owen and Black 1991, McKay et al. 2006, Fox and Madsen 2017). Jefferies et al. (2006) explained that these agricultural lands set higher carrying capacities than the ever-decreasing natural wetlands and grasslands in which geese once foraged. Within these habitats, spring migrating geese compete with cattle for forage, consuming agricultural crops (Mckay et al. 2001, Montras-Janer et al. 2019), leading farmers to mitigate losses by scaring geese from private land to adjacent public land (Vickery and Summers 1992, Cope et al. 2003, Mini et al. 2011, Madsen et al. 2014). Farmers attempting to scare geese from pastures use various strategies like parking farm equipment in fields, erecting scarecrows, flagging, augmented with periodic loud, and exploding noises from gas cannons (Mason et al. 1993, Gosser et al. 1997, McKay et al. 2001, de Jager et al. 2023).

A compromise to these labor-intensive methods is the establishment of alternative foraging areas (AFAs). First proposed by Owen (1977), the concept of disturbance free areas within regions frequented by geese could be used to mitigate human-goose conflict. Establishment of these areas coupled with appropriate hazing of geese off of crops may encourage use. AFA's benefit both parties, geese are able to spend more time foraging without significant depredation of surrounding crops (Vickery et al. 1994, Owen 1977, Eythórsson et al. 2017, Koffijberg et al. 2017). Part of such management schemes involve paying landowners to use a portion of their land to create semi or disturbance free areas to attract geese (Cope et al. 2003, Black et al. 2007, see Fox et al. 2017 for a review). A prime example of success of AFA's can be seen from barnacle goose (*Branta leucopsis*) at the Caerlaverock refuge along the Solway Firth, Britain (Owen et al. 1987; Cope 2003; Black et al. 2007, 2014).

In northern Norway, increasing disturbance can influence forage site selection in pink-footed geese (*Anser brachyrhynchus*) (Simonsen et al. 2015). Tombre et al. (2005, 2013) found that as a result of five years of intense hazing from farmers, geese selected less-productive and less-disturbed grassland. Additionally, goose use of central Norwegian staging sites increased during this period, indicating a spatial shift from the historic northern staging site. When faced with hazing or sub-optimal foraging conditions wild geese, in general, are expected to compensate by seeking out alternative habitats or locations (Prop et al. 1998; Madsen 2001; Black et al. 2007, 2014).

This shift away from pastures with intense hazing regimes may lead to expansion of the problem to adjacent landowners (Black et al. 2004, Jensen et al. 2008). In California, Aleutian cackling geese (*Branta hutchinsii luecopareia*), a once endangered, now recovered subspecies has, like many goose populations, grown and led to conflicts with farmers (Black et al. 2004, Mini and Black 2009, Mini et al. 2011). A multi-pronged recovery program was launched in 1976 and in 1991 eradication of their introduced predator, the arctic fox *Alopex lagopus* on Aleutian goose breeding grounds set off rapid population growth (Byrd and Springer 1976, Byrd et al. 1991). A small population (~5,000 in 1986) of Aleutian geese eventually re-inhabited their historic spring staging grounds in Crescent City, California, near Castle Rock National Wildlife Refuge (NWR) (Woolington et al. 1979). Hazing began from February to April 1995 as a result of conflict between local farmers and geese over consumption of crops (Mini and LeValley 2006). By 2001, the population was above 30,000 individuals, causing appreciable depredation (Mini et al. 2011). Landowners in Crescent City began organizing more intensive hazing regimes to prevent depredation of crops and push geese to nearby public fields intended for geese (Mini et al. 2011). Much like in Norway, this caused a spatial shift from historic spring staging grounds in Crescent City, to new sites in located around

Humboldt Bay, Arcata Bottoms, Eel River Bottoms and Humboldt Bay National Wildlife Refuge (Mini and Black 2009). Aleutians first made use of Arcata Bottoms during spring migration in 1997 and have since increased their numbers and length of stay (Black et al. 2004, Mini and Black 2009, Spragens et al. 2015). In 2007, Aleutian goose flocks were present from mid-January to mid-April, with peak numbers in late February (Spragens et al. 2015).

Frequent interruptions due to disturbances were linked to increased vigilance and reduced time spent foraging in Aleutian goose flocks, resulting in lower accumulation of body stores (Mini and Black 2009). Compared to geese that remained in Crescent city, Mini and Black (2009) reported that geese in Arcata had more time spent foraging without disturbances, used less effort to forage determined via activity budgets, and had higher API (abdominal profile index) scores indicating better body condition. However, as goose numbers increased in the new area conflict with local farmers began again (Black et al. 2004).

Akin to management plans in Europe for barnacle and pink-footed geese, the Pacific Flyway Council (PFC) management plan was created in 1999 and revised in 2006 (PFC 2006). The PFC plan sought to maintain a stable population, mitigate human-goose conflict, and allow recreational hunting (PFC 2006). In Arcata Bottoms from 2001-2006, hunting pressure gradually increased with larger daily bag limits and longer hunting seasons (Mini et al. 2011). Beginning in 2007, California department of Fish and Wildlife (CDFW) implemented a 16-day late-season-hunt conducted from 24 February to 10 March exclusively on private land to encourage geese to utilize publicly managed lands adjacent to private fields (Mini et al. 2011). The late-season-hunt resulted in a large increase of public land use and an instant decline of 10,000 geese in Arcata Bottoms reported by Spragens et al. (2015). Interestingly, during spring staging in 2007, geese utilized 54% of all fields available. Such variation in spatial distribution may be explained by differing foraging conditions and landscape characteristics yielding differing forage opportunities (Spragens et al. 2015). For example, size of agricultural fields, distance to roads, tidal sloughs, structures, and surface water potential may provide strong descriptors for foraging site availability (Black et al. 2004, 2007, Spragens et al. 2015).

If a landscape contains clutter like structures or farming equipment, it may limit site availability by not providing sufficient open space (Owen 1977). This effect increases with flock size as larger flocks are known to have longer escape flight distances (Madsen 1995, Gill 1996). Roads, structures like barns, sheds, and large farm equipment may represent landscape characteristics that are considered unusable habitat, causing fragmentation, limiting site availability (Larsen and Madsen 2000, Spragens et al. 2015). Degrees of disturbance experienced by individual geese may be influenced by field size, distance to field edge, roads, structures, flock size, nearby hunting and hazing activity, and disturbance history of a landscape (Gill 1996, Vickery and Gill 1999, Hake et al. 2010). Proximity to these characteristics may be useful in explaining patterns of tolerance to them. Tolerance, as defined by Nisbet (2000) is "the intensity of disturbance that an individual bird tolerates without responding in a defined way." For example, in northwestern Jutland, Denmark, pink-footed geese reduced their avoidance distance of wind turbines by 50% over the course of 8-10 years from first installation, increasing their tolerance over time (Madsen and Boertmann 2008).

The Aleutian goose population was largest on record at 215,000 geese in 2022 (USFWS 2022). With an increase in goose numbers and no follow up from managers, farmers are left to contend with geese themselves. In this study, I sought to re-describe spatial and temporal distribution of Aleutian geese in terms of landscape features and influence of ‘disturbance management’ that has been in practice since 2007. My objectives were to: 1) assess birds’ change in proximity to anthropogenic features over time; 2) compare models of Aleutian goose distribution while foraging in relation to habitat, geospatial landscape characteristics, sources of disturbance, and current utilization patterns with historic data with (Spragens et al. 2015); 3) assess contribution of public land as alternative foraging areas; and 4) quantify goose body condition to compare with historic patterns (Mini and Black 2009, Spragens et al. 2015). A reassessment of Aleutian geese’s spatial and temporal distribution during spring staging may provide managers with insight on those spatial characteristics that affected site selection perhaps leading to goose conflict mitigation.

METHODS

Study Area

The Arcata Bottoms (~2,500 ha) are located north of Humboldt Bay and west of highway 101 in Arcata, California (Figure 1). Current lands are the product of filling and diking from 1897 – 1973 that reduced salt marshes along Humboldt Bay and Mad River slough (Hoff 1979, Barnhart et al. 1992). In 2022, agricultural fields contained remnants of past tidal sloughs that create seasonal waterbodies (Colwell and Dodd 1995). Between October and April, 90% of annual rainfall occurs, filling waterbodies and allowing forage to grow year-round (Diamond 1990). Primary species found in Arcata Bottoms grass complex are bent grass (*Agrostis spp.*), rye grass (*Lolium perenne*), marsh grass (*Heleochloa schoenoides*), velvet grass (*Holcus lanatus*), bluegrass (*Poa spp.*), tall fescue (*Festuca arundinacea*), white clover (*Trifolium repens*), and buttercup (*Ranunculus spp.*) (Verhey 1992, Long 1993).

Field Methods

All methods were approved by the Cal Poly Humboldt Institutional Animal Care and Use Committee (IACUC) in Protocol Number 2021W69-E, approved on 22 December 2021.

Field type

During spring 2022, fields were categorized by land management type as: 1)

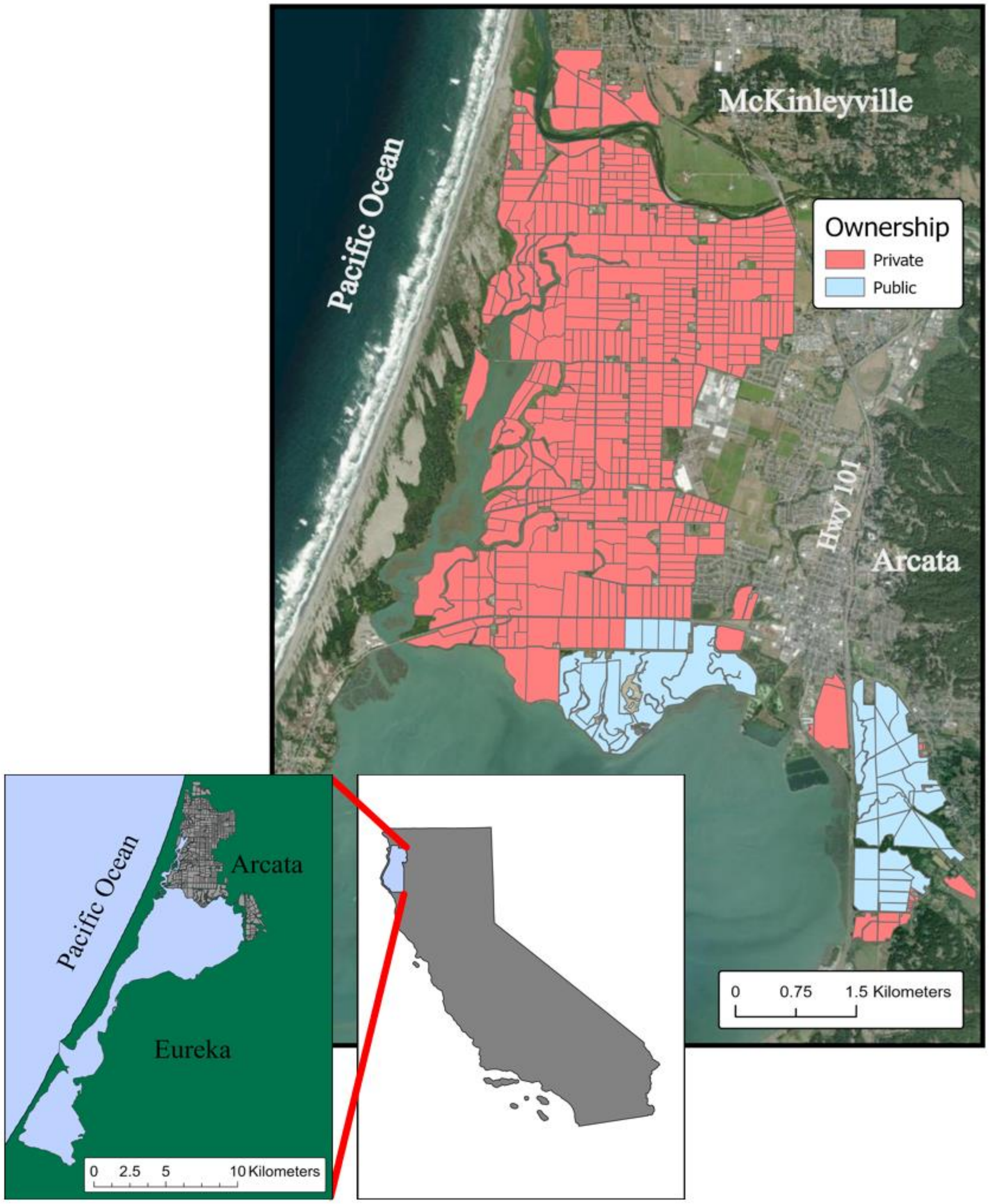

Figure 1. Map showing the location of Arcata Bottoms study area, outlined in black, north of Humboldt bay in Arcata, California, US. Red fields indicate privately owned fields whereas blue fields indicate publicly owned fields (WGS 1984 UTM Zone 10N).

grazed by beef cattle (*Bos tarus*) on privately and publicly managed lands (beef: n = 277 private, 32 public fields); 2) grazed by dairy cows on privately managed lands (dairy: n = 134 fields); 3) managed wildlife areas on publicly managed lands (restoration: n = 18 public fields); and 4) other non-grazed agriculture privately managed lands (NGA: n = 77 fields), including fields mown for silage or hay, flower bulb meadows, and recently plowed crop fields. Public ownership (n = 50) comprised two areas at the north end of Humboldt Bay managed by CDFW and CalTrans, to the southeast an additional area was managed by the City of Arcata.

Three publicly managed parcels functioned as potential AFAs for Aleutian geese in 2022. 1) Mad River Slough Wildlife Area (MRSWA) managed by CDFW (40 ha), 2) 'Humboldt Bay Area Mitigation' (HBAM) managed by California Department of Transportation (CalTrans) (32 ha), and 3) Jacoby Creek - Gannon Slough Wildlife Area (JCGSWA) managed by the City of Arcata (228 ha). MRSWA was open to hunting from October – January 2022. All 3 wildlife public lands represented closed areas (no hunting or public access) during the late-season-hunt from 24 February to 10 March 2022. HBAM and JCGSWA both had no public access at any time. MRSWA included an additional 105 ha of restored salt marsh habitats and tidal sloughs. Two fields in the center of this restoration area were grazed by beef cattle in 2007. No grazing was observed in my study. This absence of grazing has allowed MRSWA to become rank overgrown and unusable for geese, however, favorable for rodents and raptorial predators (Johnson and Horn 2008). In 2014, CalTrans purchased approximately 32 ha of land along V street, south of Samoa Highway, Arcata. It was restored to a wetland that contains shallow seasonal freshwater ponds and an intertidal channel that holds water for half of the year. In the southeast of the study area, in Sunny Brae, JCGSWA was managed by the City of Arcata for beef grazing that geese used as foraging fields. Similar to the Bottoms, tidal sloughs and seasonal waterbodies are found throughout the site.

Goose Surveys

Surveys of geese in Arcata Bottoms were conducted from a vehicle along a 33-km systematic roadside route. Surveys were conducted 4 – 6 times per week and began 1 January until the vast majority of geese left 21 April 2022. Starting times (morning, afternoon, evening) and locations (north, south) were alternated to reduce observer bias. Alternative counts were done to make up days with inaccurate or incomplete counts from poor visibility or significant disturbance events. Observations were divided into six periods within the spring staging season (Table 1). These correspond to periods of biological significance (staging start and population peak) and times of human related disturbance (Late-Season- Hunt). The six periods are as follows: Period 1 (Staging Start); staging begins during the regular hunting season with limited use of fields. Period 2 (Post-Regular-Hunt); geese expand field use from lack of hunting. Period 3 (Pre-Late-Hunt); time before the late-season-hunt spanning only 6 days, yielding a low sample size for modeling. Period 4 (Late-Season-Hunt); since 2007, the late-season-hunt has been used to shift geese onto public lands with high disturbance. Period 5 (New peak); time after the late-season-hunt and new peak in goose population occurred with highest levels of intraspecific competition. Period 6 (Departure); geese forage intensely and begin to

Table 1. Spring 2007 and 2022 survey periods used for data collection incorporated in logistic regression analyses (2007 periods; Spragens et al. 2015).

Period #	Survey Period 2022	Survey Period 2007	Biological Significance
1	STAGING START (Beginning January)	ARRIVAL (Beginning January)	Staging begins during regular season hunting. Geese exhibit exploratory behavior of landscape, safety in numbers. Second highest disturbance pressure in 2022.
2	POST-REGULAR HUNT (Early February)	POST-REGULAR HUNT (Early February)	Post-regular season hunt. Geese are able to use larger area of landscape.
3	PRE-LATE-HUNT (Mid-February)	PEAK (Mid-February)	Historic population peak in Arcata Bottoms region that was no longer observed. Shortest period (6 days) before the late-season-hunt.
4	LATE-SEASON-HUNT (24 Feb -10 Mar)	LATE-SEASON-HUNT (24 Feb -10 Mar 2007)	Late-season-hunt implemented to encourage goose use on public lands; highest disturbance pressure in 2022.
5	NEW PEAK (Late March)	POST-LATE HUNT (Late March)	Post-late-season hunt and new peak in goose population creates highest level of intraspecific competition.
6	DEPARTURE (Early April)	DEPARTURE (Early April)	The last two weeks of goose presence before departure to northern staging-areas. Geese exhibited intense foraging behavior.

migrate.

Flock size, location, and disturbance were recorded in ESRI's (Environmental Systems Research Institute) ArcGIS (geographic information system) Survey123 mobile application. Fields had corresponding names within a shapefile containing all fields in which flock counts were attributed to (Spragens et al. 2015). Fields were defined as used when one or more geese were observed foraging within the boundary of that field during an observation period. Observations were conducted using 8x binoculars (Nikon) and a 20x - 60x spotting scope (Leica).

Utilization of fields was measured via goosedays (goose-use-unit), where one goose observed within a field is equal to one gooseday (Owen et al. 1987, McKay et al. 2001). Total observed goosedays for a field, field type, and ownership was determined via summing count values. Assuming similar (average) goose use of field and field types on days not surveyed, estimates of total goosedays for the study area was derived from mean counts prior to and after the missing day (Owen et al. 1987).

Spatial Characteristics

A GIS was used to collect spatial habitat characteristics for each of the 556 fields. All GIS analyses were conducted using ArcGIS Pro 3.0.3. All polygon (field), point (goose surveys), and maps were projected in WGS (World Geodetic System) 1984 UTM (Universal Transverse Mercator) Zone 10N (North). Seven spatial factors were reselected from Spragens et al. (2015) that were important to goose forage site selection and from general goose ecology literature (Owen 1977, Black et al. 2004, 2007). Selected factors were; 1) field size in ha, 2) distances from field edges, 3) roads, 4) tidal sloughs, 5) and structures, 6) surface water potential, and 7) a spatial auto covariate. The spatial join tool was used to combine goose survey data with field data (centroid, field type, distance to roads, etc.). Euclidean distance rasters were calculated for each forage site selection factor (field edge, sloughs, roads, and structures) at a 10-meter cell output. The extract multi-values to points tool was used to extract distance values into goose and field layers. The field polygon layer was adapted from Spragens et al. (2015) and tidal slough polygon layer was adapted from the City of Arcata. Surface water potential data was assumed to be similar for 2022 as in 2007 and reused from Spragens et al. (2015).

Two datasheets were created for 2 modeling approaches. Modeling approach 1 used field centroids and presence or absence for goose use. Approach 1 was used to create comparable models to analyze 2007 data against with field centroids as locations and presence/absence for use. Approach 2 used locations of goose flocks provided by Survey123 and observed flock size, used to investigate landscape characteristics at a finer scale.

<u>Disturbance</u>

I haphazardly counted hazing and hunting pressure attributable to all 556 fields. Sources of disturbance events included hazing (all-terrain vehicles, cattle rotation, etc.) and hunting activity (Mini et al. 2011). The total number of disturbances during the time of observation were ranked with a disturbance index value based on 2 categories; 0 (no disturbance events) and 1 (low disturbance) (Table 2).

Table 2. Disturbance index values for Arcata Bottoms fields during spring 2022 study.

Value	Level	Description
0	No Disturbance	No anthropogenic attempts of hazing were ever observed or heard about upon these fields. No hunting pressure. Geese were allowed to feed freely.
1	Low Disturbance	Farming equipment was moved on roads surrounding fields. Distant gunshots and empty hunting blinds observed. Geese were unphased by these activities and fed freely (100% of observed disturbances).

Public contribution

Public lands in Arcata Bottoms were not managed with intent to offer alternative foraging areas for Aleutian geese but may in effect do so. I quantified the contribution of public lands by summing total goosedays observed within publicly managed fields and interpreted model predictions of these fields.

Body Condition

To describe birds' body condition and rate of fat accumulation between years (Mini and Black 2009), I measured fat reserves via visual inspection using the abdominal profile index (API), adapted from Owen (1981). API estimates fat reserve content of a goose's abdominal profile (Figure 2). Studies of other goose species have shown that API rankings were linearly related to fat stores (Fe´ret et al. 2005, Madsen and Klaassen 2006, Zillich and Black 2014). I scored fatness of foraging geese that were standing, with head down, bodies parallel to the ground, and perpendicular to the observer in the field and via pictures (Owen 1981, Mini and Black 2009). Rankings ranged from 0 (convex) - 7 (very concaved) (Figure 2). Geese at the middle and edges of flocks were sampled to reduce possible bias due to flock position (Black and Owen 1989, Black et al. 1992). Estimations were conducted at the end of goose surveys to allow time for the digestive tract to be filled, following Owen (1981). Fifty - 250 API scores were collected per week and averaged weekly in each survey period (Mini and Black 2009). These data were used to compared to API values obtained from Aleutian geese in the study area in 2004.

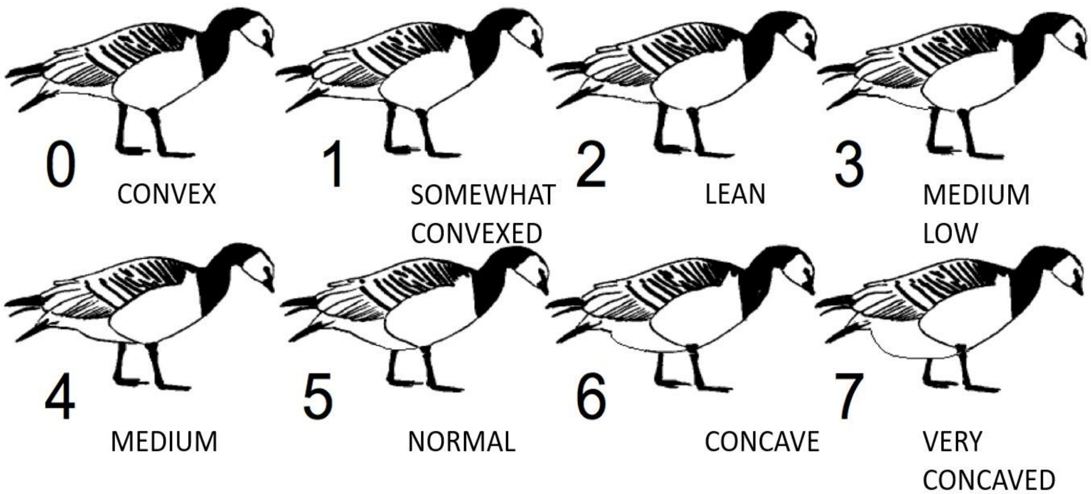

Figure 2. Abdominal Profile Index (API) rankings from 0 (convex) to 7 (very concaved) on barnacle geese (*Branta leucopsis*).

Statistical Analyses

Although geese were observed in the study area before observations began, my analyses focus on spring staging from 1 January to 21 April 2022 (Sparks 2021). Four field classifications were used for all analyses except the number of fields visited and revisited, modeling, and selection ratios. Where feasible, I reported percent change from 2022 estimates to 2007 estimates (Spragens et al. 2015). For visits, revisits, and modeling, fields were classified by combining ownership and type to make public beef, private beef, private dairy, and private NGA. Restoration fields were lumped into public beef. This was done to reduce collinearity between field types and to bolster sample size when low when modeling. For predictive modeling approach 1: goose presence was the response variable; field characteristics were the independent variables; and sample units were fields of the study area. For modeling approach 2: flock size (>0) was the response; field characteristics and period were the independents; and sample units were goose flocks. Absences of geese were not included in modeling approach 2. When comparing disturbance events between my study and 2007 (Spragens et al. 2015), values at or above DI value 2 in 2007 represented disturbances that caused geese to take flight. During my study no geese took flight as a result of observed sources of disturbance, enabling a comparison at low levels of disturbance (DI = 1). In comparing API scores from 2004 (Mini and Black 2009), all disturbances in this study were events that caused 50% or more of a flock to take flight attributed to a source (i.e. shotgun, ATV, etc.). By this definition then, no disturbance events I observed would be counted as disturbance.

Spatial characteristics

To compare differences of geospatial characteristics of used beef and dairy fields, a one-way analysis of variance (ANOVA) was conducted for each characteristic. Broad comparisons for all periods of spatial characteristics in 2022 for used to unused fields were conducted using nonparametric Mann-Whitney U tests. Period specific analyses of spatial characteristics between used and unused fields were conducted using two-way analysis of variance. Tukey-Kramer multiple-comparison tests were used to identify direction of statistical differences. All analyses and modeling used a significance level of alpha = 0.05 and were conducted in R Studio Version 4.2.2.

Proximity

Proximity was assessed by comparing mean field centroid distance values for spatial characteristics from 2007 and 2022. Used and unused fields were grouped separately be able to compare significance of a year effect. However, full data was unavailable for 2007. Low sample size and predictive power rendered other statistical analyses unusable. Instead, percent change was calculated by:

$$\%\ change = \frac{(new - original)}{original} * 100$$

where ‘new’ is equal to mean 2022 values for the variable of interest and ‘original’ is mean 2007 values.

Distribution

Multiple strategies can be used by individuals within a population, making stopover ecology and goose migration complex. These strategies influence the timing of staging, spatial extent used, and carrying capacity (Madsen 2001, Prop et al. 2003). I used predictive modeling to describe these phenomena of Aleutian goose life history. Predictive modeling requires a generalization of patterns but sacrifices precision (Levins 1966, Guisan and Zimmermann 2000). I used generalized linear models (GLMs) with a binomial distribution to predict goose presence (modeling approach 1). For each survey period, I used the same set of 35 *a priori* models using observed goose presence (1) or absence (0) as the response variable. The following explanatory variables were included in each period: field size in ha, distance to roads, sloughs, and structures, presence or absence of disturbance, a spatial auto covariate used to measure the correlation of values of neighboring fields, surface water potential, and field type (private beef, public beef, private dairy, and private NGA). This modeling process used centroids of fields for location, making distance to field edge correlated with field size, therefore dropped from models.

I used a GLM with a negative binomial distribution to model goose flock size and location during each period (modeling approach 2). The same predictor variables as approach 1 were used including distance to field edge with a set of 27 *a priori* models. I used Akaike's Information Criteria (AIC) to evaluate models from both approaches (Burnham and Anderson 2004). Models within 2 AIC values of each other were considered competitive and were evaluated further. Performance metrics used for evaluation included R^2 for binomial models and a pseudo R^2 value for negative binomials, and model weight. Sub-sampling was used to cross validate binomial models and variable confidence intervals for negative binomial models.

Predictive mapping

Using the raster package, predictive maps were created for top binomial GLM models in each study period and one for the negative binomial GLM. However, period was dropped from the negative binomial model because it was not possible to rasterize such a variable. After the top model was inputted in R, all rasters represented in the model were compiled in a raster stack. The logistic function was used to predict probability of goose presence with the binomial GLM:

$$p = \exp(z)\,/(1 + \exp(z))$$

p is a value between 0 and 1, equal to the probability of that outcome, exp(z) is the exponential function of input z variable, z is the prediction applied to the top model given the raster stack.

Flock size

In predicting flock size, a negative binomial distribution was used over a Poisson because of overdispersion calculated by residual model deviance divided by residual degrees of freedom (Manly et al. 2002, McDonald et al. 2005). Flock size was predicted with the negative binomial GLM model with the logistic function:

$$z = raster :: predict(rasterstack, top\ model)$$

Past use

I analyzed changes in goose utilization of the Bottoms by comparing selection ratios for each field type in 2005 - 2007 to 2022 (Spragens et al. 2015). A selection ratio is the proportion of a resource used to the proportion available (Manly et al. 2002). Goosedays and field size were measurements of resources on different field types.

Therefore, the selection ratio is the proportion of goosedays present on a field type and the proportion of area of that field type during each year. Ratios were derived for each period to investigate impacts of study period. Pearson chi-square statistics were calculated with the following formula:

$$\chi_p^2 = \sum_{i=1}^{c} (O_i - E_i)^2 / E_i$$

O_i is observed sample frequency, E_i is expected value of O_i according to the hypothesis being considered, and the summation over all resource categories (McDonald et al. 2005). Standard errors were calculated for selection ratios according to Manly et al. (2002):

$$SE(Oi) = \sqrt{\{Oi(1 - Oi)/U_+}$$

O_i is observed proportion used, and U_+ is the total number of used resource units sampled. From this a 95% confidence interval can be calculated for each selection ratio (SR):

$$SR\_estimate \pm Z_{\propto/2} * SE$$

$SR\_estimate$ is the selection ratio of interest, $Z_{\propto/2}$ is the critical value, and SE is standard error. Higher selection ratio values indicate selection of a field type above expected proportional availability of that type on the landscape; SR>1.

Body condition

I assessed variation in body condition (API) from weekly averaged scores using two-way ANOVA with week (1-10) and year (2004 or 2022) as factors. I used a 2-sample t-test to detect which year had higher mean API for each week.

RESULTS

Seventy-eight goose surveys were conducted from 1 January to 21 April 2022. During this time, 1,472,595 goosedays and 3,389 flocks were observed, with an estimated total of 2,248,512 goosedays (Figure 3). Estimates for 2022 were 215.9% and 236.9% higher than 2007 estimates of 466,101 observed and 667,485 estimated goosedays, respectively. Numbers peaked on 18 March (Period 5) 2022 at 70,146 geese, which was 22 days later than in 2007 when numbers peaked on 25 February (Period 4) 2007, at 17,882 geese (Spragens et al. 2015). In 2022, numbers had increased to 39,000 the day before the late-season-hunt began and fell 86.1% to just 5,400 geese on the first day of the late-season hunt. Spragens et al. (2015) reported a less substantial decline in numbers (44.1%) coinciding with the late-season-hunt in 2007 from 17,882 to 10,000 geese. In 2022, goose numbers rebounded after the late-season-hunt and continued to increase until 2 April 2022 (Period 6) after which numbers declined (Figure 4).

In 2022, geese were observed foraging on 395 of 556 fields available (Figure 5), which increased by 38.6% since 2007 when 258 of 529 fields were used (Spragens et al. 2015). In 2022, 39 fields - the top 10% - contained 40% of total observed goosedays. Number of fields used per day increased throughout the spring, reaching a maximum of 124 fields on 2 April 2022 (Period 6). At which point goosedays and number of fields used began declining (Figure 6). Fields were visited repeatedly during the study differing in type and period (Table 3).

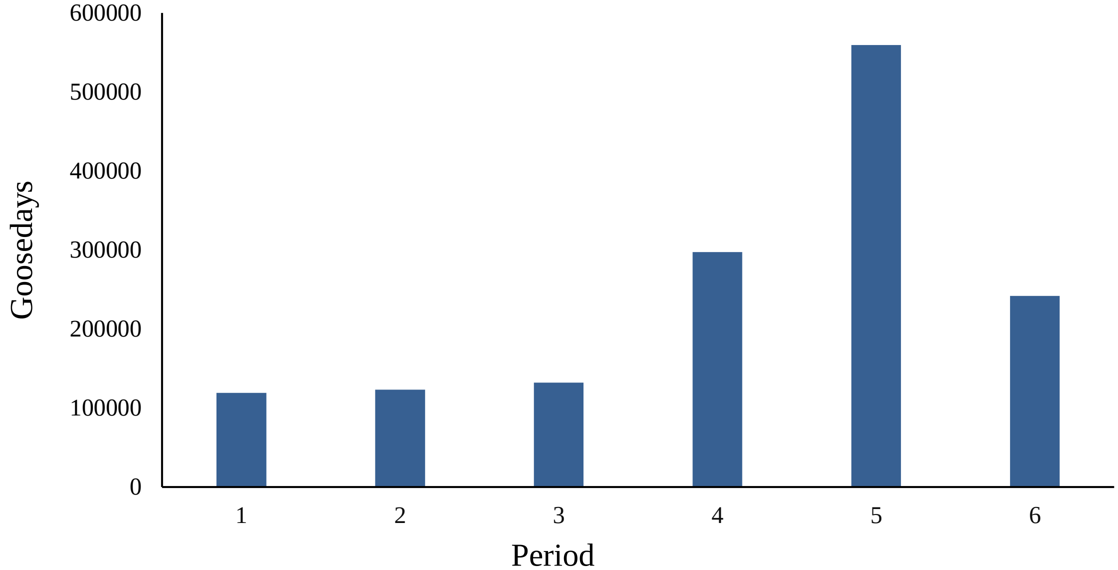

Figure 3. Total goosedays per period observed in Arcata Bottoms study area during spring 2022, Arcata, Ca.

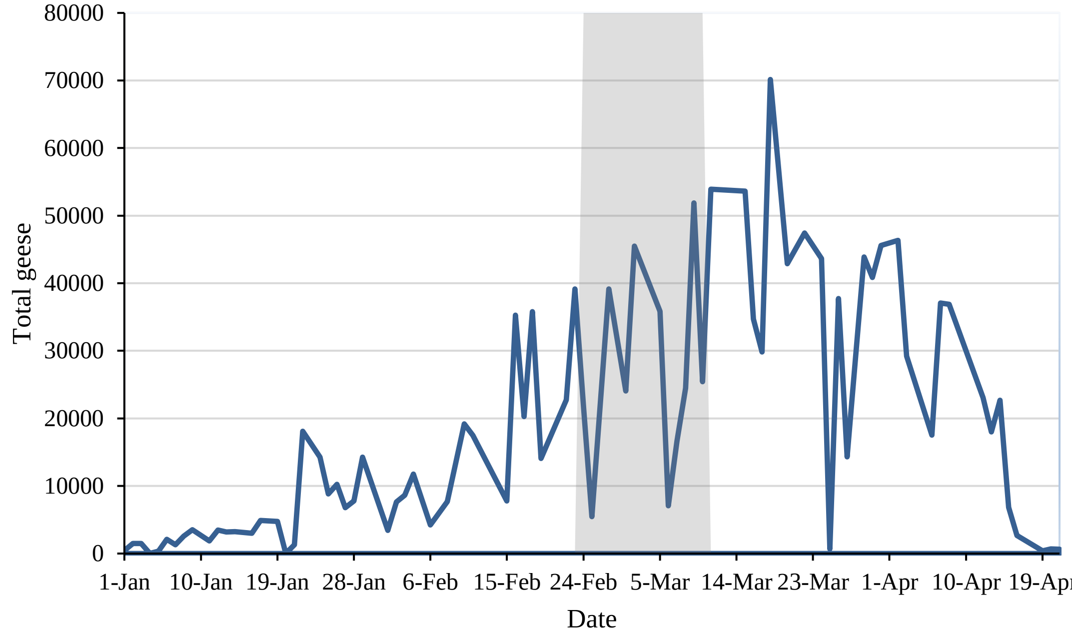

Figure 4. Aleutian goose abundance on Arcata Bottoms during spring 2022. Shaded area represents the late-season-hunt period intended to shift geese to public lands and off private lands. Peak count occurred on 18 March 2022.

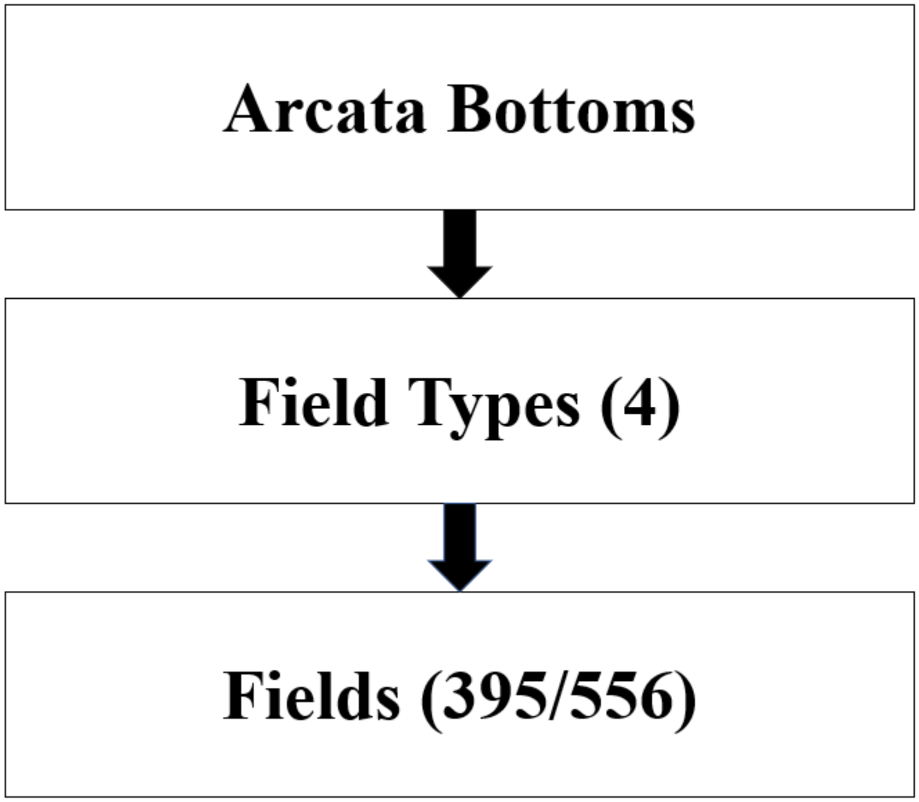

Figure 5. Hierarchical divisions of Arcata Bottoms staging area during spring 2022. Number in parentheses represent the number of each respective category utilized out of the total available on the landscape. All 4 field types were utilized in 2022.

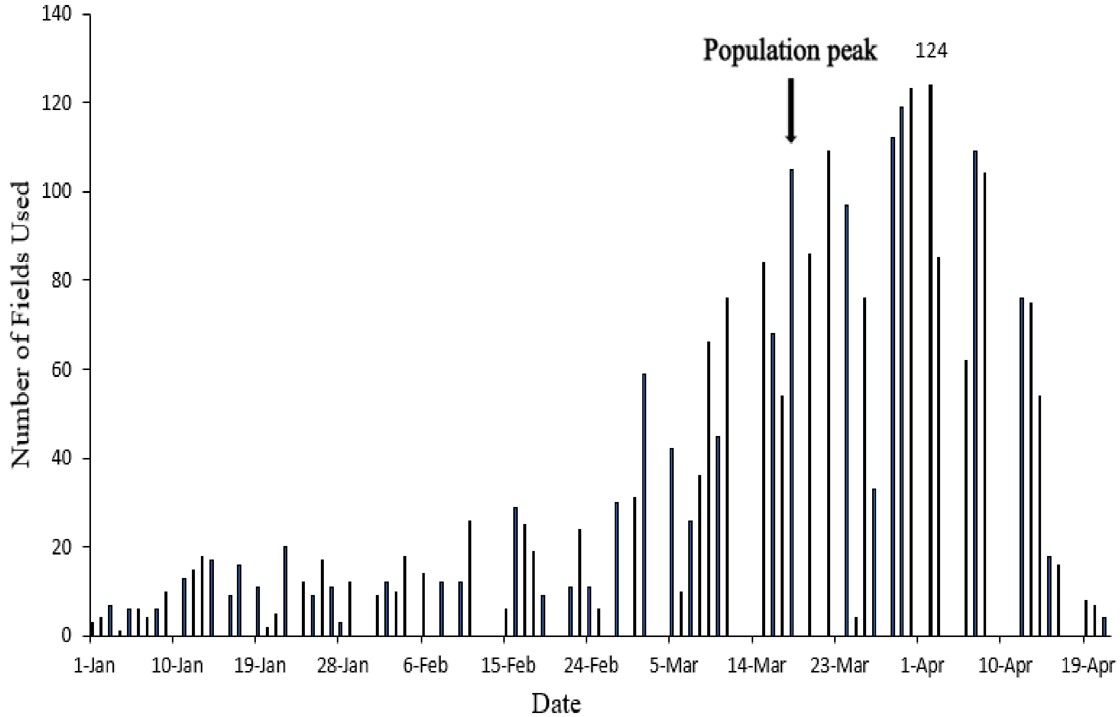

Figure 6. Number of fields observed being utilized during spring surveys. Maximum number of fields used (124) on a given day occurred 2 April 2022, while population peak occurred on 18 March 2022.

Table 3. Summary of foraging field visits and revisits. The total number of fields in Arcata Bottoms within each field type. The number of visited during each period during spring 2022 (left) and number of revisits to fields during each period (right).

Field Type	N Visit	1	2	3	4	5	6	N Revisit	1	2	3	4	5	6
BEEF - PRIVATE	532	12	38	41	109	185	147	1571	53	86	58	254	698	422
BEEF - PUBLIC	122	29	23	15	22	20	13	495	208	45	29	82	77	54
NGA	65	7	4	3	11	24	16	160	34	11	4	17	61	33
DAIRY	285	3	25	11	48	103	95	1163	8	56	20	119	556	404
Totals	*1004*	*51*	*90*	*70*	*190*	*332*	*271*	*3389*	*303*	*198*	*111*	*472*	*1392*	*913*

Field Characteristics

Field type

All four field types were used during each survey period during spring 2022. Goose use of beef fields, proportionally was ≥50% for all periods except Period 6 (Departure) (Figure 7). Period 6 (Departure) dairy fields were at peak use (50%), an increase from 2.6% utilization in Period 1 (Staging Start). Publicly managed land was at its highest use (55%) during Period 1, more than private land (45%) but was not utilized at a high proportion again (see Past Use section, and Figure 7). However, a notable increase to 11% utilization occurred during Period 4 (Late-Season- Hunt).

Spatial characteristics

When compared broadly, Mann-Whitney U tests revealed two spatial landscape characteristics between used and unused fields were significantly different. Fields used by geese tended to larger in size ($W = 22150, p < 0.001$) and had a higher surface water potential ($W = 24970, p < 0.001$) than unused fields (Table 4). Period specific analysis revealed field size (ha) was larger in used fields versus unused fields $\left(\text{ANOVA; use: } F_{1,3324} = 98.335,\ p < 0.001; \text{interaction: } F_{5,3324} = 7.653,\ p < 0.001\right)$ in all periods. Distance to slough $\left(\text{ANOVA; use: } F_{1,3324} = 94.141, p < .001; \text{interaction: } F_{5,3324} = 4.706, p < .001\right)$ was lower in used versus unused fields in all periods. Distance to roads was lower between used and unused fields in Period 3 (Pre-Late-Hunt), Period 4 (Late-Season-Hunt), Period 5 (New Peak) and Period 6 (Departure)

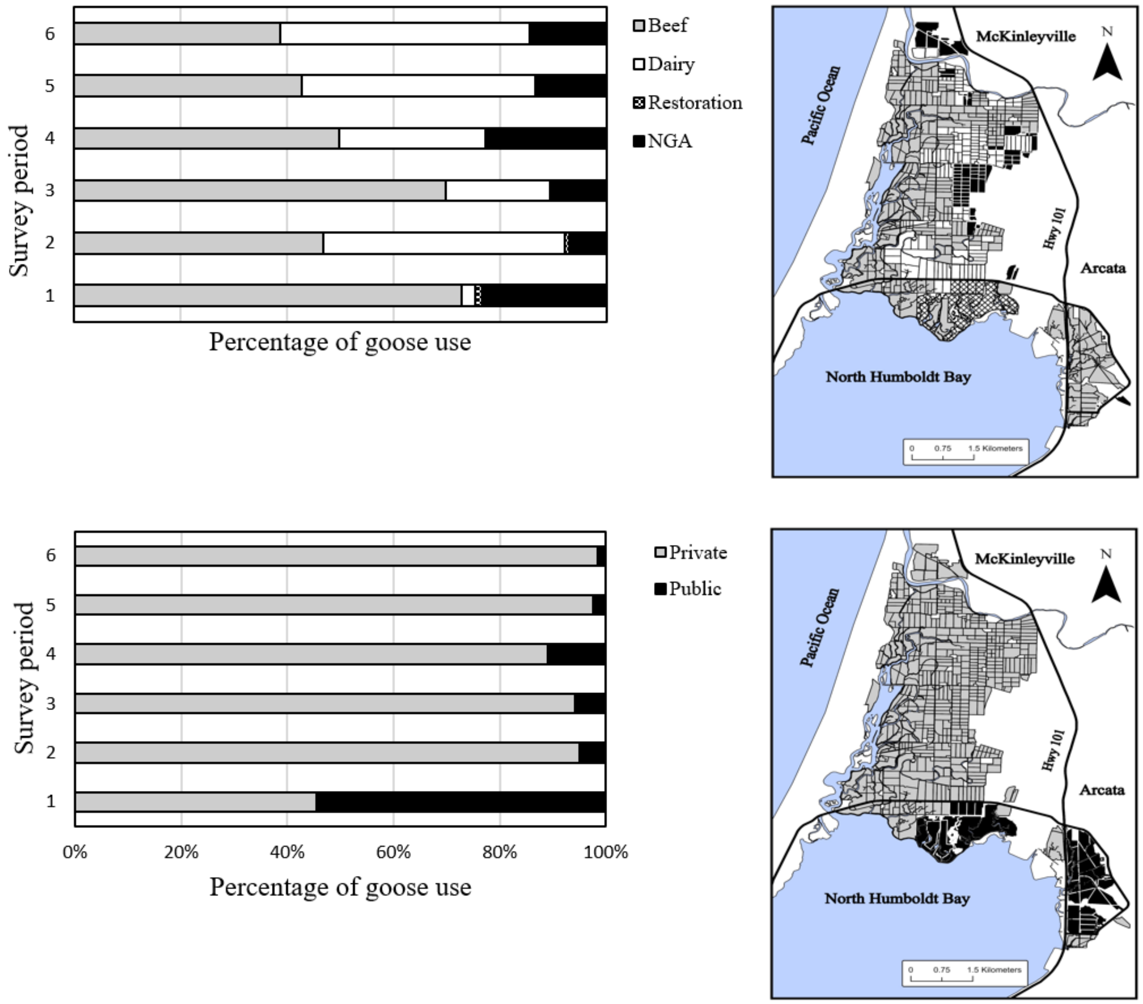

Figure 7. Percent of goose use on the four field types and type of ownership during each of the six survey periods during spring staging, 2022. Aleutian geese used beef fields, which were generally closer to tidal sloughs, earlier in the season and then used a mix of primarily beef and dairy as the season progressed. When Aleutian geese first arrived in Arcata Bottoms (Period 1), represented the only period geese used public land greater than in proportion to its availability. Shading in graphs correspond to field and ownership types in maps.

Table 4. Summary of non-parametric Mann-Whitney U tests conducted to compare spatial characteristics of used (left) and unused (right) fields within Arcata Bottoms in Humboldt County, California based on spring utilization by Aleutian geese from January 2022 – April 2022.

Used	Mean	Range	SE	n	Unused	Mean	Range	SE	n	P value
Area (Ha)	4.60	0.08-29.92	0.204	395		3.58	0.01-55.58	0.462	161	<0.001
Road	250	20-1010	9.36	395		317	10-1190	21.95	161	0.2178
Slough	413	0.5-1744.9	19.62	395		539	0-1765.51	39.3	161	0.0704
Struct	275	10-993.60	9.41	395		312	14.14-1164.08	20.3	161	0.8947
Waterpot[a]	1.82	0-63.14	0.23	395		1.33	0-21.32	0.26	161	<0.001

$\left(\text{ANOVA; use: } F_{1,3324} = 32.262,\ p < 0.001;\ \text{interaction: } F_{5,3324} = 2.344,\ p = 0.039\right)$. Distance to structures was higher in used versus unused fields in Period 1 (Staging Start) and Period 3 (Peak), but lower in Period 5 (New Peak) and Period 6 (Departure) $\left(\text{ANOVA; use: } F_{1,3324} = 7.310, P < 0.001; \text{interaction: } F_{5,3324} = 5.480,\ p < 0.001\right)$. Surface water potential was higher in used versus unused fields in Period 1 (Staging Start), 2 (Post-Regular-Hunt), 3 (Peak), and 4 (Late-Season-Hunt) $\left(\text{ANOVA; use: } F_{1,3324} = 36.131,\ p < 0.001; \text{interaction: } F_{5,3324} = 7.888,\ p < 0.001\right)$. Between used beef and dairy fields, beef field size (ha) was larger (ANOVA; use: $F_{1,354} = 4.274, p = .039$) were farther from sloughs (ANOVA; use: $F_{1,354} = 23.32, p < .001$), and structures (ANOVA; use: $F_{1,354} = 18.97, p < .001$), and had higher surface water potential (ANOVA; use: $F_{1,354} = 7.09, p = .008$).

Proximity

Between used ($W = 10, p = .690$) and unused fields ($W = 10, p = .690$) Mann-Whitney U tests revealed no significant difference between 2007 and 2022 (Spragens et al. 2015). Of used fields in 2022, geese were observed in an average field size of 4.60 ha, 8% smaller than in 2007 when geese were observed in a field size of 5 ha. Geese were an average of 250 m away from roads, 17% closer to than in 2007 when geese were 303 m away. Geese were an average 413 m from sloughs, 30% closer than in 2007 when geese were 594 m away. Geese were an average 275 m away from structures, 19% closer than in 2007 with geese 339 m away. Geese were observed in fields with an average water potential value of 1.82, a 9,000% increase compared to 2007 when geese were found in fields with a 0.02 water potential value.

Disturbance

Disturbances in my study were less frequent in 2022 (n=81) than in 2007 (n=487), additionally, all observed sources of disturbance scored a DI value of 1, therefore all disturbance events were summed together. Number of disturbances were highest on beef fields accounting for ~68% of all disturbance events (Table 5), the majority occurred in Period 4 (Late-Season-Hunt). Private lands contained triple the amount of disturbance events than public lands. Fields types that were least utilized (restoration and non-grazed agriculture) remained at little to no disturbance throughout the study (Table 5).

Distribution

Characteristics of used and unused fields in relation to spatial distribution were analyzed using GLM models and differed between each survey period (Table 6). Top models indicated that predicted goose presence: increased with 1) field size in all survey periods, 2) were closer to roads and sloughs in all periods except the first, and 3) increased with the presence of disturbance in all periods (Table 7). Spatial auto correlation was highest in Period 1 (Staging Start) but was weak in all periods. Of field types included in top binomial models, all were predicted to have higher use (Table 7). Predicted use increased with dairy and public beef fields in Periods 2 (Post-Regular-Hunt), 3 (Pre-Late-Hunt), 5 (New Peak), and 6 (Departure). The variable private beef did

Table 5. Summary of disturbances on number of fields stratified by field type and ownership during the six survey periods conducted January 2022 - April 2022 in Arcata Bottoms. All disturbance index values were equal to one, numbers represent a total count of all disturbances.

	Period	1	2	3	4	5	6	*Total*
Field Type								
	Beef	15	10	0	27	2	1	55
	Dairy	0	3	2	6	4	0	15
	Restoration	2	0	0	0	0	0	2
	NGA	4	0	0	2	3	0	9
	Total	21	13	2	35	9	1	81
Ownership								
	Public	11	3	0	6	0	0	20
	Private	10	10	2	29	9	1	61
	Total	21	13	2	35	9	1	81

Table 6. Top logistic regression models for predicting presence of Aleutian geese on fields for each of the six survey periods during spring staging in Arcata Bottoms, Arcata, CA, 2022. Models are displayed based upon AICc values. All models within 2 AICc values are shown. AIC weights give relative support of data for each model and can be considered as relative support for each period (i.e. in Period 2 the top model has 2.7 times the support that the next competing model has .578/.211=2.7).

Model	Description	R^2	k^1	AICc	Delta AIC	log likelihood	AIC weight
Period 1							
*13	ha+waterpot+dist+ac**	0.386	5	137.5	0.00	-63.704	0.727
12	ha+struct+waterpot+dist+ac**	0.386	6	139.5	1.96	-63.664	0.273
Period 2							
*4	use~ha+slough+road+dist+ac**+waterpot+dpriv+bfpub	0.256	9	384.9	0.00	-183.286	0.578
1	use~ha+slough+road+dist+ac**+waterpot+ngapriv+dpriv+bfpub+bfpriv	0.256	10	386.9	2.01	-183.255	0.211
2	use~ha+slough+road+dist+ac**+waterpot+ngapriv+dpriv+bfpub	0.256	10	386.9	2.01	-183.255	0.211
Period 3							
*4	use~ha+slough+road+dist+ac**+waterpot+dpriv+bfpub	0.279	9	321.7	0.00	-151.677	0.475
1	use~ha+slough+road+dist+ac**+waterpot+ngapriv+dpriv+bfpub+bfpriv	0.279	10	323.7	1.99	-151.636	0.175
2	use~ha+slough+road+dist+ac**+waterpot+ngapriv+dpriv+bfpub	0.274	10	323.7	1.99	-151.636	0.175
3	use~ha+slough+road+dist+ac**+waterpot+ngapriv+bfpub	0.279	9	323.7	2.01	-152.681	0.174

Table 6 (*continued*)

Model	Description	R^2	k^1	AICc	Delta AIC	log likelihood	AIC weight
Period 4							
*10	use~ha+slough+road+struct+waterpot+dist+ac**	0.296	8	518.9	0.00	-251.319	0.412
3	use~ha+slough+road+dist+ac**+waterpot+ngapriv+bfpub	0.298	9	519.3	0.38	-250.479	0.339
4	use~ha+slough+road+dist+ac**+waterpot+dpriv+bfpub		9	519.9	1.00	-250.789	0.249
Period 5							
1	use~ha+slough+road+dist+ac**+waterpot+ngapriv+dpriv+bfpub+bfpriv	0.224	10	602.2	0.00	-290.919	0.361
*2	use~ha+slough+road+dist+ac**+waterpot+ngapriv+dpriv+bfpub	0.224	10	602.2	0.00	-290.919	0.361
3	use~ha+slough+road+dist+ac**+waterpot+ngapriv+bfpub	0.220	9	602.8	0.52	-292.218	0.278
Period 6							
1	use~ha+slough+road+dist+ac**+waterpot+ngapriv+dpriv+bfpub+bfpriv	0.241	10	604.6	0.00	-292.099	0.405
*2	use~ha+slough+road+dist+ac**+waterpot+ngapriv+dpriv+bfpub	0.241	10	604.6	0.00	-292.099	0.405
3	use~ha+slough+road+dist+ac**+waterpot+ngapriv+bfpub	0.237	9	606.1	1.51	-293.889	0.191

* = top model after cross validation, k^1 = number of parameters
** = spatial auto covariate used to assess correlation with neighboring fields used

Table 7. Coefficients from each top binomial GLM model. Coefficients marked with a "+" are binary variables and indicated a positive relationship.

Terms	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Ha	0.4662	0.298	0.538	0.718	0.678	0.676
Slough		-0.950	-0.595	-0.583	-0.348	-0.311
Road		-0.323	-0.514	-0.302	-0.316	-0.377
Disturbance	+	+	+	+	+	+
AC*	1.453	0.187	0.745	1.024	1.031	1.108
Waterpot	0.498	0.383	0.382	0.230	-0.013	0.027
NGApriv					+	+
DAIRYpriv		+	+		+	+
BEEFpub		+	+		+	+
BEEFpriv						

* = spatial auto covariate used to assess correlation with neighboring fields used.

not appear in any top models. Goose use was predicted to be closer to sloughs during Period 2 (Post-Regular-Hunt) but furthest during Period 6 (Departure). Maps for the top performing model of each period depict shifts in regions of highest probability of Aleutian goose use. For example, from Period 3 (Pre-Late-Hunt) to Period 4 (Late-Season-Hunt) there was a visible shift from few fields with differing field types to use of man dairy and private beef fields. (Figure 8).

Relative Use

The negative binomial distribution GLM used to predict flock size of Aleutian geese suggested that size and distribution of flocks were influenced by time period and sets of environmental and spatial variables during spring staging (Table 8). Predicted flock size got smaller as field size increased. Flock size was predicted to increase at larger distances from roads and increased with presence of disturbance. Spatial autocorrelation was weak during the study, having very little effect on flock size (Table 9, 10). Publicly managed beef fields (bfpub) had a strong negative effect, with smaller flock sizes being predicted in them (Figure 9). The remaining field types ngapriv (NGA), dpriv (dairy), and bfpriv (private beef), were not good predictors of flock size on fields. Compared to Period 1 (Staging Start), Period 3 (Pre-Late-Hunt) was predicted to have larger flock sizes, but Period 5 (New Peak) and 6 (Departure) were predicted to have smaller flock sizes with Period 6 having the smallest flock sizes.

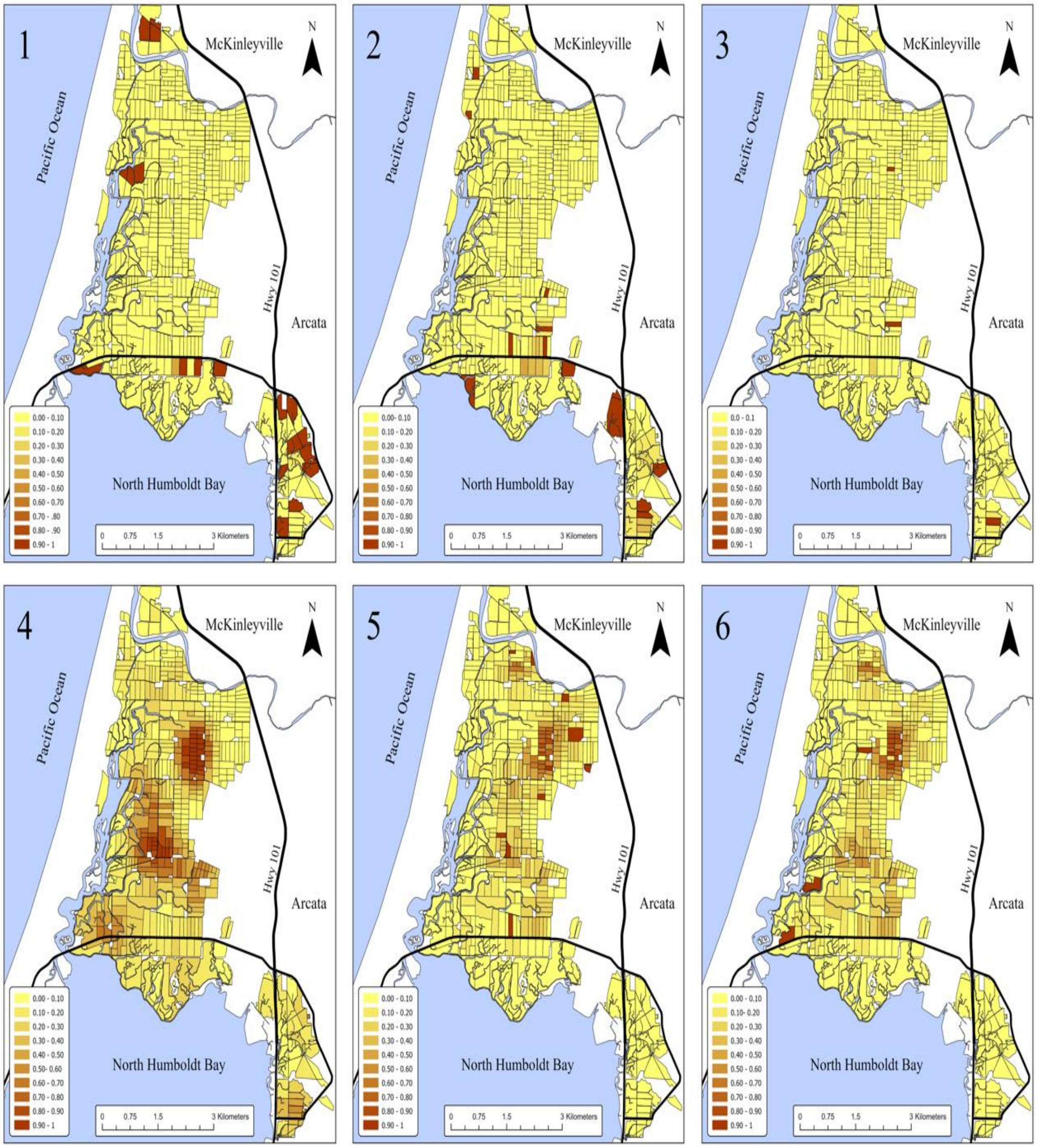

Figure 8. Period-specific maps for the probability of use for Aleutian cackling geese in fields of Arcata Bottoms during spring staging. Values are derived from binomial logistic regression analyses. Darker values represent higher probabilities of use.

Table 8. Top negative binomial logistic regression models for predicting goose abundance on fields for the entire duration of the study during spring staging in Arcata Bottoms, Arcata, CA, 2022. Models are displayed upon AIC values. All models within 2 AIC values are shown (Burnham and Anderson 2002). AIC weights give relative support of data for each model.

Model	Description	Pseudo R^2	k^1	AICc	Delta AIC	Log likelihood	AIC weight
*18	goosedays ~ period+ha+field+road+struct+waterpot+dist+ac**+bfpub	0.0162	10	46820.4	0.00	-23395.14	0.408
17	goosedays ~ period+ha+field+road+slough+waterpot+dist+ac**+bfpub	0.0162	10	46820.9	0.43	-23395.36	0.328

* = top model after cross validation, k^1 = number of parameters in each model
** = spatial auto covariate used to assess correlation with neighboring fields used

Table 9. Confidence intervals from top negative binomial logistic regression abundance model. Analysis used alpha = 0.95. Those variables with no value were not included in the top model.

Terms	5%	95%
Ha	-0.1438	-0.6612
Field	0.0044	0.0069
Slough		
Road	0.2388	0.3216
Disturbance	0.1077	0.4909
AC	0.0004	0.0007
Waterpot	-0.0952	-0.0213
NGApriv		
DAIRYpriv		
BEEFpub	-0.8533	-0.6269
BEEFpriv		
Period 2	-0.0361	0.3335
Period 3	0.5055	0.9425
Period 4	-0.0626	0.2372
Period 5	-0.5079	-0.2177
Period 6	-0.9522	-0.6505

Table 10. Coefficients from top negative binomial logistic regression abundance model. Those variables with no value were not included in the top model. Period 1 was used as the intercept to be able to compare others from.

Terms	Coefficient
Ha	-0.1054
Field	0.1665
Slough	
Road	0.2800
Disturbance	0.2943
AC	0.1248
Waterpot	-0.0596
NGApriv	
DAIRYpriv	
BEEFpub	-0.7410
BEEFpriv	
Period 2	0.1478
Period 3	0.7212
Period 4	0.0877
Period 5	-0.3618
Period 6	-0.8005

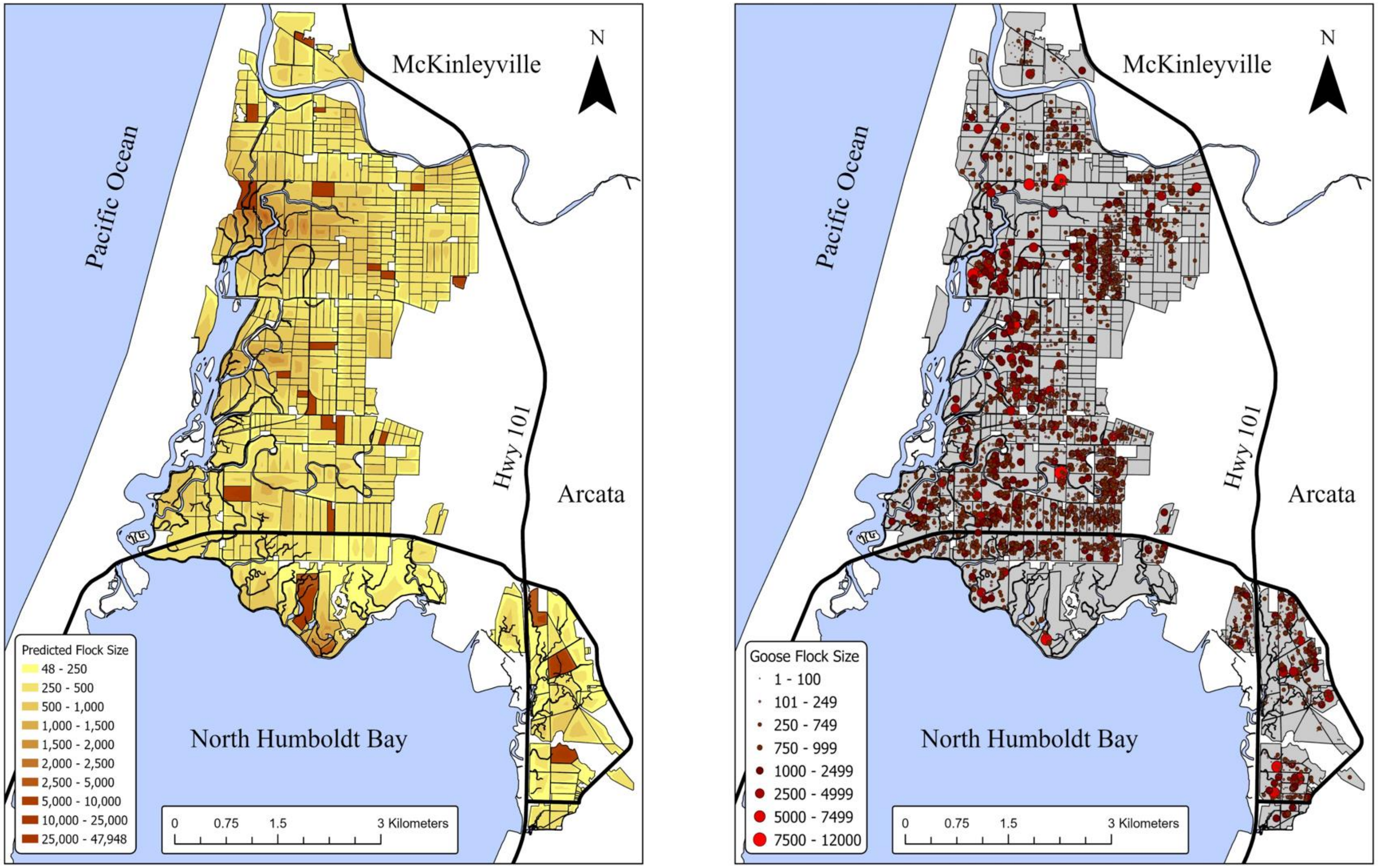

Figure 9. Maps showing predicted Aleutian cackling goose flock size (left) and observed goose flock sizes (right) overlain on fields of Arcata Bottoms, Arcata, Ca. Values are derived from negative binomial logistic regression analysis. Darker values represent higher number of predicted goose abundance. Larger and brighter red circles represent larger flock sizes.

Past Use

From 2007 to 2022 patterns of observed Aleutian goose foraging have significantly changed with population growth. Geese arrived earlier than in 2007 (Sparks 2021) and began departing in mid-April. In 2022, geese increased area of use to 1,816 ha with Spragens et al. (2015) reporting 761 ha. However, concentrations of geese per unit of area has increased over 200% to 366 goosedays per ha, close to concentrations observed in 2005 at 388 goosedays per ha (Table 11). Consistent with 2005-2007 patterns, largest total area of use was experienced during Period 5. Interestingly, patterns of a decrease in the number of goosedays per hectare following the historic ‘peak’ in mid-February (Period 3) was no longer experienced. Instead, in 2022, numbers of geese per hectare increased from mid-February to a ‘new peak’ in late March (Period 5) (Table 11).

Past years have shown that geese have increased total foraging area and expanded types of fields they forage in, a pattern that continued in 2022. In 2005, geese foraged only within beef and dairy fields and in 2006, foraged in public fields. Similar to 2007, geese used all four field types (beef, dairy, non-grazed agriculture, public) were used in 2022. However, selection ratios showed that geese exhibited differing proportions of use in 2022. Dairy fields were the most selected field type in all periods except for Period 1 (Staging Start) and 3 (Pre-Late-Hunt). Dairy field use, beginning in Period 4 (Late-Season-Hunt) began increasing until the end of the study (Table 12). Dairy fields experienced increased use compared to past years (ratios <2) in Period 5 (New Peak) and

Table 11. Summary of utilization of Arcata Bottoms spring staging area during spring 2005, 2006, 2007, and 2022(2005: Mini 2005; 2006-2007: Spragens et al. 2015; 2022: current study). The amount of land utilized by period is compared to the number of observed goosedays received. Relative densities of geese during each period allow comparisons of changing use.

Year		Total Area ha (acres)	Goosedays (relative proportions)	Goosedays/ha (goosedays/ac)
2005				
	1	--	--	--
	2	--	--	--
	3	331 (817)	128,485 (0.37)	388 (157)
	4	465 (1,148)	104,809 (0.30)	226 (91)
	5	562 (1,389)	92,288 (0.26)	164 (66)
	6	279 (689)	23,977 (0.07)	86 (35)
2006				
	1	--	--	--
	2	142 (350)	18,609 (0.06)	131 (53)
	3	295 (730)	74,254 (0.24)	251 (102)
	4	528 (1,305)	77,021 (0.25)	146 (59)
	5	923 (2,281)	120,531 (0.39)	131 (53)
	6	671 (1,658)	17,497 (0.06)	26 (11)
2007				
	1	177 (437)	28,706 (0.08)	162 (66)
	2	363 (896)	61,878 (0.17)	171 (69)
	3	583 (1,441)	95,056 (0.25)	163 (66)
	4	740 (1,828)	95,882 (0.26)	130 (52)
	5	761 (1,880)	46,893 (0.13)	62 (25)
	6	544 (1,344)	45,816 (0.12)	84 (34)
2022				
	1	404 (998)	119,146 (0.08)	294 (119)
	2	628 (1552)	123,110 (0.08)	196 (79)
	3	508 (1255)	132,021 (0.09)	260 (105)
	4	1068 (2639)	297,147 (0.20)	278 (112)
	5	1528 (3773)	559,195 (0.38)	366 (148)
	6	1267 (3131)	241,976 (0.16)	191 (77)

Table 12. Statistics for Selection Ratios comparing spring 2005, 2006, 2007, and 2022 by period for Aleutian goose foraging habitat selection. Left to right numbers correspond to selection ratios for each year and standard ratios. Numbers in parentheses are the standard error corresponding to each selection ratio. The standardized ratio helps to understand the magnitude of use on each field type.

Time Period	Field Type	2005	2006	2007	2022	2005	2006	2007	2022
Period 3									
	NGA	--	--	0.08 (0.000)	0.00 (0.001)	--	--	0.02	0.00
	Beef	1.44 (0.001)	1.50 (0.002)	1.37 (0.002)	1.49 (0.001)	0.73	0.73	0.34	0.54
	Dairy	0.54 (0.001)	0.55 (0.002)	1.01 (0.001)	0.92 (0.000)	0.27	0.27	0.25	0.34
	Public	--	0.00 (0.000)	0.18 (0.001)	0.33 (0.001)	--	0.00	0.04	0.12
	Sheep	--	--	1.43 (0.001)	--	--	--	0.35	--
Period 4									
	NGA	--	--	2.86 (0.001)	0.52 (0.001)	--	--	0.44	0.15
	Beef	1.29 (0.001)	0.62 (0.002)	1.12 (0.002)	1.12 (0.001)	0.65	0.19	0.17	0.31
	Dairy	0.69 (0.001)	1.39 (0.002)	0.43 (0.001)	1.30 (0.000)	0.35	0.42	0.07	0.37
	Public	--	1.33 (0.001)	1.47 (0.001)	0.61 (0.000)	--	0.40	0.23	0.17
	Sheep	--	--	0.58 (0.001)	--	--	--	0.09	--
Period 5									
	NGA	--	--	0.04 (0.000)	0.46 (0.001)	--	--	0.01	0.13
	Beef	0.81 (0.002)	0.78 (0.001)	1.03 (0.002)	0.97 (0.001)	0.40	0.36	0.24	0.26
	Dairy	1.20 (0.002)	1.33 (0.001)	1.53 (0.002)	2.09 (0.000)	0.60	0.62	0.36	0.57
	Public	--	0.04 (0.000)	0.09 (0.001)	0.13 (0.000)	--	0.02	0.02	0.04
	Sheep	--	--	1.56 (0.001)	--	--	--	0.37	--
Period 6									
	NGA	--	--	0.12 (0.000)	0.32 (0.001)	--	--	0.03	0.09
	Beef	0.89 (0.003)	0.92 (0.004)	1.28 (0.002)	0.90 (0.001)	0.45	0.43	0.36	0.25
	Dairy	1.11 (0.003)	1.18 (0.004)	1.36 (0.002)	2.35 (0.000)	0.56	0.55	0.38	0.64
	Public	--	0.06 (0.000)	0.00 (0.000)	0.09 (0.000)	--	0.03	0.00	0.02
	Sheep	--	--	0.81 (0.001)	--	--	--	0.23	--

6 (Departure). Beef fields ranked second among the most selected (SR>1) before Period 3 (Pre-Late-Hunt) but began to decline thereafter. The first 3 periods showed little selection of NGA fields, however, ratios increased in Period 4 (Late-Season-Hunt) and 5 (New Peak) (SR~0.50). Public fields received their highest use ever recorded in Period 1 (Staging Start) (SR >3, Figure 10), doubling those reported by Spragens et al. (2015). Still, public field use did not receive proportional use within its availability in any other period (Figure 10).

Public Contribution

Publicly managed fields may have served as AFA's to Aleutian geese by providing closed areas for them to forage in. Throughout all six study periods, public fields contained 9% (133,081 goosedays) of total goosedays. This included 2 restoration areas; 7,910 goosedays observed on CDFW fields, and 4,915 goosedays observed on CalTrans managed fields. The remaining 120,256 goosedays were observed grazed beef fields managed by the city of Arcata.

Body Condition

Body condition was measured to compare differences in the rate geese accumulated fat between years. Mean abdominal profile scores varied as a function of year ($ANOVA;\ F_{1,9} = 276.91, P < 0.001$), week $\left(ANOVA;\ F_{9,9} = 298.03, P < 0.001\right)$, and the interaction of year and week ($ANOVA;\ F_{9,9} = 26.08, P < 0.001$). Body

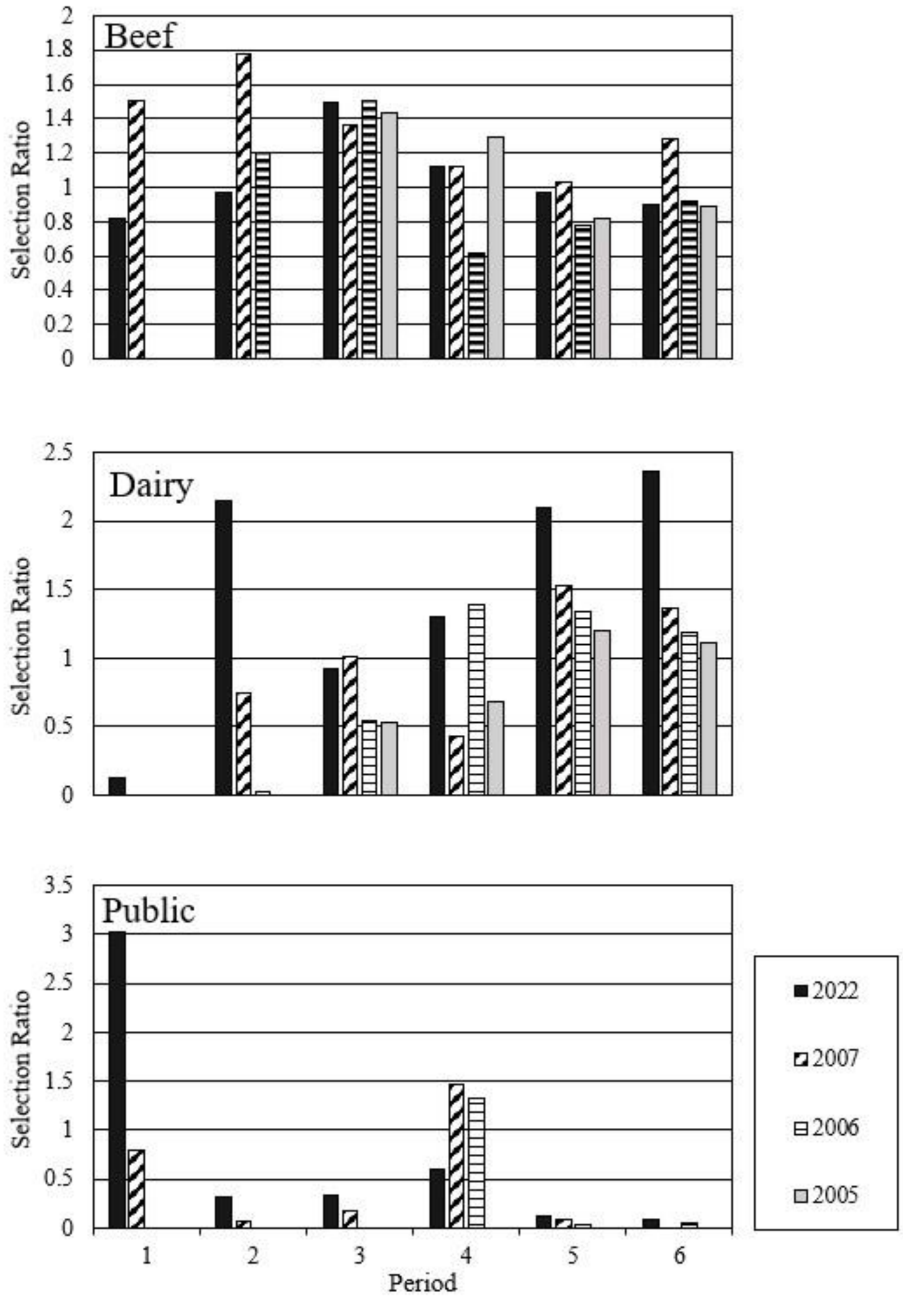

Figure 10. Comparison goose selection ratios throughout years 2005-2007, and 2022 (2005: Mini 2005; 2006-2007: Spragens et al. 2015; 2022: current study). Use ratio is the proportion of geese in a given time period to the proportion of that land type available. Use ratios > 1.00 represent goose use of a field type greater to the proportion available. Period 1 not utilized during 2005 and 2006, Period 2 was not utilized during 2005 from geese not being present in the study area.

condition was significantly lower in 2022 ($t = 18.05,\ df = 4485.8, P < 0.001$) than in 2004 (Mini and Black 2009). Rates of change per week were higher in 2022 ($0.15\ per\ week,\ SE = 0.14$) than in 2004 ($0.13\ per\ week,\ SE = 0.03$) (Figure 11).

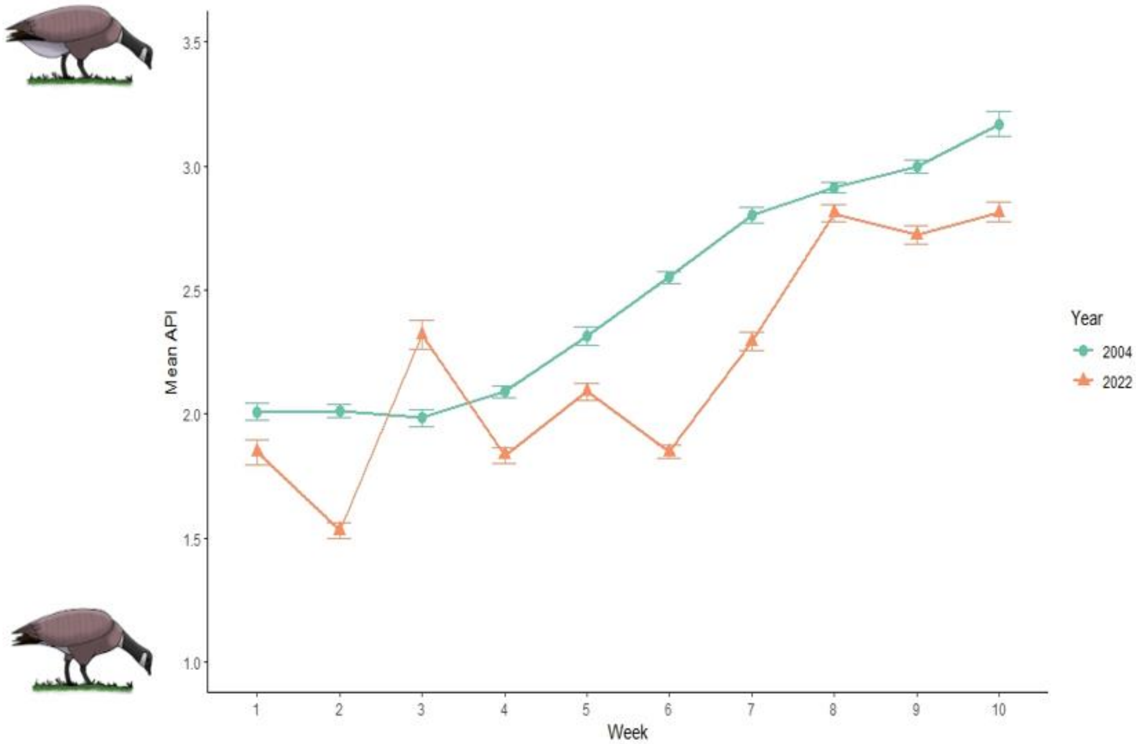

Figure 11. Mean Abdominal Profile Index (API) scores of Aleutian geese in Arcata Bottoms study area, February – April in two years (2004: Mini and Black 2009; 2022: current study). Data points are means derived from an average of 160.6 scores per week (range 109-361) in 2004; and from 318 scores per week (range = 146–499) in 2022. Standard error bars are shown for each week per year.

DISCUSSION

In 2022, Aleutian cackling geese continued to use pastures with a wide range of landscape characteristics in Arcata Bottoms spring staging area, primarily represented by livestock grazing practices. Goose use was highest on beef-cattle fields early and on dairy-cow fields later in the season. Spragens et al. (2015) investigated Aleutian goose use in the area in 2007 and found the same shift away from beef fields later in spring. Comparing values for 2022 with those from 2007, goose numbers more than doubled. In 2022, geese visited each field more than once. Revisits were most common in privately managed beef and dairy fields and least common in publicly managed beef and privately managed NGA fields. Revisits occurred most during period 5 (New Peak) and 6 (Departure). Ydenberg and Prins (1981) suggested that geese may benefit from foraging on the more nutritious and digestible new leaves in routinely grazed pastures, particularly during the period of spring fattening prior to migration.

Wild geese have been known to decrease distances to sources of disturbance over years as seen with pink-footed geese in wind farms (Madsen and Boertmann 2008). The proximity of used fields to roads and anthropogenic structures followed consistent patterns of decreasing distance when compared to unused fields throughout the study, except initially (Period 1 and 2) when distances to roads were similar. Interestingly, during Period 3 (Pre-Late-Hunt), the distance to roads decreased while the distance to structures increased. In Period 4 (Late-Season-Hunt), the distance to roads rebounded but subsequently decreased for the duration of the study. Meanwhile, the distance to structures continued to decrease after the initial increase observed in Period 3 (Pre-Late-Hunt) and persisted until geese migrated. During 2022, when all study periods were compared together, field size (ha) was larger and surface water potential was higher in used fields versus unused fields. It became apparent when broken down by period that the geese initially (Periods 1, 2, 3) used larger fields (typically beef fields) that were closer to tidal sloughs with higher water potential compared to unused fields. Field use changed later in the study (Periods 4, 5, 6) when geese used smaller fields (typically dairy) that were farther from sloughs with lower water potential compared to unused fields. Despite containing similar amounts of geese in the same periods, geese utilized contrasting sets of spatial characteristics as well, found in beef and dairy fields. Suggesting that in 2022, geese did not solely rely on landscape characteristics for forage site selection (Spragens et al. 2015).

As of 2022, the disturbance management plan that included the late-season-hunt was in place for 15 years. The most common source of disturbance was road noise in 2022 and was low and never resulted in geese taking flight. However, in 2007, the majority of disturbances caused geese to take flight. Over this amount of time disturbance pressure had eased possibly aiding in the explanation of discrepancies found in the proximity to spatial features between 2022 and 2007. In Europe, Chudzińska et al. (2015) suggested that when forage quality was relatively homogenous, pink-footed geese selected foraging sites based on predation/disturbance risk theoretical models. While not homogenous in my study, geese are expected to use an array of strategies when selecting foraging sites (Madsen et al. 1997, Jensen et al. 2017, Harrison et al. 2018). In 2022, geese were found in smaller fields, closer to roads, tidal sloughs, and structures, and in higher water potential than in 2007. Selection of smaller fields showed that geese may not have needed protection larger fields offer in the form of greater flock size capacity and predator detection (Madsen 1995, 1998, Chudzińska et al. 2013). Closer distances to potential sources of disturbance suggest that they no longer represented a significant enough disturbance to warrant larger distances. An alternative explanation for this pattern might be that geese foraged at edges of fields, closer to roads and structures, where forage is less depleted and higher biomass may be found as noted by Black and Owen (1989) in barnacle geese. On the contrary, geese increased distance to tidal sloughs and increased water potential, which is an antipredator strategy observed in other water bird species (Mayhew and Houston 1998, Berl and Black 2011). Disturbances were most frequent during Period 4 (Late-Season-Hunt), especially in beef fields, which contained 27 of 35 disturbances. In 2007, on the first day of the late-season-hunt, 56% of geese returned, redistributed amongst public fields (Spragens et al. 2015). However, in 2022, on the first day of the late-season-hunt only 14% of geese from the prior day, returned, suggesting that even with less intense disturbance geese avoided the study area. Geese numbers rebounded the second day of the hunt and continued to climb until geese began migrating. Perhaps this was in response to initial threats of hunting pressure, that later was observed to be low, allowing geese to return. The most numerous sources of disturbance were road noise in 2022. In contrast, in 2007, the most abundant source of disturbance was all-terrain-vehicles (ATV’s) that were used daily to scare geese. This decrease in disturbance may have also allowed geese to expand foraging range, increase repeated visits to fields, and form smaller flocks. Despite differing levels of disturbance pressure between 2007 and 2022, patterns of increasing visits and revisits during Period 4 (Late-Season-Hunt) and peak during Period 5 (New Peak) stayed consistent.

For a foraging site to be energetically profitable for wild geese, forage quality and time able to spend foraging are key factors. Studies of goose foraging ecology suggest that preferred fields are large, away from roads and human structures, and lack disturbance (Owen 1977, Summers and Critchley 1990, Madsen 1995, Simonsen 2014). In my study, analyses of predictive models revealed that in all periods, goose presence/absence models suggested geese preferred fields that were 1) large, having less perceived predation risk; 2) closer to roads which may no longer be perceived as anthropogenic sources of disturbance; 3) closer to sloughs which can fill seasonable waterbodies, creating favorable conditions for goose foraging, bathing, and drinking in early spring; and 4) contained disturbance. Period 3 (Pre-Late-Hunt) was the shortest of all periods spanning 6 days. Geese used the smallest number of fields during this period and therefore had a low sample size, which statistically, makes predictions difficult. This resulted in a map with low predicted presence. It was surprising that the probability of goose presence increased on publicly managed beef fields in most periods as this was not reflected in observed goose abundance. Although constant goose presence was observed on public beef fields, total goosedays observed within them was low. Not being able to predict goose numbers, rather only predicting presence or absence illustrates a limitation of this modeling approach. Goose presence was predicted to increase on dairy fields in the last two periods (5 and 6) during times when goose numbers were highest.

Geese may behave differently depending on the size of flock they are in (Lazarus 1978). Smaller flocks tend to occupy less space and are distributed in dense vigilant clusters. Larger flocks tend to be less vigilant, spread out quickly, and occupy more space (Black and Owen 1989, Carbone et al. 2003). In addition, forage depletion may cause geese with lower foraging success to move to smaller flocks with less competition, causing flock sizes to fluctuate (Rowcliffe et al. 2004). The same variables used to predict presence/absence were used to predict flock size with the addition of period as a variable. Public beef was the only field type that improved model performance of predicted flock size and was found to have a depressive effect. These fields were large, close to roads, and less disturbed than other field types, potentially allowing geese to spread out in smaller flocks. Period 3 (Pre-Late-Hunt) contained largest predicted flock sizes, coinciding when geese were rather sedentary. During this period low goose numbers were observed with fewer fields visited and the least number of revisits occurring. Geese primarily utilized public and private beef fields during this period. Although, this is likely due to a lack of data from such a short period. In contrast, Period 5 (New Peak) and 6 (Departure) had smallest predicted flock sizes with high visits and revisits using a mix of both beef and dairy. This was likely predicted from an influx of geese that increased competition and lowered forage abundance. Further investigation was done to explain the mismatch of predicted and observed results from the flock size model. Although some fields had high flock size predicted but low observed use, all did contain at least one or more observed goose flock. Between those fields with high predicted flock size but low observed use, fields were similar in size and water potential as those with high predicted flock size and high observed use. These fields were medium in size, being slightly larger than what was found in the comparisons of used and unused fields. Surface water potential of these fields was high and reflected what was seen in the used vs unused analysis. Other valuable variables that may improve models in the future could focus on the quality and quantity of forage and the propensity of geese to return to a field (past use).

Publicly managed pastures primarily managed for beef-cattle grazing may have functioned as potential AFAs. In 2022, public fields contained 9% of all observed goosedays, 90% of which were located within Jacoby Creek – Gannon Slough Wildlife Area (JCGSWA). In Period 1 (Staging Start) and Period 2 (Post-Late-Hunt), both JCGSWA and Humboldt Bay Area Mitigation had the highest presence predictions within the landscape. The only time Mad River Slough Wildlife Area (MRSWA) had presence predicted, it was low, in Period 4 (Late-Season-Hunt). MRSWA contained large predicted flock sizes in the final map, probably because of the suite of spatial characteristics it contained. Spatially, MRSWA differed from other public fields by being larger, further from structures, and had higher water potential, possibly outside of geese's preference. A notable lack of grazing of MRSWA had taken place in between studies of this region and vegetation has become overgrown. During Period 1 (Staging Start) when geese preferred high water availability lack of accessibility of this area may have made JCGSWA more attractive for geese. Geese did roost within MRSWA in 2007, suggesting it was quality habitat while being grazed (Spragens et al. 2015). In 2022, geese increased use of publicly managed fields in Period 1 (Staging Start) higher than previously recorded in 2007 during Period 3 (Pre-Late-Hunt). Initial high public land use and low use thereafter suggested that public fields did not contain high quality forage and/or that forage was depleted rather quickly, possibly leading geese to explore more profitable sites to accumulate sufficient fat reserves. In Period 4 (Late-Season-Hunt) both public and NGA fields experienced an increase in goose use but were not comparable to levels in 2007. Lack of intense disturbance pressure may have let geese prioritize higher quality sites in beef and dairy rather than NGA and public field types. NGA fields, after Period 4 (Late-Season-Hunt), maintained higher use than public fields possibly indicating higher quality forage sites.

Arctic breeding geese have a limited amount of time to accumulate fat reserve at stopover sites to prepare for migration and breeding (Prop and Black 1998, Ebbinge and Spanns 1995). Fat reserves accumulated during spring staging has been directly linked to reproductive success (Ankney and MacInnes 1978, Teunissen et al. 1985, Prop and Black 1998). Black et al. (2007) reported that barnacle geese sample less profitable sites before focusing on the most dense and nutritious patches. In 2007, the most nutritious forage was found in dairy fields, indicating another possible explanation for the shift observed from beef to dairy fields later in spring (Spragens et al. 2015). Geese accumulated fat quicker than in 2022 than in 2004, with higher weekly change in mean API scores. However, geese in 2004 had higher overall body condition throughout the entire study except period 3. During this time geese were colonizing the current staging site and experienced disturbance that resulted in 50% or more of the flock flying away, more frequently than combined sources of potential disturbances in 2022. In 2022, disturbances were not comparable to those in 2004 because geese did not take flight as a result of them. Rather they would be considered potential sources of disturbance in 2022. How then, could geese have lower body condition in 2022 if disturbance pressure is an important factor when accumulating fat? Bachman (2008) reported that Aleutian goose foraging intensity in the same study area was positively correlated with protein levels. Assuming previous findings of protein levels found in the area remains similar, foraging intensity was likely higher on dairy fields from high observed goose concentrations. These high concentrations persisted despite geese using more total area were probably explained by increased competition and rate of forage depletion causing geese to spread out. Therefore, rates of fat accumulation may have been limited by increased competition and the amount of forage. Early in spring, Spragens et al. (2015) suggested that spatial characteristics drove variation in distribution of Aleutian geese, whereas forage quality may drive goose distribution later in spring. Results of this study support this contention. This hypothesis illustrates a subset of the overall combination of factors that influence decisions of geese when selecting foraging sites (McKay et al. 1996, Black et al. 2007). Future studies could investigate the importance of proximity to sources of water at traditional sites over time, temporal differences in forage quality between field types, and carrying capacity of forage in Arcata Bottoms to better understand how and when geese select foraging sites. Ultimately, this will allow for better management decisions to effectively shift geese to alternative foraging areas, mitigate losses for agriculture, and reinforce the Aleutian goose as an asset to the community.

CONCLUSION

This reassessment of Aleutian goose spring staging indicates that patterns of goose spatial and temporal distribution have stayed relatively consistent over the 15-year interval. Both presence and flock size of Aleutian geese may be predicted on a combination of similar spatial characteristics, field type, and disturbance experienced. Between studies, goose numbers increased and disturbance pressure eased. This may have enabled geese to expand to new pastures within the study area and allowed for more foraging potential at the cost of increased competition. Geese continued to initially frequent pastures grazed by beef-cattle with lower forage quality, and shift to higher quality dairy-cow pastures (Spragens et al. 2015). This shift may adversely affect dairy farmers more than beef because proportionally, there were more geese on dairy fields than beef fields, likely containing greater foraging intensity. A recent study in the same area has suggested that Aleutian geese may provide an ecosystem service to private landowners that boosts productivity from fertilizer via goose droppings, offsetting some loss (Fagundes 2022). However, if populations continue to increase geese may disproportionately graze private land, increasing stress for farmers. Therefore, as managers, decisions could be made on how to mitigate losses while allowing geese to thrive. Continued conservation of this once endangered species requires that they represent an asset to the community they interact with rather than a pest.

Prior management of Aleutian geese in this area had focused on hazing and hunting programs to shift geese from private lands onto public lands to offset losses of private landowners (Spragens et al. 2015). Public land refuge areas (AFAs) in my study accounted for only 9% of total observed goosedays in the north Humboldt Bay area. The 105 ha pasture in CDFW's Mad River Slough Wildlife Area (MRSWA) had become over grown, and the 228 ha of Arcata City's Jacoby Creek - Gannon Slough Wildlife Area did not continue to attract large amounts of Aleutians throughout the study period.

Owen (1977) stated that "small refuge areas free from disturbance in traditional goose haunts can attract the birds from the surrounding area, and that proper land management may enable the carrying capacity to be more than doubled." I suggest we consider what "proper land management" to attract geese might mean in the Humboldt Bay area. Owen (1977) suggested to provide a disturbance-free habitat that is grazed by livestock during the months when geese are not present (May through mid-September) that would provide a short-sward upon the bird's arrival. Aleutian geese have a short-bill but avoided tall swards (>60 cm, Black et al. 2004) in favor of short (5-9 cm, Spragens et al. 2015) and short-medium height swards (13-30 cm, Black et al. 2004).

Mad River Slough Wildlife Area (MRSWA) has failed to uphold the objectives of the Aleutian goose working group, become overgrown and unusable to geese. Refuges that allow hunting, including MRSWA, have limited time to manage the area and ease the burden on local farmers. In addition, interpretive signage here explaining when access is allowed around the hunting season is not clear, with members of the public often mistaking the area as a recreational trail and disrupting the refuge. JCGSWA has no hunting but has livestock grazing throughout the year, rather than ensuring a goose-only season as employed by AFAs (Owen et al. 1987, Madsen 1995, Black et al. 2007, 2014).

Another promising Alternative Foraging Area may be created somewhere within dairy fields, as recommended by Spragens et al. (2015), that could retain geese during the latter half of staging, offsetting diary losses. Efforts to mitigate human-goose conflict could be improved upon with ‘proper land management’ of Alternative Foraging Areas for geese resulting in a significant and lasting solution (Owen 1977, Vickery et al. 1994, Mini et al. 2011, Fox et al. 2017).

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