



Habitat Relations

Geographic Variation in Migration Chronology and Winter Distribution of Midcontinent Greater White-Fronted Geese

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ABSTRACT We evaluated spatial and temporal differences in migratory behavior among different breeding groups of midcontinent greater white-fronted geese (*Anser albifrons*) using band-recovery data and observations of neck collared geese during migration and winter. Birds from different breeding areas were initially delineated by geographic distance into 6 banding reference areas (BRAs): 1) interior Alaska, 2) North Slope of Alaska, 3) western Northwest Territories (NWT), 4) western Nunavut, 5) central Nunavut, and 6) eastern Nunavut. The banding groups also differed by breeding habitat, with geese from interior Alaska nesting in the boreal forest (taiga), and all other groups breeding in tundra habitats. Geese from interior Alaska migrated earlier during autumn, and were more likely to winter farther south (in Mexico) than geese from other breeding areas. Geese banded in central and eastern Nunavut (Queen Maud Gulf and Inglis River) wintered farther east (in Louisiana) than geese from other breeding areas. Small-scale (within-state) geographic segregation of wintering flocks was evidenced by the recent (post-1990) nearly exclusive use of a new wintering area in north central Texas by geese from interior Alaska. Segregation among BRAs was also apparent in Mexico, where taiga geese were found predominantly in the central Highlands (states of Zacatecas and Durango), whereas tundra geese mostly used states along the Gulf Coast (primarily Tamaulipas). Interior Alaska birds initiated spring migration earlier than geese from other areas, and were more likely than others to stop in the Rainwater Basin of Nebraska, a region where cholera outbreaks periodically kill thousands of geese. Geese from interior Alaska were the first to arrive at spring staging areas in prairie Canada where BRAs exhibited spatial delineation (a longitudinal cline) in relation to breeding areas. Our results show significant geographic and temporal variation among taiga and tundra breeding cohorts during autumn, winter, and spring. Temporal and spatial differences in migratory behavior may allow management practices that accommodate potential demographic differences between taiga and tundra populations. © 2013 The Wildlife Society.

KEY WORDS Alaska, *Anser albifrons*, Canada, Central Flyway, distribution, greater white-fronted goose, midcontinent, migration, Mississippi Flyway, winter.

Greater white-fronted geese, hereafter white-fronts, from the midcontinent of North America breed from the Seward Peninsula in northwestern Alaska to the northwestern shore of Hudson Bay (Bellrose 1980, Ely and Dzubin 1994). Management of waterfowl species with large geographic ranges is difficult, given likely spatial variation in factors influencing recruitment and survival (Williams et al. 2008). Progressive

management of geese in general, and white-fronts in particular, is often not possible because of a lack of breeding area-specific information on movements, distribution, and abundance (e.g., Ely and Takekawa 1996). The need for such information for midcontinent white-fronts has become apparent given perceived past declines in indices of specific breeding groups (Spindler 1999), high annual variation in counts, and proposals to increase harvest at staging and wintering areas (Sullivan 1999). Information on distribution is also necessary to assess the relevance of current harvest management boundaries in the Central and Mississippi Flyways.

An analysis of the migration routes of white-fronts in North America has not been published since the winter distributions of midcontinent and Pacific Flyway geese were first described over 40 years ago (Miller et al. 1968) and King

Received: 11 December 2010; Accepted: 28 March 2013
Published: 1 July 2013

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and Hodges (1979) assessment of the continental distribution of white-fronts banded in molting flocks on the North Slope of Alaska. Miller et al. based their summary on the limited bandings available at the time, primarily from staging areas in Saskatchewan, along with a nominal number of bandings in interior Alaska and western Northwest Territories (NWT). The Arctic Goose Joint Venture (AGJV) initiated an inclusive marking program in 1990 to better document the breeding and wintering affinities of midcontinent white-fronts, in part to ascertain whether breeding-stock specific management was warranted. Our objective was to use this marking data to provide detailed information on the distribution and timing of movements of geese from different breeding areas across northern Alaska and Canada.

Temporal changes in the distribution of white-fronts, especially in response to changing agricultural practices, means that wildlife managers must remain vigilant and continually reassess management goals and objectives on a geographic basis. Midcontinent white-fronts use many of the same wintering sites as midcontinent lesser snow geese (*Chen caerulescens*), a population that has rapidly expanded in response to agricultural changes and an ameliorating climate on breeding areas, to the degree that breeding habitats have been compromised (Abraham et al. 2005).

STUDY AREA

We trapped molting geese throughout the longitudinal breeding range of midcontinent white-fronts, which included northern Canada west of Hudson Bay, and areas in Alaska north of the Alaska Range and east of the Yukon-Kuskokwim Delta (Ely and Dzubin 1994; Fig. 1). We observed geese from autumn through spring at staging and wintering areas from southern Canada to northern Mexico, and used location information from banded birds recovered as far south as central Mexico (Fig. 1).

METHODS

We trapped geese while they were flightless during the mid-summer wing molt, 1990–1994. We aged geese based on plumage characteristics and determined sex by cloacal examination (Dzubin and Cooch 1992). We fitted all geese with metal leg-bands, and fitted a large subsample (70%) of birds with coded plastic neckbands (Alisauskas and Lindberg 2002).

We obtained banding and recovery data from the United States Geological Survey (USGS) Bird Banding Laboratory (BBL) in Laurel, Maryland for geese recovered from 1990 to 1996 in Canada and the United States, and for 1949 through 2008 in Mexico. We used recoveries from August 1990 through May 1996 when comparing leg-band recovery data with neckband observation data (see below). We restricted analyses of band-recovery data to birds reported shot by hunters, found dead, or caught because of disease (How Obtained codes 00, 01, and 20, respectively, in the USGS North American Bird Banding Manual; Patuxent Wildlife Research Center 2004) to avoid biases associated with birds reported to the BBL as being observed rather than recovered.

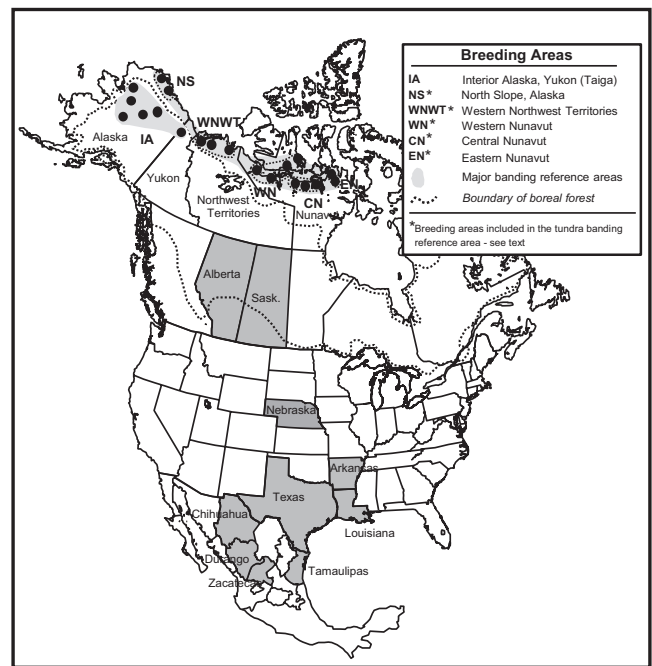


Figure 1. Location of marking of greater white-fronted geese on breeding areas, 1990–1994, and primary staging and wintering regions (shaded in medium gray), 1990–1996.

Band-recovery locations in the United States and Canada are coded in data files as the southeast corner of the 10-minute block in which the band was encountered; hence, distributional analysis is limited to this level of accuracy. Prior to June 1989, recovery coordinates (latitude and longitude) in Mexico were not recorded by the BBL, only the state in which the bird was recovered. The BBL has recently assigned coordinates to Mexican recoveries before 1989 by calculating the centroids of each Mexican state. We included centroid data for comparing breeding and wintering longitudes, but for the purposes of mapping recovery distributions in Mexico, we only used recoveries from 1989 to 2008. We assumed reporting rates did not vary among staging and wintering areas (Sheaffer et al. 2004, Zimmerman et al. 2009). An extensive network of observers was established to re-sight neck-banded geese on staging and wintering areas from Alberta to Mexico during September–May, 1990–1996. Observation effort was spatially and temporally distributed in an attempt to sample geese in proportion to their actual distribution as determined from aerial inventories and regional counts.

Designation of Banding Reference Areas

We initially divided our marked sample of geese into 6 banding reference areas (BRAs) based on the spatial (longitudinal) distribution of banding sites (Fig. 1): 1) interior Alaska (Innoko, Kanuti, Koyukuk, Selawik, Tanana, and Yukon River drainages including Old Crow Flats, Yukon Territory); 2) North Slope of Alaska (includes birds banded near Teshekpuk Lake and Kuparuk); 3) western NWT (Mackenzie River, Anderson River, and Liverpool

Bay regions); 4) western Nunavut (includes markings near Coppermine, Victoria Island, and Kent Peninsula); 5) central Nunavut (Queen Maud Gulf); and 6) eastern Nunavut (Rasmussen Basin, including the Inglis River drainage). Prior to our work, very few white-fronts were banded at northern breeding and molting areas, so most of our banding sites were selected a priori to be representative of known breeding areas across the north. In contrast, most assessments of recovery distributions of waterfowl are generally based on recoveries of birds from banding sites that are grouped a posteriori with the result that BRAs are often clumped and unstratified across the breeding range. For some analyses, we a posteriori combined North Slope, western NWT, western Nunavut, central Nunavut, and eastern Nunavut into a tundra BRA because of the high degree of overlap in wintering distributions compared to the birds from the taiga of interior Alaska.

Breeding Status

We assigned geese to reproductive status (breeder or failed/non breeder) based on the proportion of pre-fledged young banded in capture groups. Adult geese captured in flocks with >10% young were considered to be breeders, whereas groups with fewer young were considered to be failed/non breeders. We calculated age-ratios of capture groups from the BBL banding summary files. Analyses of the effects of breeding status were restricted to direct (the year after marking) observations of geese, as breeding status was only known for the first year after capture. Most birds in this study were marked as non-breeders and may not be representative of locally nesting birds, although local molt migrations are unlikely to affect large spatial analyses such as ours (Ely and Takekawa 1996).

Estimates of Distribution and Movement

We examined movements and spatial aspects of temporal variation with a geographic information system (GIS; Arcview, ESRI, Inc., Redlands, CA), and quantified primary areas of use with an extension of Arcview (Hooge and Eichenlaub 1997). We identified key activity areas during autumn, winter, and spring for each BRA using a kernel modeling approach (ANIMAL MOVEMENT extension program for ARCVIEW; Hooge and Eichenlaub 1997) to depict 50% and 90% encounter probabilities for the distribution of leg-band recoveries and observations of neck-banded birds (Sheaffer et al. 2004). These core use areas (CUAs) are similar to more traditional home range estimates in that they depict the area in which an animal has a specified probability of being encountered (Worton 1995). We used the default settings for grid size as recommended to accommodate small sample sizes (Hooge and Eichenlaub 1997). When assessing areas of core use, we constrained observations to a single sample of each neck-banded goose from each BRA during a specific time period and location to assure independence among sampling points (De Solla et al. 1999). We limited our analysis of CUAs to BRAs with locations for at least 30 geese during a specified time period and location, given the potential for small samples

to inflate kernel home range estimates (Seaman et al. 1999). We calculated the timing of arrival of neck-banded geese to specific areas based on the date of first observation of a goose within a specific geographic area as an approximation of true arrival.

Previous studies of winter distribution based on leg-band recovery data often have constructed band-recovery reference areas (Hestbeck 1993), or statistically compared distributions with centroid models (Diefenbach et al. 1988). We initially used a multiresponse permutation procedure (MRPP—BLOSSOM statistical package; Cade and Richards 2001) to further assess the uniqueness of our BRAs by testing for differences between banding sites in patterns of observations and band recoveries on staging and wintering areas. However, we found highly significant differences between BRAs with extremely similar winter distributions. Like Green and Kremetz (2008), we decided that the high sensitivity of such tests when using large data sets (such as band-recovery data) might lead to “significant differences between distributions that may not be biologically relevant.” Hence, we took a graphical approach to assess spatial distribution of continuously distributed band-recovery and observation data (Sheaffer et al. 2004, Green and Kremetz 2008). We present our findings with respect to political boundaries as well, to be more relevant to wildlife managers from jurisdictions with different harvest regulations.

Winter distribution data based on leg-band recoveries is presented separately for the United States and Mexico, as differential harvest pressure and band reporting rates between the 2 countries could lead to biased estimates of distribution. Assessment of distribution based on neckband resighting was also compromised in Mexico because observation effort in Mexico was minimal compared to other areas, and the effort in Mexico was not evenly distributed spatially or temporally.

Statistical Analyses

We tested for differences among birds from different breeding areas in the use of staging and wintering areas during specific time periods with contingency table analyses (Sokal and Rohlf 1981). In an attempt to constrain our analyses to biologically meaningful results, we decided a priori to dismiss statistical comparisons of proportion data unless BRA differences varied by at least 5%. We identified departures from normal distributions in arrival data by examining box-plots of individual arrival times and then following up with a Kolmogorov–Smirnov test (Sokal and Rohlf 1981). We used analysis of variance (PROC GLM, SAS Institute 1999) to test for the effects of several variables on the timing of arrival (observation and recovery data). Independent variables tested included banding reference area, breeding status, and province or state birds were arriving to. If data were not normally distributed, we ranked data (PROC RANK, SAS Institute 1999) prior to performing an analysis of variance. We examined relationships among independent variables with Pearson correlation coefficients (PROC CORR, SAS Institute 1999).

Table 1. Location and timing of marking of midcontinent greater white-fronted geese, 1990–1994.

Year of marking	Location and number marked ^a											
	Interior Alaska		North Slope Alaska		Northwest Territories		Western Nunavut		Central Nunavut		Eastern Nunavut	
	Leg ^b	Neck ^c	Leg	Neck	Leg	Neck	Leg	Neck	Leg	Neck	Leg	Neck
1990	1,351	808		20	342	691	266	675	446	699		
1991	60	406	58	199	35	1,262	503	608	167	403	330	326
1992	68	611	7	248	1	1,122	256	696	1,111	967		
1993	127	1,087	1	172	1	626	63	568	739	728	743	373
1994	88	1,464	60	347		1,357	259	349	1,010	1,003	53	1,008
Total	1,694	4,376	126	986	379	5,058	1,347	2,896	3,473	3,800	1,126	1,707

^a Ages and sexes combined.

^b Leg band. Birds with leg bands only.

^c All neck-banded birds were also leg-banded.

RESULTS

Marking, Re-Sighting Effort, and Observations

Over 26,000 white-fronts were trapped and leg-banded at 6 northern breeding areas during 1990–1994; nearly 19,000 of these were also neck-banded (Fig. 1, Table 1). Sample sizes were smallest for birds from eastern Nunavut (Rasmussen Basin), and the North Slope of Alaska, but for even the latter location, nearly 1,000 birds were fitted with neck collars. Observers averaged 2,090 person-days per year observing geese from 1990 to 1996 (Fig. 2). Observation effort was greatest in Saskatchewan during autumn. Observation effort was also high (>50 person days/month) during winter in Texas and Louisiana and during early spring (Mar) in Nebraska (combined in Midwest in Fig. 2). Observation effort was fairly broadly distributed overall. However, in the

following instances, temporal or spatial variation in observation effort was apparent: 1) fewer person-days were dedicated to observing geese during August than September on autumn staging areas in Alberta, which may have led to an under-representation of early-migrating birds; 2) observations of neck collared birds in Mexico were restricted almost exclusively to the month of January and in selected states of Mexico, thereby limiting conclusions concerning the distribution of birds in Mexico. Overall, more than 63,000 sightings were made of neck-banded individuals during the course of the study.

Effect of Breeding Success on Migration Behavior

Captured groups were composed primarily of non- or failed-breeding adult birds, as the proportion of hatch year (HY) birds during 1990–1994 varied from 0.3% to 10.9% among

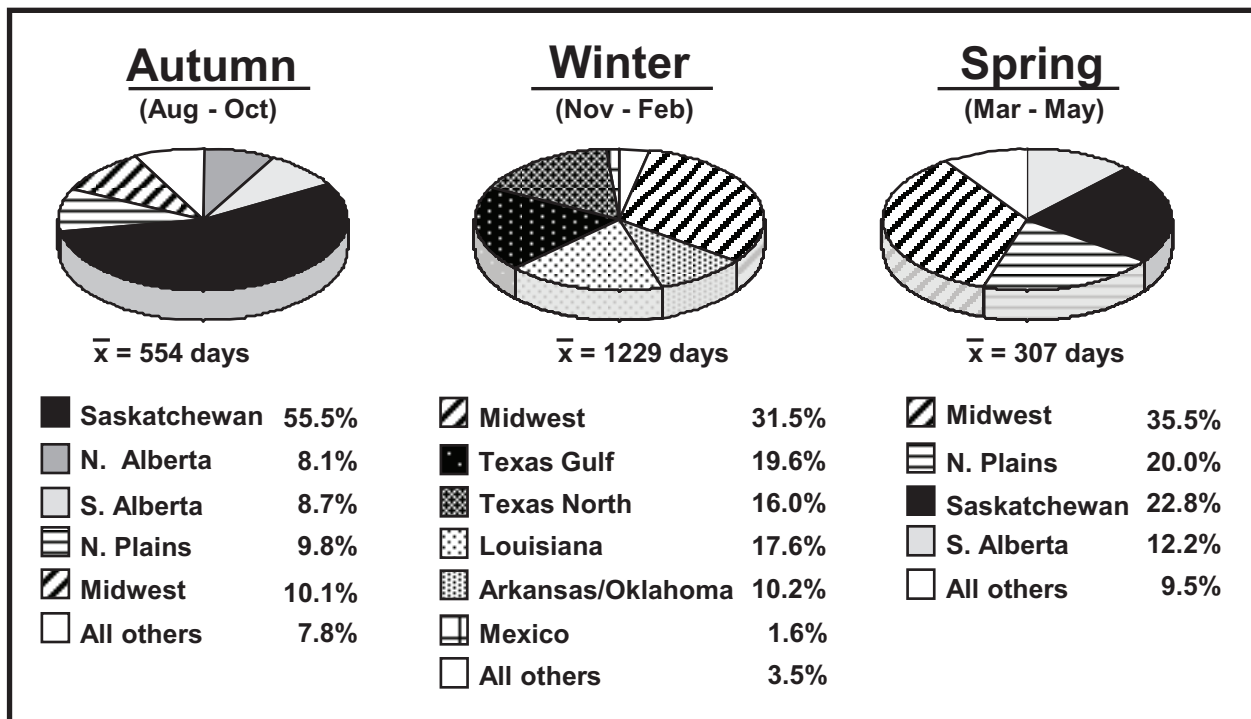


Figure 2. Seasonal and geographic variation in mean annual effort (person-days/year) expended observing greater white-fronted geese, 1990–1996. Northern Plains = ND, SD, MN; Midwest = NE, IA, CO, MO, KS.

BRAs, except for eastern Nunavut where HY birds comprised > 50% of the sample in 2 of the 3 years of marking. We found no differences in timing of autumn migration ($F_{1, 8,176} = 0.26, P = 0.609$) between brood flocks and molting flocks when we compared ranks of time of first arrival to autumn staging areas in Alberta and Saskatchewan by breeding and non-breeding birds, while controlling for effects of banding location (interior Alaska, the North Slope of Alaska, western NWT, and western, central, and eastern Nunavut). We pooled data for subsequent analyses, although our inability to determine whether individual birds were specifically with or without young limited our power to detect effects of breeding success.

Overall Migratory Path

Observation data and leg-band recovery data revealed that white-fronts from all breeding areas moved to autumn staging areas in Alberta and Saskatchewan before migrating south through the northern plains and mid-western states to

winter in Louisiana, Arkansas, Texas, and Mexico (Fig. 1). A very small and variable proportion of birds overwintered in mid-western states each year. Geese followed a similar return route during spring migration.

Seasonal Variation in Distribution

Autumn.—We found substantial differences between taiga and tundra BRAs in the portion of birds staging in Alberta versus Saskatchewan during autumn as revealed by both leg-band recovery data and observations of neck-collared birds (Fig. 3). A greater proportion of taiga birds leg-banded in interior Alaska (IA; 60.1% of 183 recoveries) were recovered during autumn (Sep–Nov) in Alberta than Saskatchewan compared to tundra birds from the North Slope (NS; 38.7% of 31 recoveries), western NWT (WNWT; 39.9% of 143 recoveries), western Nunavut (WN; 26.2% of 122 recoveries), central Nunavut (CN; 16.9% of 178 recoveries), and eastern Nunavut (EN; 2.0% of 51 recoveries; $\chi^2_5 = 107.7, P < 0.001$). Analysis of observation data also revealed IA

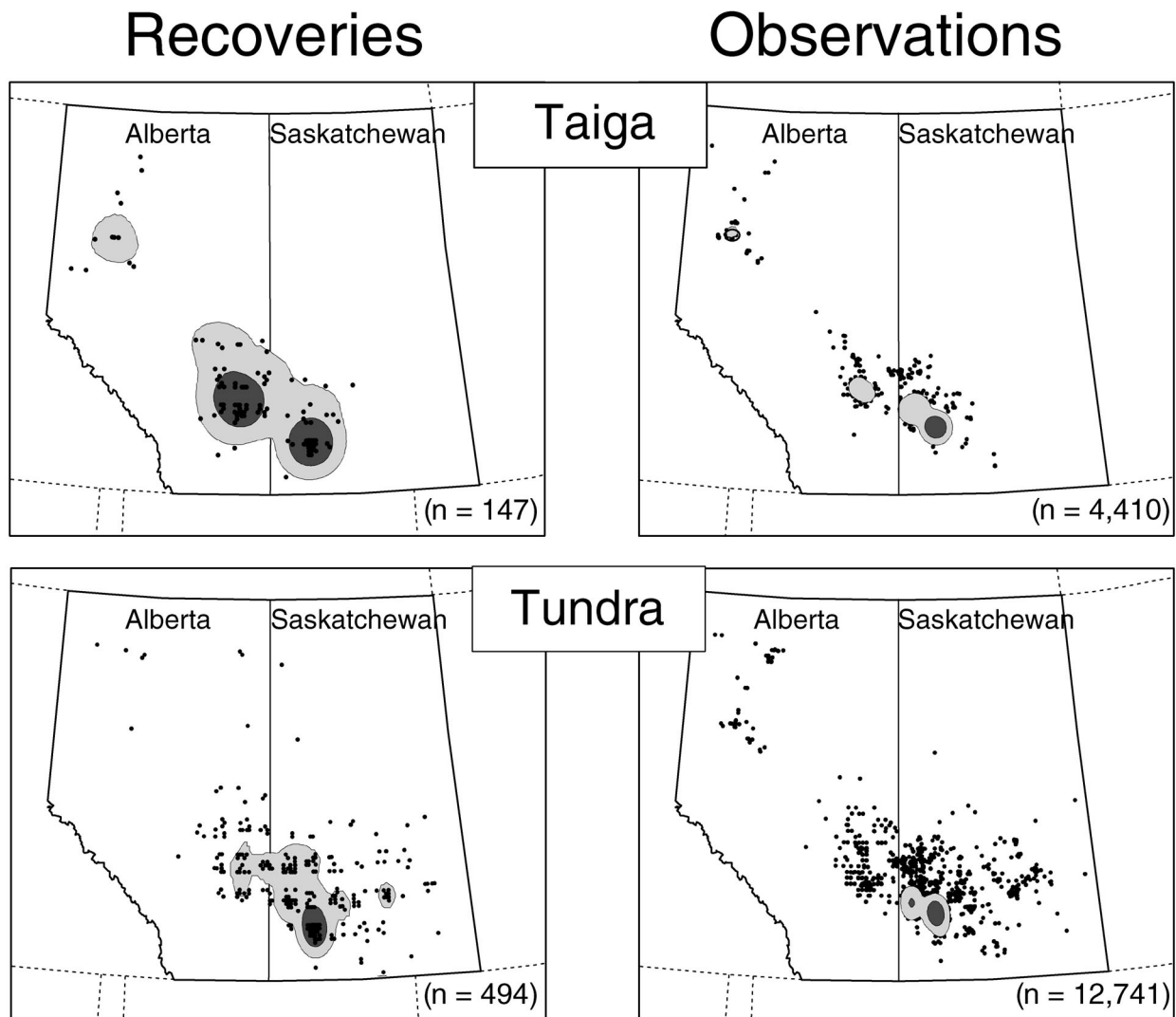


Figure 3. Autumn distribution of recoveries and observations of leg-banded and neck-banded greater white-fronted geese in the Canadian prairies (Alberta and Saskatchewan), 1990–1996, with 50% (dark shading) and 90% (light shading) kernel home range sizes. We banded geese in taiga and tundra breeding areas in northern Alaska and Canada.

geese more often staged in Alberta than geese from birds from other areas, with 24.0% of 4,912 first-autumn observations in prairie Canada in Alberta (as opposed to Saskatchewan), compared to 9.8% of NS birds ($n = 778$), 10.9% of WNWT birds ($n = 5,411$), 5.7% of WN birds ($n = 3,572$), 4.4% of CN birds ($n = 4,865$), and 1.1% of EN birds ($n = 1,340$; $\chi^2_5 = 1,308.5$, $P < 0.001$). A moderate degree of spatial segregation is also suggested by the positive correlation between the longitude at which a goose was neck-banded and longitude of where it was first sighted on autumn staging areas ($r = 0.26$, $n = 17,155$, $P < 0.001$).

The timing of arrival to northern staging areas varied among BRAs as well. Re-sighting data from 1990 to 1996 indicated that IA birds migrated into Alberta slightly earlier than birds from other areas ($F_{1, 2,556} = 34.99$, $P < 0.001$). Mean date of first observation of IA geese was 15.5 September \pm 0.33 days (SE), compared to 18.7 September \pm 1.1 for NS birds, 20.1 September \pm 0.40 for WNWT birds, 20.2 September \pm 0.56 days for WN birds, 19.0

September \pm 0.55 days for CN birds, 21.7 September \pm 2.66 days for EN birds, and 19.8 September \pm 0.27 for all non-IA BRAs combined. Early autumn immigration by IA geese to the Canadian prairies (Alberta and Saskatchewan) compared to tundra-nesting geese was also corroborated by band-recovery data during the same time period ($F_{1, 626} = 21.31$, $P < 0.001$), despite the fact that hunting seasons opened well after many birds had arrived. Analyses based on hunter recoveries and re-sightings likely under-sampled the earliest migrating birds, as no open hunting season was scheduled and little observation effort occurred before September (Fig. 2), by which time many geese were already present on staging areas.

Winter.—Texas and Louisiana were the primary wintering areas of geese from all midcontinent breeding areas, as reflected in the distribution of leg-band recoveries and observation data (Fig. 4). The gulf coast of Texas was the dominant harvest area for geese from all areas but central and eastern Nunavut, the latter of which were recovered

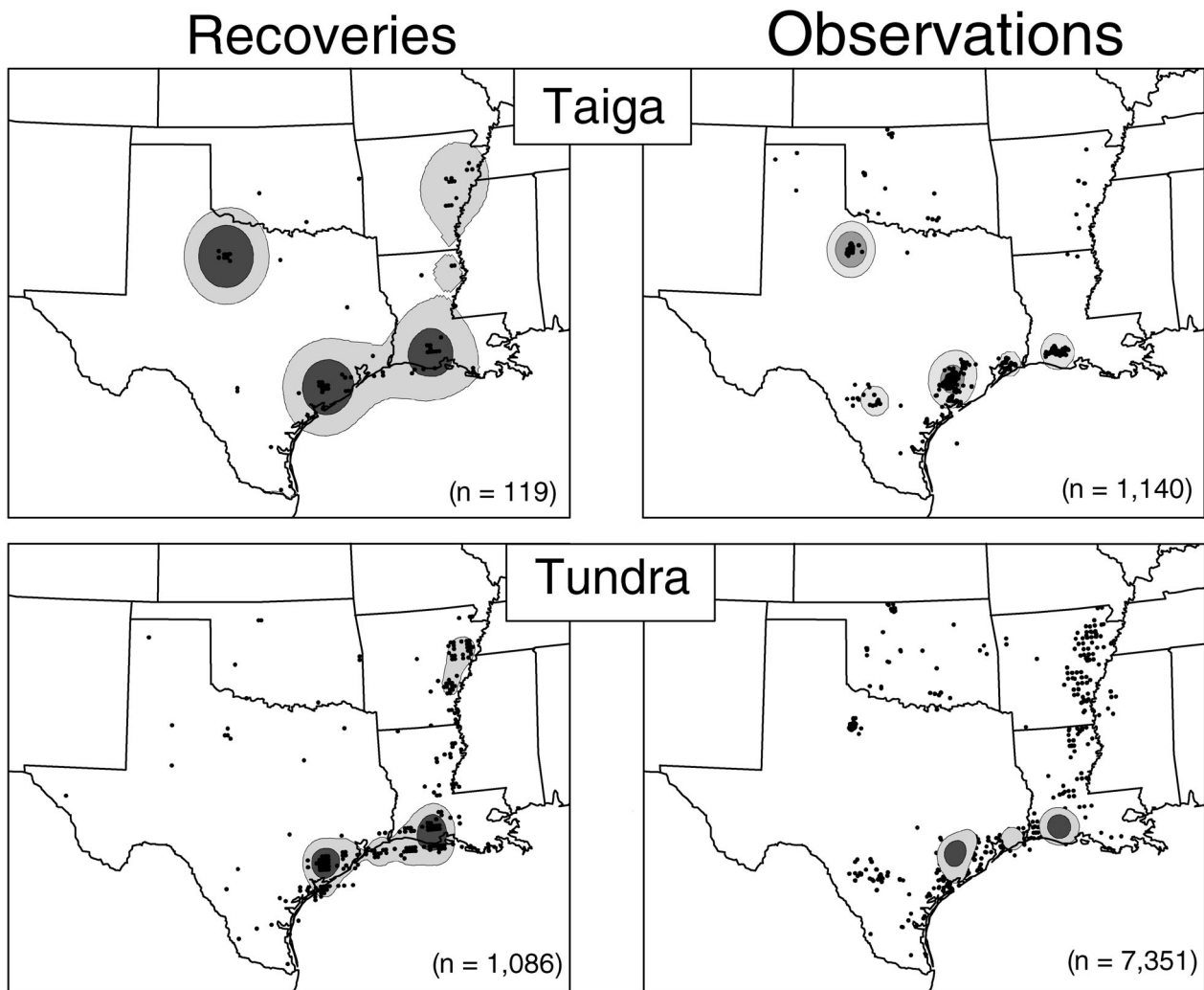


Figure 4. Winter distribution of recoveries and observations of leg-banded and neck-banded greater white-fronted geese in Texas, Louisiana, and Arkansas, 1990–1996, with 50% (dark shading) and 90% (light shading) kernel home range sizes. We banded geese in taiga and tundra breeding areas in northern Alaska and Canada.

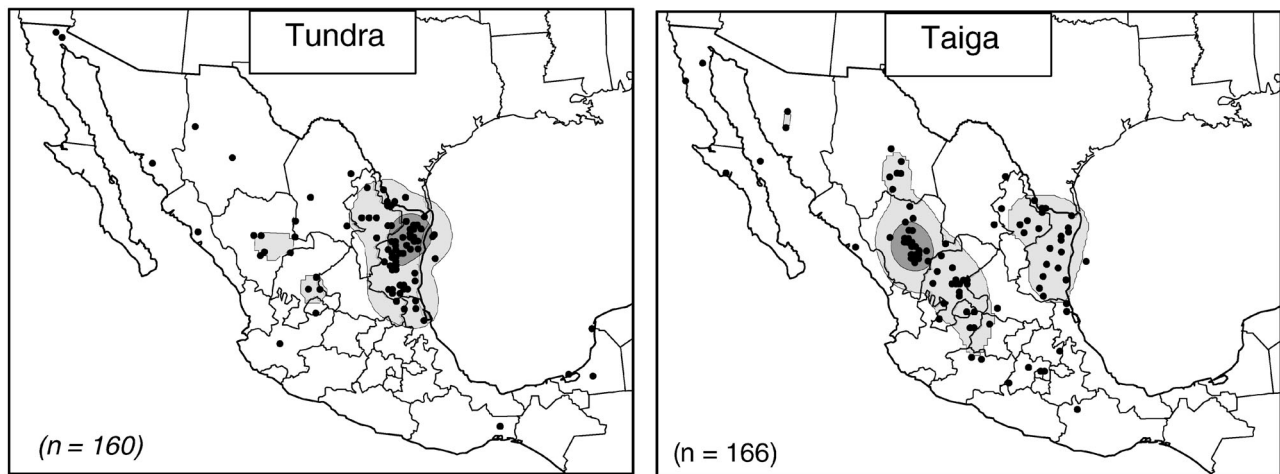


Figure 5. Distribution of recoveries of midcontinent populations of leg-banded greater white-fronted geese in Mexico, 1989–2008, with 50% (dark shading) and 90% (light shading) kernel home range sizes. Recoveries in Mexico from tundra breeding areas (northern Canada and the North Slope of Alaska) included 11 birds from the North Slope, 11 from western Northwest Territories, 33 from western Nunavut, 101 from central Nunavut, and 4 from eastern Nunavut.

predominantly in Louisiana. We observed some modest discrepancies between recovery and observation CUAs, with recovery data showing a greater proportion of birds using Louisiana than observation data. The longitude of capture of leg-banded birds was positively correlated with longitude of recovery during winter ($r = 0.41$, $n = 5,146$, $P < 0.001$; includes all recoveries in TX, LA, AR, OK, and Mexico).

Small-scale geographic segregation among BRAs was evident in the patterns of distribution of band recoveries in Texas. Nearly 50% of the recoveries and observations of IA birds occurred in north central Texas, whereas birds from all other BRAs were primarily harvested or observed near the Gulf Coast (Fig. 4).

Birds from interior Alaska arrived at wintering areas in Texas, Louisiana, and Arkansas almost a week earlier than birds from other areas. Mean date of first observation of IA geese was 8.7 November \pm 0.62 days (SE), compared to 16.0 November \pm 0.27 for all other BRAs ($F_{1, 7,942} = 113.76$, $P < 0.001$). In contrast, the timing of harvest of leg-banded

birds on wintering areas varied little between taiga and tundra BRAs ($F_{1, 812} = 0.40$, $P > 0.05$).

Mexico was a more common wintering area for geese from interior Alaska than from other breeding areas, with 13.5% of 1,144 winter (Nov–Feb) recoveries reported from Mexico compared to 2.9% of 5,331 recoveries from all other areas since 1989 ($\chi^2 = 229.3$, $P < 0.001$, comparing interior Alaska geese vs. all other breeding areas combined; Fig. 5). An analysis of all recoveries of midcontinent birds recovered in Mexico since 1949 shows that the state of Tamaulipas, bordering the Gulf Coast of northeastern Mexico, was the predominant wintering state for geese from all breeding areas except IA (i.e., tundra-nesting geese; 72% of 287 Mexican recoveries). Interior Alaska birds wintered primarily in the states of Durango and Zacatecas in the Central Highlands, with Tamaulipas of tertiary importance (Table 2).

Spring.—Nebraska was the predominant early spring (Feb–Apr) staging area for all midcontinent white-fronts (Fig. 6). Interior Alaska birds were especially likely to use

Table 2. Distribution of recoveries of leg-banded greater white-fronted geese in Mexico, 1949–2008.

Region/state	Percent of recoveries by banding location ^a					
	Interior Alaska	North Slope Alaska	Northwest Territories	Western Nunavut	Central Nunavut	Eastern Nunavut
East Coast						
Tamaulipas	16.5	83.3	59.0	69.7	72.4	75.0
Nuevo Leon		2.4	1.6		4.8	
San Luis Potosi	6.0	3.6			1.0	
Vera Cruz	0.6		1.6	9.2	7.6	25.0
Campeche					3.8	
Central Highlands						
Coahuila	5.2	2.4	1.6	9.2	3.8	
Chihuahua	2.2		1.6		1.9	
Durango	31.3	2.4	16.4	6.1		
Zacatecas	24.5	2.4	16.4	3.0		
Jalisco	3.9	1.2	1.6		1.0	
Other	9.8	2.3		2.8	2.7	
Total returns	364	84	61	33	105	4

^a Other category comprised of states not listed with <2% of recoveries.

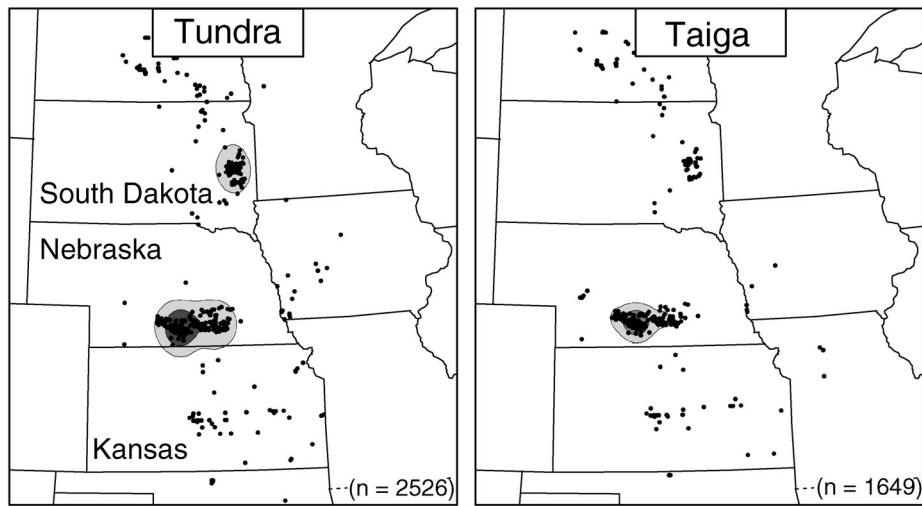


Figure 6. Distribution of observations of neck-banded greater white-fronted geese in the upper Midwest states during spring (Feb–Apr), 1990–1996, with 50% (dark shading) and 90% (light shading) kernel home range sizes. We banded geese in taiga and tundra breeding areas in northern Alaska and Canada.

Nebraska, as 85% of unique spring observations of IA birds in the Midwest were reported in Nebraska, compared to 65% for other BRAs ($\chi^2_1 = 205.6$, $P < 0.001$). Interior Alaska birds were also earliest to arrive in Nebraska, with a mean arrival date of 11.8 March \pm 0.28 days versus 15.3 March \pm 0.21 days for birds from other BRAs combined ($F_{1, 3,174} = 104.0$; $P < 0.001$).

Spatial segregation among birds from different breeding areas was even more pronounced at Canadian staging areas in spring than in autumn, with a much greater proportion of taiga birds (91.0% of 502 first observations) using Alberta than birds from tundra BRAs (56.8% of 1,274 first observations; $\chi^2_1 = 189.8$, $P < 0.001$; Fig. 7). Conversely, birds from the easternmost BRA (eastern Nunavut) were much more likely to be encountered in Saskatchewan than birds from other banding areas ($\chi^2_1 = 91.36$, $P < 0.001$). Longitude of spring staging area was positively correlated

with longitude of original banding location ($r = 0.41$, $n = 1,776$, $P < 0.001$). Timing of arrival to spring staging areas in Alberta and Saskatchewan also varied significantly among BRAs ($F_{5, 1,774} = 78.9$; $P < 0.001$), with geese from IA arriving the earliest (mean arrival of 17.5 April \pm 0.28 SE days), birds from eastern Nunavut the latest (mean arrival of 30.1 April \pm 1.14), and arrival of birds from other breeding areas varying from 23 to 27 April.

DISCUSSION

Temporal and Spatial Segregation

Midcontinent white-fronted geese breeding across northern Canada and Alaska exhibited spatial and temporal segregation during portions of the non-breeding season. Generally, the farther east that white-fronts nested, the farther east they tended to occur during autumn, winter, and spring. These

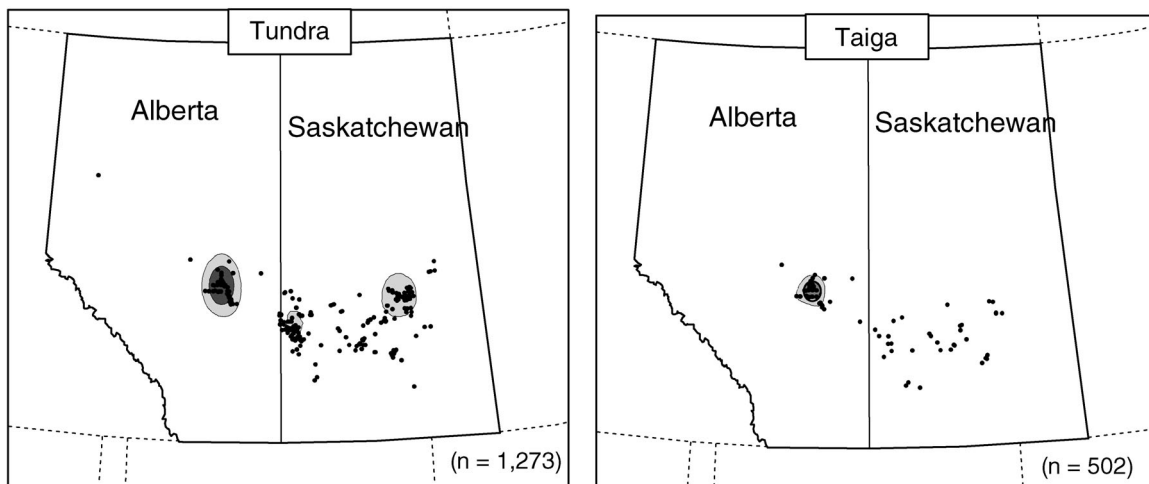


Figure 7. Spring distribution of observations of neck-banded greater white-fronted geese in Alberta and Saskatchewan, 1990–1996, with 50% (dark shading) and 90% (light shading) kernel home range sizes. We banded geese in taiga and tundra breeding areas in northern Alaska and Canada.

longitudinal relationships have been similarly observed in other species of waterfowl, including lesser snow geese (Dzubin 1979) and Canada geese (*Branta canadensis*; Bellrose 1980). Such patterns are likely not simply a consequence of proximity between breeding and wintering areas, as many waterfowl species undergo lengthy longitudinal migrations, and some midcontinent white-fronts breed farther west than some Pacific Flyway white-fronts (Bellrose 1980). In this study, white-fronts from Alaska's North Slope had migratory patterns more similar to western NWT geese than to geese from interior Alaska despite breeding only a few hundred kilometers directly north of interior Alaska geese. Hence, migratory routes of white-fronts, although somewhat constrained by breeding location, are likely dictated primarily by long-established migratory traditions (Alerstam et al. 2003).

White-fronts from IA exhibited the largest degree of spatial and temporal segregation from other nesting groups on staging and wintering areas. Geese in Alaska's interior breed in the taiga (boreal forest; Fig. 1) and begin nesting nearly 2 weeks earlier than the tundra-nesting geese from the North Slope of Alaska and western Nunavut (Ely et al. 2005). Environmental variables that limit the extent of the taiga biome (e.g., degree days, frost-free period) likely influence the onset and length of the nesting period. The uniqueness of taiga geese likely also is manifest in ecological attributes other than nesting habitat and nesting chronology. The boreal forest harbors a different suite of predators than tundra biomes, predators that undoubtedly affect demographic variables such as nesting success, gosling survival, and adult mortality. Recent analyses indicate the adult survival of white-fronts is about 4% less per year for IA geese than North Slope geese, though the cause for this difference is unclear (J. Schmutz, U.S. Geological Survey, unpublished data).

Breeding ground-specific variation in migratory pathways evident in midcontinent white-fronts is similar to patterns observed among white-fronts in the Pacific Flyway. Geese from the taiga of interior Alaska are much more likely to winter in Mexico than are tundra-nesting white-fronts (a finding also supported by a more recent study of satellite-marked white-fronts from the interior and North Slope of Alaska; Webb 2006). Similarly, among Pacific Flyway geese, a greater proportion of early-nesting geese using shrub-tundra habitats in the Bristol Bay region of southwest Alaska wintered in Mexico than later-nesting tundra birds from the Yukon-Kuskokwim Delta (Ely and Takekawa 1996). The early arrival of boreal forest geese to Alberta and Saskatchewan in autumn closely parallels how white-fronts from the Bristol Bay region arrive and depart the Klamath Basin, their main autumn staging area, well before the bulk of Pacific Flyway white-fronts that breed on the Yukon-Kuskokwim Delta (Ely and Takekawa 1996). Temporal segregation among birds from different breeding areas is, however, less pronounced in the midcontinent than in the Pacific Flyway, as considerable overlap exists among geese from different breeding areas despite the detection of the patterns reported here.

Influence of Migration Variation on Demography

The unique movements and distribution of taiga geese might differentially expose them to greater rates of mortality than their tundra-nesting counterparts. Examples of breeding area-specific exposure to factors influencing survival and recruitment include the greater proportion of IA birds exposed to cholera (*Pasturella multocida*) in Nebraska, compared to birds from other BRAs. Mortalities exceeded 10,000 white-fronts in some years (Windingsted et al. 1984, Ely and Dzubin 1994). Samuel et al. (2005) found greater white-fronted geese sampled in interior Alaska had an elevated exposure rate to cholera compared to birds from the North Slope (3.9% vs. 3.0%), although they found little evidence of cholera die-offs on wintering areas during the time of their study. Differences among birds from different breeding areas in the use of wintering habitats, especially in Mexico (where cyclic drought can be severe), could also influence body condition and survival (Schmutz and Ely 1999).

MANAGEMENT IMPLICATIONS

Temporal and spatial differences among taiga- and tundra-nesting midcontinent white-fronted geese may provide opportunities for breeding area-specific management in the form of differential bag limits, season lengths, and timing of harvest. Although temporal segregation is apparent among taiga and tundra white-fronts during autumn in Alberta, it may not be pronounced enough to implement specific management strategies to target or protect taiga-origin versus tundra-origin geese. Also, timing of migration is likely influenced by environmental factors, and the warming of the arctic may blur population differences in chronology of breeding and migration unless climate change is uniform across the north. Anderson and Haukos (2003) initially identified the use of north-central Texas by geese from interior Alaska, and suggested special management consideration for the area. Our analysis supports this contention and substantiates continued breeding area-specific harvest monitoring, which can be accomplished by continued leg banding of midcontinent white-fronts from taiga and tundra habitats.

ACKNOWLEDGMENTS

This was an extremely ambitious project that involved staff from many federal, provincial, and state agencies from Canada, the United States, and Mexico, as well as numerous volunteers. We acknowledge the efforts of the multitude of people who assisted with trapping and marking geese at northern breeding areas, and the army of state, provincial, and federal personnel who followed geese and diligently read collars during autumn, spring, and winter. We are grateful for the efforts of banders across Canada and Alaska, especially R. Bromley (Government of Northwest Territories), and R. Kerbes (Canadian Wildlife Service [CWS]), R. Oates, R. King, E. Mallek, and M. Spindler (U.S. Fish and Wildlife Service [USFWS]). Coordinators and crews of observers participated throughout staging and wintering

areas in North America; R. Kerbes (CWS) was especially helpful in organizing the observation effort, and K. Meeres (CWS) compiled the data and managed the database. Key observers (contributing >1,000 observations) included K. Lamont, P. Pryor, R. Kerbes, M. Schwitters, N. Lyman, J. Mulhern, D. Boudreaux, K. Warner, G. Gentle, and J. Smith. The implementation and continuity of this work would not have been possible without the support of D. Caswell (CWS) and R. Leedy (USFWS). Observations in Mexico were coordinated by G. Quintana Martínez (Universidad Autónoma de Chihuahua) and facilitated by Dr. H. Berlanga García (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Gobierno Federal de México), and S. Wendt (CWS). Funding and support for this project was provided by CWS, USFWS, the Department of Environment and Natural Resources of the Northwest Territories, the Polar Continental Shelf Program (Natural Resources Canada), the Arctic Goose Joint Venture, the State of Nebraska, and the Inuvialuit Final Agreement. We greatly appreciate J. Horne's (University of Idaho) considerations for presenting kernel home range estimates. Reviews by J. Fischer, M. Spindler, T. Moser, J. Dubovsky, M. Eicholz (associate editor), and 2 anonymous reviewers improved the quality of the manuscript. Use of trade, product, or company names is solely for descriptive purposes and does not imply endorsement by the U.S. Government.

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Associate Editor: Michael Eichholz.