Effects of the Light Goose Conservation Order on non-target waterfowl distribution during spring migration

Authors: Dinges, Andrew J., Webb, Elisabeth B., and Vrtiska, Mark P.

Source: Wildlife Biology, 21(2) : 88-97

Published By: Nordic Board for Wildlife Research

URL: https://doi.org/10.2981/wlb.00063

Wildlife Biology 21: 88–97, 2015
doi: 10.2981/wlb.00063

Subject Editor: Kjell Einar Erikstad. Editor-in-Chief: Ilse Storch. Accepted 2 December 2014

Effects of the Light Goose Conservation Order on non-target waterfowl distribution during spring migration

Andrew J. Dinges, Elisabeth B. Webb and Mark P. Vrtiska

A. J. Dinges, Dept of Fisheries and Wildlife Sciences, Univ. of Missouri, Columbia, MO 65211, USA. Present address: 1213 S. German St., New Ulm, MN 56073, USA. – E. B. Webb (webbli@missouri.edu), U.S. Geological Survey, Missouri Cooperative Fish and Wildlife Research Unit, Dept of Fisheries and Wildlife Sciences, Univ. of Missouri, Columbia, MO 65211, USA. – M. P. Vrtiska, Nebraska Game and Parks Commission, 2200 N. 33rd Street, Lincoln, NE 68503, USA

The Light Goose Conservation Order (LGCO) was initiated in 1999 to reduce mid-continent populations of light geese (lesser snow geese *Chen caerulescens* and Ross's geese *C. rossi*). However, concern about potential for LGCO activities (i.e. hunting activities) to negatively impact non-target waterfowl species during spring migration in the Rainwater Basin (RWB) of Nebraska prompted agency personnel to limit the number of hunt days each week and close multiple public wetlands to LGCO activities entirely. To evaluate the effects of the LGCO in the RWB, we quantified waterfowl density at wetlands open and closed to LGCO hunting and recorded all hunter encounters during springs 2011 and 2012. We encountered a total of 70 hunting parties on 22 study wetlands, with over 90% of these encounters occurring during early season when the majority of waterfowl used the RWB region. We detected greater overall densities of dabbling ducks *Anas* spp., as well as for mallards *A. platyrhynchos* and northern pintails *A. acuta* on wetlands closed to the LGCO. We detected no effects of hunt day in the analyses of dabbling duck densities. We detected no differences in mean weekly dabbling duck densities among wetlands open to hunting, regardless of weekly or cumulative hunting encounter frequency throughout early season. Additionally, hunting category was not a predictor for the presence of greater white-fronted geese *Anser albifrons* in a logistic regression model. Given that dabbling duck densities were greater on wetlands closed to hunting, providing wetlands free from hunting disturbance as refugia during the LGCO remains an important management strategy at migration stopover sites. However, given that we did not detect an effect of hunt day or hunting frequency on dabbling duck density, our results suggest increased hunting frequency at sites already open to hunting would likely have minimal impacts on the distribution of non-target waterfowl species using the region for spring staging.

Hunting disturbance has been identified as one of the factors influencing waterfowl distribution and habitat use during migration (Madsen and Fox 1995, Dooley et al. 2010, Webb et al. 2010a). Indeed, disturbance is more likely to affect waterfowl during spring migration compared to other times of the year because of the high energetic requirements associated with migration and subsequent breeding activities (Madsen and Fox 1995, Arzel et al. 2006). Providing areas free from hunting disturbance (refuges) generally concentrates waterfowl at these sites and reduces waterfowl use of disturbed areas (Giroux and Bedard 1988, Madsen and Fox 1995, Madsen 1998, Evans and Day 2002). Changes in waterfowl distribution caused by hunting disturbance may lead to the under-utilization of food resources on disturbed areas, as well as artificially high densities and increased competition in areas free from disturbance (Madsen and Fox 1995).

Mid-continent populations of light geese, composed of lesser snow geese *Chen caerulescens* and Ross's geese *C. rossi*, have grown rapidly since the late 1960s and recent estimates suggest 10–15 million adult birds in the population (Alisauskas et al. 2011). Substantial increases in light goose populations have resulted in destruction of some arctic breeding habitats (Abraham et al. 2005), with intense grazing of shoots, grubbing of roots and rhizomes by light geese, in conjunction with a short growing season, leading to irreversible vegetation loss, increased soil salinity, erosion, and desertification in some areas (Srivastava and Jefferies 1996, Abraham and Jefferies 1997, Jefferies and Rockwell 2002). The Light Goose Conservation Order (LGCO) was implemented by the U.S. Fish and Wildlife Service (USFWS) in 1999 in an effort to reduce mid-continent populations of light geese (Abraham et al. 2005, USFWS 2007). As a special spring hunt season, the LGCO allowed the legal harvest of light geese after 10 March, following closure of all other waterfowl seasons, and use of special measures (e.g. unplugged shotguns). Prior to enaction of the LGCO, no legal waterfowl hunting occurred after 10 March since the signing of the Migratory Bird Treaty Act in 1918 (USFWS 2007). Although the LGCO was legally considered a conservation harvest because it was implemented outside of the regular hunting season and for the purpose of reducing light goose populations (Abraham and Jefferies 1997, Bechet et al. 2004), we refer to it as a spring hunt for the purpose of this study because it was carried out by migratory bird hunters.

Hunting during the LGCO is a potential source of disturbance for non-target waterfowl at spring migration stopover sites, including the Rainwater Basin (RWB) of Nebraska (Bechet et al. 2004, Webb et al. 2010a, 2011, Pearse et al. 2012). Prior to implementation of the LGCO, wetland loss combined with annual variation in flooded wetland availability and the movement of millions of light geese into the region contributed to an increase in migratory bird densities on RWB wetlands (Gersib et al. 1989, Bishop and Vrtiska 2008). Hunting disturbance during the LGCO could also potentially contribute to greater waterfowl densities on individual wetlands in the RWB. High waterfowl densities have been suggested to increase avian stress levels and disease susceptibility (Friend 1981, Smith and Higgins 1990, Wobeser 1997, Bishop and Vrtiska 2008). Underutilization of food resources in wetlands or use of suboptimal habitats as a result of hunting disturbance during the LGCO in the RWB both have potential to limit nutrient acquisition during this crucial time period (Madsen and Fox 1995, Bechet et al. 2004, Arzel et al. 2006). Reduced nutrient acquisition could ultimately affect subsequent reproductive output and breeding success of waterfowl using the RWB during spring migration (Madsen and Fox 1995, Mainguy et al. 2002, Bechet et al. 2004).

Regulations for the LGCO in the RWB were implemented with caution due to concern that hunting disturbance might impact the distribution and behavior of non-target waterfowl species during spring migration (Vrtiska and Sullivan 2009). Although regulations were established with the concurrent goals of maximizing light goose harvest and reducing potential impacts of hunting disturbance on non-target species, effects of these regulations on waterfowl distribution in the RWB during the LGCO are still relatively unknown (Vrtiska and Sullivan 2009). Therefore, our objectives for this study were to assess hunter activity at public wetlands during the LGCO and evaluate how hunting disturbance on established temporal (i.e. closed days) and spatial (i.e. closed wetlands) refuges affected waterfowl distribution during spring migration in the RWB of Nebraska. Given the importance of the region to migrating mallards *Anas platyrhynchos*, northern pintails *A. acuta*; hereafter pintails, and greater white-fronted geese *Anser albifrons*; hereafter white-fronted geese, we placed additional focus on those species.

Study area

The RWB region is recognized as one of the most important waterfowl migration areas in North America (USFWS and Canadian Wildlife Service 1986). The region occupies a 16 000 km^2 area within 21 counties in south–central Nebraska (Bishop and Vrtiska 2008). Wetlands in the RWB are categorized as playas (Smith 2003, LaGrange 2005) and were formed through a combination of wind deflation and dissolution of subsurface basin material (Osterkamp and Wood 1987, Gustavson et al. 1995, Reeves and Reeves 1996). Precipitation in the region increases along a gradient from west to east, with mean annual precipitation ranging from 43 cm in Phelps County in the west to 74 cm in Fillmore County in the east (Gilbert 1989). The RWB is located in a semi-arid climate and most wetlands in the region do not receive groundwater inflow, resulting in high annual variation in flooded wetland availability (Brennan et al. 2005, LaGrange 2005, Vrtiska and Sullivan 2009). In years with low precipitation, wetland hydrology is often supplemented by pumping groundwater directly from the Ogallala aquifer on multiple publicly owned wetlands (Smith et al. 1989, Smith and Higgins 1990). Most wetlands in the region can be classified into one of three palustrine emergent wetland hydrologic regimes (Gersib et al. 1989): temporarily, seasonally, or semi-permanently inundated (Cowardin et al. 1979). Current distribution of wetlands in the RWB by hydrologic regime include; 26% temporary, 46% seasonal, and 28% semi-permanent (Smith and Higgins 1990). Most RWB wetlands range in area from $<$ 1 ha to 16 ha, although several wetlands were $>$400 ha (Brennan et al. 2005). Prior to European settlement, the RWB contained an estimated 4000 naturally occurring wetlands, covering approximately 38 000 ha (Erickson and Leslie 1987). However, only an estimated 445 of the original wetlands remained, representing 11% of the original number and 30% of the original wetland area (Smith and Higgins 1990). Of the remaining wetlands, approximately 80% have undergone hydrologic alterations, affecting wetland area, function and quality for wildlife habitat (Schildman and Hurt 1984, Smith and Higgins 1990, Bishop and Vrtiska 2008). Despite the loss and degradation of RWB wetlands, the area still serves as a major spring staging area for waterfowl in North America (Gersib et al. 1989) and Bishop and Vrtiska (2008) estimated approximately 9.8 million waterfowl use the RWB region each year during spring migration. Approximately 50% of the mid-continent population of mallards and 30% of the continental population of pintails, and an ever-increasing number ($>$1.5 million) of light geese use the RWB region during spring migration (Gersib et al. 1989, Krapu et al. 1995, LaGrange 2005, Bishop and Vrtiska 2008, Vrtiska and Sullivan 2009).

Prior to and during our study, LGCO regulations limited hunting to four days a week (Saturday, Sunday, Wednesday and Thursday) until the third week in March, after which hunting was allowed seven days a week. The LGCO season closed in the RWB during the second week of April. Throughout the entire LGCO, 16 specific public wetlands also were closed to hunting. Both the days of the week and public wetlands closed to hunting have remained consistent since 2004. Participants primarily harvest light geese in the RWB during the LGCO by shooting birds over decoys in fields and in wetlands, stalking geese in fields and wetlands, and harvesting birds traversing from roost and feeding sites. Given the relatively small area of RWB wetlands, typically all waterfowl occupying a wetland are affected by hunting activity occurring on that wetland.

Material and methods

Due to annual variation in precipitation and wetland availability (Bishop and Vrtiska 2008), we selected study wetlands on an annual basis, assessing potential sites for presence of water using ground surveys in late January/early February 2011and 2012. We paired public wetlands closed to LGCO hunting with either one or two public wetlands open to LGCO hunting (hunting category) based on similarities in wetland area, percent vegetative cover, and location. Wetland area was visually estimated as a percentage of the hydric footprint containing water and vegetative cover types were determined using methods previously described for the region (Stewart and Kantrud 1971). We used a total of 40 public wetlands (24 open to hunting and 16 closed to hunting) as study sites over the two years of our study (Fig. 1).

We concurrently surveyed open and closed study wetlands in the same region for the presence of migratory birds and LGCO participants during spring (mid-February – late March) migrations 2011 and 2012. We spent approximately 1.5–2 h at each wetland pair and then moved to another wetland pair upon completion; we typically visited 4–5 wetland pairs/day and surveyed each wetland pair approximately 3–4 times per week. If two wetlands open to hunting were grouped with one wetland closed to hunting, we alternated visits between wetlands open to hunting for that group. We divided diurnal time period into four time intervals; dawn (30 min before sunrise – 09:00), morning (09:00–12:30), afternoon (12:30–16:00), and evening (16:00–30 min after sunset) and attempted to conduct an equal number of observations for each wetland pair/group within these time periods (Webb et al 2010a). To quantify hunting participation on wetlands open to hunting during the LGCO, we recorded the number of hunting parties present during each survey. Although study objectives did not include quantifying LGCO participation in non-wetland habitats, if we opportunistically observed hunters in agricultural fields or on non-study wetlands, we recorded the date, location (coordinates and site description), and number of participants. We also opportunistically stopped potential hunters on roads, parking lots, etc. to gather as much information as possible about their hunting behavior for that day, including times and locations of their hunting activities.

After recording the presence of any observable hunters present in study wetlands, we then surveyed the site for waterfowl abundance. During each waterfowl survey, we observed study wetlands for the presence of dabbling ducks *Anas* spp. and geese (tribe: Anserini). We examined wetlands for the presence of only these two groups because few diving (*Aythya* spp.) or sea (*Bucephala* spp.) ducks use the RWB during spring. We recorded all waterfowl visible in open water from a pre-determined vantage point(s) and then entered the wetland to visit pre-determined points to detect waterfowl not visible in open water. We used both spotting scopes and binoculars, whichever was most appropriate given the conditions, to count waterfowl. To ensure consistent sampling effort, number of points within a wetland varied with wetland area: one point in wetlands ≤ 5 ha; two points in wetlands 5.1–25 ha; three points in wetlands 25.1–100 ha; and four points in wetlands >100 ha (Brown and Dinsmore 1986, Webb et al. 2010a, b). All birds observed while walking between observation points were included in the overall count for that wetland, however, if birds previously counted flew to another part of the wetland they were not included

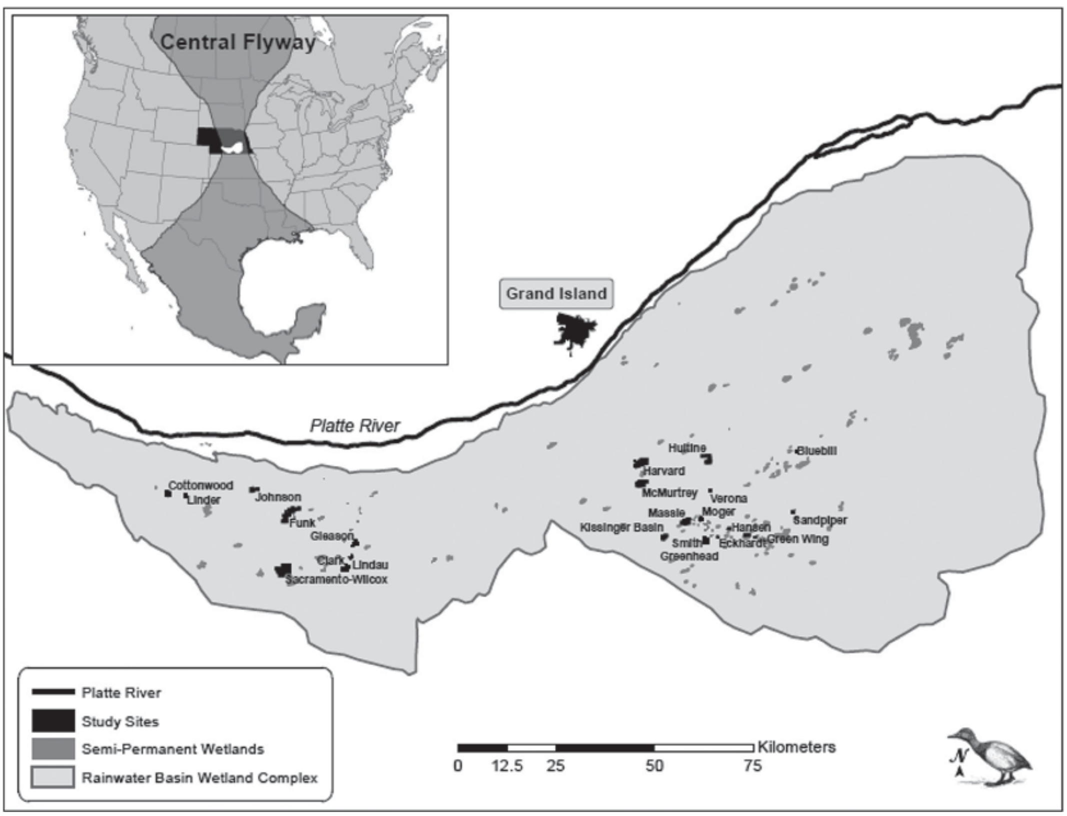

Figure 1. Public wetlands (n = 40; 16 closed and 24 open to hunting) used as study sites to conduct waterfowl surveys and observe hunting participation during the Light Goose Conservation Order in the Rainwater Basin of Nebraska in springs 2011 and 2012.

(Fairbairn and Dinsmore 2001, Webb et al. 2010a, b). In flocks with <100 birds, individual number and species were recorded; in flocks of >100 birds, species were recorded and the numbers of birds for each species were visually estimated (Webb et al. 2010a, b). Flocks of >100 birds were estimated based on the following criteria; 100–500 birds were estimated to the nearest 10, 501–2000 birds to the nearest 100, and nearest 1000 for larger flocks.

During each wetland observation we estimated the percent of the wetland containing water (% full) by visually comparing current water levels with aerial photographs and the extent of the wetland plant boundary (Webb et al. 2010a). We used aerial photos in ArcMap (ArcGIS) to construct polygons and calculate the area of each wetland footprint (i.e. area of wetland when 100% full) for all study sites (ESRI 2010). We then multiplied % full by the area of each wetland footprint, providing an estimate of inundated wetland area during each survey, which we used to calculate total dabbling duck density as well as densities of mallards and pintails (ducks ha^{-1}). Because of the importance of the RWB region as a staging area for white-fronted geese, mallards and pintails, we analyzed densities of these species separately and in addition to total density (Bishop and Vrtiska 2008). We excluded all surveys where we observed zero waterfowl and either ice cover exceeded 90% or if less than 10% of the wetland was inundated at the time of the survey. We also reclassified three study wetlands that were open to hunting in 2012 as closed for data analysis because no hunting encounters were observed on them. The variable hunt day was determined for each waterfowl survey based on the designation of that day being open or closed to hunting. We defined season (early and late) based on the decline of light geese observed on study wetlands. Early season was classified as the time from when surveys began up through the week when $>95\%$ of all light geese observed on study wetlands each year left the RWB region; with late season occurring after the designated week (Webb et al. 2011). Consequently, hunting encounters recorded on study wetlands open to hunting also declined sharply during late season.

We used analysis of variance (ANOVA) to test for differences in wetland area and percent vegetative cover between wetlands open and closed to the LGCO. We used a generalized linear mixed-model with a Poisson distribution (typical for count data; Bolker et al. 2009) and a multiplicative overdispersion component to test for differences in total dabbling duck densities, as well as individual mallard and pintail densities (Schabenberger 2005). Wetland site was designated as a random residual effect, which was equivalent to using it with the repeated statement in the PROC MIXED procedure in SAS (Schabenberger 2005). We used the generalized mixed-model to test for fixed effects of year, hunt category, hunt day, season and all possible interactions (PROC GLIMMIX; SAS Inst.).

For those wetlands open to hunting, we also tested for effects of observed hunting frequency on dabbling duck densities. We calculated mean weekly dabbling duck density for each site open to hunting to account for differences between when surveys were conducted and hunting encounters were recorded at sites. We used a generalized linear mixed-model with a Poisson distribution, a multiplicative overdispersion component, and designated site as a random residual effect to test for effects of weekly and cumulative hunting encounter frequencies on dabbling duck density at wetlands open to hunting (PROC GLIMMIX; SAS Inst.). For weekly hunting frequency, we tested for differences among sites open to the LGCO among three frequency categories; zero, one and two or more weekly hunting encounters. We classified cumulative hunting encounters at sites open to hunting into five categories; zero, one, two, three-four, and $>$ five total hunting encounters. We based cumulative hunting categories primarily on the frequency distribution of cumulative hunting encounters, resulting in a relatively equal sample size among categories. We restricted our analyses of weekly and cumulative hunting encounter frequencies to early season under the assumption that late season densities were more likely affected by departure of large numbers of dabbling ducks from the region. The ratios of the generalized χ^2-statistic to the degrees of freedom were used to evaluate fit of all generalized linear mixed-models. A ratio of approximately 1 indicated variability in our data had been properly modeled, and there was no residual overdispersion (Schabenberger 2005).

We observed few white-fronted geese during waterfowl surveys. Therefore, we converted white-fronted goose observations to a binary response variable (presence/absence) for each survey (Bewick et al. 2005). If >1 white-fronted goose was recorded during a survey, they were classified as present and if ≤ 1 white-fronted goose was observed we classified them as absent. We used logistic regression to test if wetlands closed to hunting were a significant predictor for the presence of white-fronted geese (PROC LOGISTIC; SAS Inst.). Analysis of white-fronted geese was restricted to early season surveys; if late season surveys were included it would have substantially lowered the presence/absence ratio and decreased the statistical power for detecting hunting effects (Bewick et al. 2005). Survey data for light geese were extremely variable and were not analyzed. All statistical analyses were performed with SAS software ver. 9.3 (SAS Inst.), type I error rate was controlled at $\alpha \leq 0.05$ and we report all means $\pm$ standard error.

Results

Study wetlands classified as open or closed to LGCO hunting did not differ in inundated area ($F_{1,38} = 0.33$, $p = 0.567$) or percent vegetative cover ($F_{1,38} = 2.51$, $p = 0.121$). We observed a total of 168 hunting parties throughout the RWB region during springs 2011 and 2012 (Fig. 2). The majority of hunting encounters (71%) were observed in 2011; however, numbers of encounters observed on study wetlands were similar between years. We observed 70 hunting parties on study wetlands during both years, 38 (54%) in 2011 and 32 (46%) in 2012. Hunting encounters on study wetlands were distributed evenly between weekdays open to hunting (35 encounters) and weekends open to hunting (35). Total hunting encounters recorded were also distributed relatively equally among the four diurnal time periods; 32% at dawn, 31% in morning, 27% in afternoon, and 10% in evening. Almost all (91%) hunting encounters on study wetlands and in the region (86%) were recorded during early season, when the majority of light geese were observed. We observed

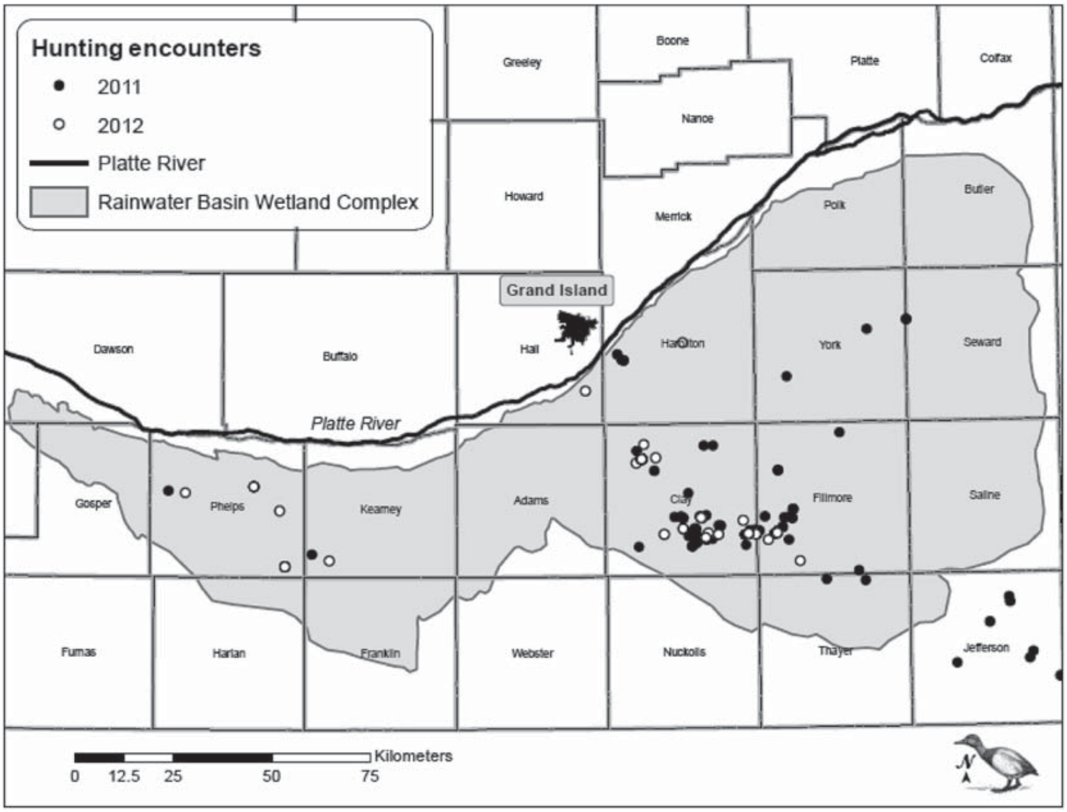

Figure 2. Location of hunting encounters observed during the Light Goose Conservation Order (n = 168) in the Rainwater Basin of Nebraska in springs 2011 and 2012.

hunters on each study wetland classified as open to hunting at least once during early season in both 2011 and 2012.

We conducted a total of 541 waterfowl surveys on wetlands open and closed to hunting (223 surveys from 16 February – 31 March 2011, and 318 surveys from 21 February – 28 March 2012). We removed 32 surveys prior to analyses because we observed no waterfowl during the surveys and wetlands were either ≥ 90% ice cover or ≤ 10% full at the time of the survey. In almost all weeks during early season of both study years, mean dabbling duck densities were at least two times greater on wetlands closed to hunting, compared to wetlands open to hunting (Fig. 3). Dabbling duck migration also occurred over a shorter time period in 2012 when compared to 2011; however, the majority of migration and data collection occurred from approximately mid-February to late March in both years of our study (Fig. 3).

We detected no interactions among independent variables in the analysis of dabbling duck densities (all $F \leq 3.84$, $p \geq 0.067$). Dabbling duck densities were greater on study wetlands during early season ($\bar{x} = 174.9 \pm 18.6$ ducks ha^{-1}), compared to late season ($\bar{x} = 48.4 \pm 7.8$ ducks ha^{-1}) ($F_{1,18} = 26.36$, $p < 0.001$). Densities of dabbling ducks were also greater on wetlands closed to hunting ($\bar{x} = 171.4 \pm 19.2$ ducks ha^{-1}), compared to wetlands open to hunting ($\bar{x} = 51.3 \pm 5.2$ ducks ha^{-1}) ($F_{1,17} = 21.40$, $p < 0.001$) (Table 1). Dabbling duck densities did not differ between hunt day categories ($F_{1,18} = 0.71$, $p = 0.412$) or years ($F_{1,18} = 0.20$, $p = 0.735$). We detected no differences in mean weekly dabbling duck densities among weekly hunting frequency categories during early season ($F_{2,18} = 1.04$, $p = 0.375$) (Fig. 4). In addition, mean weekly dabbling duck densities at sites open to hunting did not differ among cumulative hunting encounter categories in early season ($F_{4,14} = 0.44$, $p = 0.777$) (Fig. 5).

We detected no interactions among independent variables in the analysis of mallard densities (all $F \leq 1.07$, $p \geq 0.323$). Mallard densities were greater on study wetlands during early season ($\bar{x} = 59.7 \pm 6.9$ ducks ha^{-1}), compared to late season ($\bar{x} = 7.9 \pm 1.5$ ducks ha^{-1}) ($F_{1,18} = 36.74$, $p < 0.001$). Mallard densities were also greater on wetlands closed to hunting ($\bar{x} = 51.1 \pm 6.9$ ducks ha^{-1}), compared to wetlands open to hunting ($\bar{x} = 17.6 \pm 2.3$ ducks ha^{-1}) ($F_{1,17} = 10.01$, $p = 0.006$) (Table 1). Mallard densities did not differ between hunt day categories ($F_{1,18} = 0.98$, $p = 0.336$) or years ($F_{1,18} = 0.07$, $p = 0.834$).

We detected no interactions in the analysis of pintail densities (all $F \leq 3.52$, $p \geq 0.078$). Pintail densities were greater on study wetlands during early season ($\bar{x} = 110.9 \pm 12.7$ ducks ha^{-1}), compared to late season ($\bar{x} = 14.3 \pm 2.8$ ducks ha^{-1}) ($F_{1,18} = 34.81$, $p < 0.001$). Densities of pintails were greater on wetlands closed to hunting ($\bar{x} = 100.1 \pm 12.8$ ducks ha^{-1}), compared to wetlands open to hunting ($\bar{x} = 26.2 \pm 3.2$ ducks ha^{-1}) ($F_{1,17} = 12.02$, $p = 0.003$) (Table 1). Pintail densities did not differ between hunt day categories ($F_{1,18} = 1.63$, $p = 0.217$) or years ($F_{1,18} = 0.09$, $p = 0.819$).

We conducted 290 waterfowl surveys during early season in both years combined and observed a total of 4286

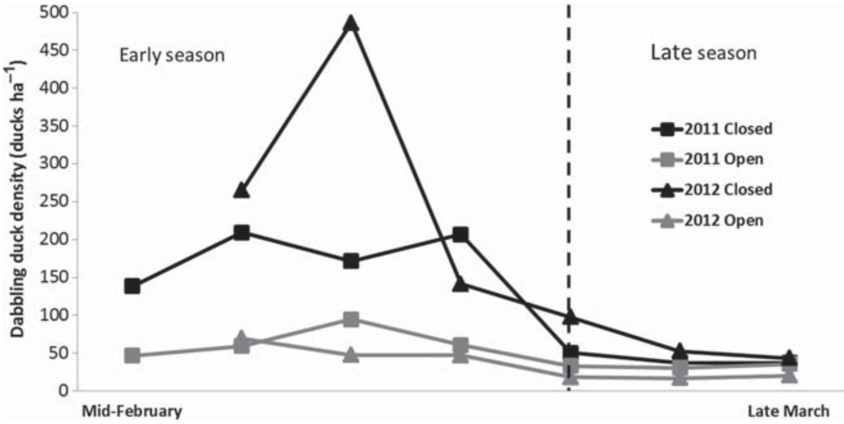

Figure 3. Mean weekly dabbling duck *Anas* spp. densities in early and late seasons on study wetlands open and closed to hunting during the Light Goose Conservation Order in the Rainwater Basin of Nebraska in spring 2011 (16 February–31 March) and 2012 (21 February–28 March). We classified early season as those weeks prior to the date when greater than 95% of all light geese observed on study wetlands each year had left the RWB region, whereas we classified late season as all weeks after that date.

white-fronted geese. White-fronted geese were observed during 34 (12%) of these surveys (18 on closed and 16 on open wetlands) and the maximum number of white-fronted geese observed during any one survey was 520 birds. Mean number of white-fronted geese observed were 10.7 ± 4.5 and 19.0 ± 6.5 on wetlands closed and open to hunting, respectively. Hunting category was not a predictor for the presence of white-fronted geese ($\chi^2 = 0.056$, $p = 0.813$).

Discussion

Although numerous studies have documented the effects of hunting disturbance on waterfowl distribution and habitat use during migration (Madsen and Fox 1995, Bechet et al. 2003, 2004, Arzel et al. 2006), our results demonstrate additional effects of LGCO disturbance on non-target waterfowl. We found greater dabbling duck densities on wetlands closed to LGCO hunting during both years of our study. When evaluated separately, mallards and pintails also exhibited similar responses to LGCO hunting, but this finding is not surprising given these species make up the majority of dabbling ducks using the RWB during spring migration (Gersib et al. 1989, LaGrange 2005, Bishop and Vrtiska 2008). Given our study design in which we simultaneously observed wetlands open and closed to hunting with similar geographic locations, wetland areas, and vegetative cover, we believe our observed differences in dabbling duck densities are due to hunting disturbance and not differences in habitat quality. Several other studies have also shown local redistribution of waterfowl in relation to hunting disturbance (Giroux and Bedard 1988, Madsen and Fox 1995, Madsen 1998, Evans and Day 2002) and Webb et al. (2010a) also reported LGCO hunting category (open to hunting) had a negative effect on dabbling duck abundance in the RWB during years with low wetland availability. However, Webb et al. (2010a) did not record hunter activity and designated wetlands as open or closed to hunting based on regulations for the LGCO in the RWB at the time of data collection. Although our study lacked experimental control of hunting activity on study wetlands (Madsen and Fox 1995, Bregnballe et al. 2004), we verified every wetland classified as open to hunting in our study was hunted at least once during early season when we observed the vast majority of hunting encounters. The length of time (1.5–2 h) we spent observing wetlands for hunting activity likely underestimated

Table 1. Mallard *Anas platyrhynchos*, northern pintail *A. acuta*, and total dabbling duck *Anas* spp. densities ($\bar{x} \pm$ SE) on study wetlands open (n = 24) and closed (n = 16) to hunting during the Light Goose Conservation Order in the Rainwater Basin of Nebraska in springs 2011 and 2012.

	Closed		Open			
	(ducks ha^{-1})	SE	(ducks ha^{-1})	SE	F-value	p-value
Mallards	51.1	6.9	17.6	2.3	10.01	0.006
Pintails	100.1	12.8	26.2	3.2	12.02	0.003
Dabbling ducks	171.4	19.2	51.3	5.2	21.40	< 0.001

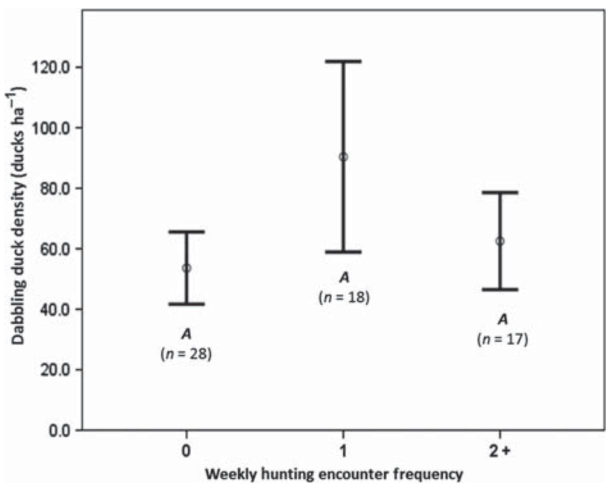

Figure 4. Dabbling duck *Anas* spp. densities ($\bar{x} \pm$ SE) on wetlands open to hunting based on weekly hunting encounter frequency during the Light Goose Conservation Order in the Rainwater Basin of Nebraska in springs 2011 and 2012. Frequency categories with differing letters are statistically different from others ($\alpha < 0.05$).

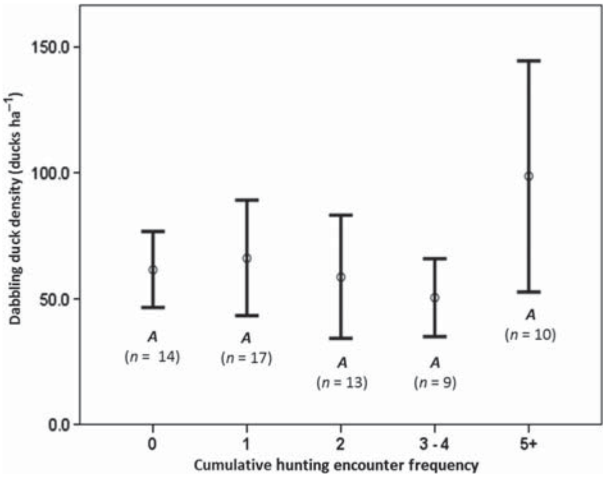

Figure 5. Dabbling duck *Anas* spp. densities ($\bar{x} \pm$ SE) on wetlands open to hunting based on cumulative hunting encounter frequency during the Light Goose Conservation Order in the Rainwater Basin of Nebraska in springs 2011and 2012. Frequency categories with differing letters are statistically different from others ($\alpha < 0.05$).

the actual amount that occurred. However, we believe our observations provided a minimum, relative measure of hunting activity for each wetland. We also note that our primary interest was assessing non-hunted wetlands and days, rather than assessing different levels of hunting activity.

The long term population effects of local redistribution caused by LGCO hunting on dabbling ducks are challenging to quantify because migratory birds use a variety of habitats and behavioral strategies to complete their annual life cycle (Owen 1993, Arzel et al. 2006, Drent et al. 2007, Sokos et al. 2013). During years with spring hunting, greater snow geese *C. c. atlantica* used habitats that yielded less metabolizable energy, which reduced the overall energy intake of geese (Bechet et al. 2004). In the same study area, lowered energy intake reduced lipid and protein reserves of departing greater snow geese during years with spring hunting (Féret et al. 2003). Mainguy et al. (2002) also demonstrated greater snow goose body condition indices and clutch sizes were lower for nesting birds in years with spring hunting. Although dabbling ducks were non-target species for the LGCO, local redistribution caused by hunting disturbance could potentially negatively impact dabbling duck lipid acquisition at spring migration stopover sites and subsequent nesting efforts. However, cross-seasonal effects of LGCO hunting on non-target species are more challenging to quantify, as dabbling ducks are not colonial breeders like greater snow geese (Mainguy et al. 2002), and are considered income breeders, relying more on nutrient sources collected locally on breeding grounds (Drent et al. 2006, 2007). Pintails collected in the eastern and western RWB in the late 1990s exhibited no difference in lipid or protein body composition during the LGCO, despite the entire western portion of the RWB being closed to spring hunting activities for light geese (Pearse et al. 2012). However, further investigation into short-term lipid acquisition (i.e. plasma metabolites) of dabbling ducks, specifically collected on wetlands open and closed to hunting during the LGCO may provide further insight into the potential physiological effects of redistribution caused by LGCO disturbance in the RWB.

Crowding of waterfowl has been suggested to increase stress levels and disease susceptibility (Friend 1981, Wobeser 1997, Bishop and Vrtiska 2008), and avian cholera has been a major focus of concern for waterfowl managers in the RWB since the mid-1970s (Zinkl et al. 1977). Smith et al. (1990) found a positive relationship between live and dead waterfowl densities (avian cholera deaths) during three out of four years of their study. Mean dabbling duck densities we observed on wetlands closed to hunting during the second week of 2012 (approximately 500 ducks ha^{-1}) exceeded or were near mean waterfowl densities reported by Smith et al. (1990) in the three years they found a relationship between bird densities and avian cholera deaths. Dabbling duck densities in our study also did not include the possibility of thousands of additional light geese on study wetlands during certain diel periods (i.e. nocturnal roosting). Dabbling duck densities we observed on closed wetlands, in conjunction with results from Smith et al. (1990), suggest that LGCO hunting has the potential to indirectly increase mortality from avian cholera in non-target species, at least during peak migration periods of some years. However, the threshold waterfowl density where crowding starts to have negative impacts on waterfowl using wetlands is poorly understood and likely depends on a variety of factors such as wetland availability (i.e. inundation), water quality, weather, and time of year (Windingstad et al. 1988, Smith et al. 1990, Blanchong et al. 2006, Webb et al. 2010a).

We found no effects of hunt day category in our analyses of dabbling ducks as a group, or mallards and pintails as individual species. We also detected no differences in dabbling duck densities among wetlands open to hunting regardless of weekly or cumulative hunting encounters frequency during early season. Availability of flooded wetlands is often limited in the RWB and only 4–23% of wetlands pond water in a given spring (Bishop and Vrtiska 2008). Waterfowl may be less responsive to days closed to hunting in dry years when fewer wetlands are inundated and hunters are more concentrated on wetlands open to hunting. In years with limited flooded wetland availability, disturbance frequency is also likely greater on RWB wetlands open to hunting, and waterfowl may have less opportunity to return to wetlands that are continuously disturbed. Indeed, Webb et al. (2010a) reported that LGCO hunt status of wetlands in the RWB had the greatest negative effect on spring dabbling duck abundance when wetland availability was lowest. However, during our study, wetland inundation in both 2011 and 2012 was above mean inundation levels for the region and, in fact included the years with greatest wetland availability since 2004 (unpubl. data, RWB Joint Venture). The same wetlands have also been closed to hunting during the LGCO in the RWB for over a decade and it is possible that dabbling ducks have become habituated to using these disturbance free sites for the duration of their migration stopover time, including days closed to hunting. Indeed, Madsen (1998) found that after the establishment of two long term refuges in Danish coastal marshes, the number of mallard bird-days increased by at least a factor of four on both established refuges over a ten year period.

Waterfowl response to intermittent hunting disturbance has varied in several studies (Madsen and Fox 1995). In Mississippi, there were no differences in duck abundance between areas open to fall hunting for two or four days, despite greater waterfowl food availability on wetlands open to hunting two days a week (St. James et al. 2013). Limiting hunting to mornings or evenings was also insufficient to ensure green-winged teal *A. crecca* abundance was consistent with control areas, which were free from disturbance (Bregnballe et al. 2004). However, individually radiomarked mallards in Colorado returned to areas within one day of experimental shooting disturbance during fall and winter (Dooley et al. 2010). Vulnerability to redistribution from hunting disturbance may vary considerably among species, time of year, and with changes in available habitat and food resources (Madsen and Fox 1995, Arzel et al. 2006, Sokos et al. 2013). For example, in order to avoid human disturbance, Eurasian wigeon *A. penelope* used habitats with food resources of lower nutritional quality, but in the same study brant *Branta bernicla* used more energetically profitable habitats, despite being heavily disturbed (Mathers and Montgomery 1997). However, Fox and Madsen (1997) reviewed the literature in Europe where shooting disturbance has been intensely studied and concluded that intermittent hunting is generally not an effective way to minimize hunting disturbance effects on waterfowl abundance. While Fox and Madsen (1997) concurred intermittent hunting improved the ability of a site to maintain greater bird numbers compared to sites with daily shooting activity, they suggested intermittent hunting requires long periods free from disturbance, measured in weeks rather than days.

We found hunting category was not a predictor for the presence of white-fronted geese. However, our statistical power for finding an effect of hunting was relatively low for this analysis (Bewick et al. 2005), given the low frequency with which we observed white-fronted geese on study wetlands. Several authors reported approximately 90% of the mid-continent population of white-fronted geese used the RWB as their primary staging area during spring migration (Gersib et al. 1989, LaGrange 2005, Bishop and Vrtiska 2008) and Krapu et al. (2005) estimated peak white-fronted goose abundance of 23 000 and 11 000 on two public wetlands alone in spring 1980. During fall 2011, biologists reported 681,700 mid-continent white-fronted geese for the population estimate in prairie Canada (USFWS 2012). We conducted over 500 surveys on RWB wetlands during the two year study and observed only 3510 white-fronted geese in 2011 and 1380 in 2012, leading us to speculate that a majority of mid-continent white-fronted geese are no longer using the RWB for spring staging. One of the primary reasons restrictive LGCO regulations were initially implemented in the RWB was to protect white-fronted geese from hunting disturbance due to their close association with light geese during this time period (Vrtiska unpubl.). Factors contributing to the apparent decrease in mid-continent white-fronted geese using the RWB for spring staging are unknown. However, the absence of white-fronted geese during spring migration in the RWB has coincided with the westerly movement of millions of light geese into the RWB during spring migration (Vrtiska and Sullivan 2009), a decrease in availability of waste corn in the region (Krapu et al. 2004), and a reduction in stored lipids in white-fronted geese staging in the RWB (Pearse et al. 2011).

Conclusions

Given that dabbling duck densities were greater on wetlands closed to hunting, providing wetlands free from hunting disturbance during the LGCO is likely an important management strategy at migration stopover sites. However, we found no effects of hunt day in our analyses of dabbling duck densities and no differences in mean weekly dabbling duck densities among wetlands open to hunting regardless of weekly or cumulative hunting encounters frequency. Distribution of the few white-fronted geese still using the RWB for staging did not seem to be affected by hunting disturbance. Given these results, we speculate that non-target dabbling duck species exhibit a threshold response to hunting disturbance and a LGCO season with more days open to hunting with the current or an increased network of closed wetlands, may minimize additional impacts on the distribution of non-target waterfowl species using the region for spring staging. An increase in days open to hunting may also increase hunter participation and ultimately aid in the reduction of mid-continent light goose populations. If allotted days open to hunting during the LGCO is increased, the closure of additional public wetlands in the RWB may help alleviate potential impacts of crowding and the under-utilization of food resources for non-target species in the region. Indeed, given that migratory bird hunters were relatively neutral in supporting potential direct control measures (i.e. measures beyond conventional hunting practices) for light goose populations (Dinges et al. 2014), increasing opportunities for public participation in the LGCO may be the most publicly acceptable regulatory alternative for reducing light goose populations. However, if LGCO regulations are changed at spring stopover sites, continued monitoring and evaluation of regulatory changes and the potential effects on waterfowl distribution, as well as hunter participation and satisfaction, will be useful in helping inform future management decisions.

Acknowledgements – We would like to thank the Nebraska Game and Parks Commission, the Missouri Cooperative Fish and Wildlife Research Unit and the E. K. Love Fellowship for providing funding and logistical support for this project. Additional logistical support was provided by the Rainwater Basin Joint Venture and Rainwater Basin Wetland Management District. We also gratefully acknowledge H. Modrow and E. Teter for their assistance collecting field data. The Missouri Cooperative Fish and Wildlife Research Unit is jointly sponsored by the Missouri Department of Conservation, the University of Missouri, the U.S. Fish and Wildlife Service, the U.S. Geological Survey, and the Wildlife Management Institute. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

References

Abraham, K. F. and Jefferies, R. L. 1997. High goose populations: causes, impacts and implications. – In: Batt, B. D. J. (ed.), Arctic ecosystems in peril: report of the Arctic Goose Habitat

Working Group. Arctic Goose Joint Venture Special Publication. U.S. Fish and Wildlife Service, Washington, D.C., USA, and Canadian Wildlife Service, Ottawa, Ontario, Canada, pp. 7–72.
Abraham, K. F. et al. 2005. The dynamics of landscape change and snow geese in mid-continent North America. – Global Change Biol. 11: 841–855.
Alisauskas, R. T. et al. 2011. Harvest, survival, and abundance of midcontinent lesser snow geese relative to population reduction efforts. – Wildl. Monogr. 179: 1–42.
Arzel, C. et al. 2006. Ecology of spring-migrating Anatidae: a review. – J. Ornithol. 147: 167–184.
Bechet, A. et al. 2003. Spring hunting changes the regional movements of migrating greater snow geese. – J. Appl. Ecol. 40: 553–564.
Bechet, A. et al. 2004. The effects of disturbance on behavior, habitat use and energy of spring staging geese. – J. Appl. Ecol. 41: 689–700.
Bewick V. et al. 2005. Statistics review 14: logistic regression. – Critical Care 9: 112–118.
Bishop, A. and Vrtiska, M. 2008. The Wetlands Reserve Program supports migrating waterfowl in Nebraska's Rainwater Basin region. – US Dept of Agriculture Natural Resources Conservation Service.
Blanchong, J. A. et al. 2006. Multi-species patterns of avian cholera mortality in Nebraska's Rainwater Basin. – J. Wildl. Dis. 42: 81–91.
Bolker, B. M. et al. 2009. Generalized linear mixed models: a practical guide for ecology and evolution. – Trends Ecol. Evol. 24: 127–135.
Bregnballe, T. et al. 2004. Effects of temporal and spatial hunting control in waterbird reserves. – Biol. Conserv. 119: 93–104.
Brennan, E. K. et al. 2005. Short-term response of wetland birds to prescribed burning in Rainwater Basin wetlands. – Wetlands 25: 667–674.
Brown, M. and Dinsmore, J. J. 1986. Implications of marsh size and isolation for marsh bird management. – J. Wildl. Manage. 50: 392–397.
Cowardin, L. M. et al. 1979. Classification of wetlands and deepwater habitats of the United States. – US Fish and Wildlife Service, Washington, D.C., USA.
Dinges, A. J. et al. 2014. Migratory bird hunter opinions regarding potential management strategies for controlling light goose populations. – Wildl. Soc. Bull. 38: 728–733.
Dooley, J. L., T. A. Sanders, and P. F. Doherty. 2010. Mallard response to experimental walk-in and shooting disturbance. Journal of Wildlife Management 74:1815–1824.
Drent, R. H et al. 2006. Travelling to breed. – J. Ornithol. 147: 122–134.
Drent, R. H. et al. 2007. Migratory connectivity in Arctic geese: spring stopovers are the weak links in meeting targets for breeding. – J. Ornithol. 148: 501–514.
Erickson, N. E. and Leslie, Jr. D. N. 1987. Soil-vegetation correlations in the Sandhills and Rainwater Basin wetlands in Nebraska. – US Dept of the Interior Biol. Rep. 87. US Fish and Wildlife Service, Washington, D.C., USA.
ESRI 2010. ArcGIS desktop and spatial analyst. – Environ. Systems Res. Inst., Redlands, CA, USA.
Evans, D. M. and Day, K. R. 2002. Hunting disturbance on a large shallow lake: the effectiveness of waterfowl refuges. – Ibis 144: 2–8.
Fairbairn, S. E. and Dinsmore, J. J. 2001. Local and landscape-level influences on wetland bird communities of the prairie pothole region of Iowa, USA. – Wetlands 21: 41–47.
Féret, M. et al. 2003. Effect of a spring hunt on nutrient storage by greater snow geese in southern Quebec. – J. Wildl. Manage. 67: 796–807.
Fox, A. D. and Madsen, J. 1997. Behavioural and distributional effects of hunting disturbance on waterbirds in Europe: implications for refuge design. – J. Appl. Ecol. 34: 1–13.
Friend, M. 1981. Waterfowl management and waterfowl disease: independent or cause and effect relationships? – Trans. N. Am. Wildl. Nat. Res. Conf. 46: 94–103.
Gersib, R. A. et al. 1989. Waterfowl values by wetland type within Rainwater Basin wetlands with special emphasis on activity time budget and census data. – Nebraska Game and Parks Commission and US Fish and Wildlife Service. Lincoln, NE, USA.
Gilbert, M. C. 1989. Ordination and mapping of wetland communities in Nebraska's Rainwater Basin Region. – CEMRO Environ. Rep. 89-1. Omaha District, US Army Corps of Engineers, Omaha, NE, USA.
Giroux, J. F. and Bedard, J. 1988. Use of bulrush marshes by greater snow geese during staging. – J. Wildl. Manage. 52: 415–420.
Gustavson, T. C. et al. 1995. Origin and development of playa basins, sources of recharge to the Ogallala aquifer, southern High Plains, Texas and New Mexico. – Bureau of Economic Geology, Report of Investigations No. 229. Univ. of Texas, Austin, TX, USA.
Jefferies, R. L. and Rockwell, R. F. 2002. Foraging geese, vegetation loss and soil degradation in an Arctic salt marsh. – Appl. Veg. Sci. 5: 7–16.
Krapu, G. L. et al. 1995. Spring staging ecology of mid-continent greater white-fronted geese. – J. Wildl. Manage. 59: 736–746.
Krapu, G. L. et al. 2004. Less waste corn, more land in soybeans, and the switch to genetically modified crops: trends with important implications for wildlife management. – Wildl. Soc. Bull. 32: 127–136.
Krapu, G. L. et al. 2005. Do arctic-nesting geese compete with sandhill cranes for waste corn in the Central Platte River Valley, Nebraska. – Proc. N. Am. Crane Workshop 9: 185–191.
LaGrange, T. G. 2005. Guide to Nebraska's wetlands and their conservation needs. – Nebraska Game and Parks Commission, Lincoln, NE, USA.
Madsen, J. 1998. Experimental refuges for migratory waterfowl in Danish wetlands II. Tests of hunting disturbance effects. – J. Appl. Ecol. 35: 398–417.
Madsen, J. and Fox, A. D. 1995. Impacts of hunting disturbance on waterbirds-a review. – Wildl. Biol. 1: 193–207.
Mainguy, J. et al. 2002. Are body condition and reproductive effort of laying greater snow geese affected by the spring hunt? – Condor 104: 156–161.
Mathers, R. G. and Montgomery, W. I. 1997. Quality of food consumed by over wintering pale-bellied brent geese (*Branta bernicla hrota*) and wigeon (A*nas penelope*). – In: Biology and environment. Proc. R. Irish Acad., R. Irish Acad., pp. 81–89.
Osterkamp, W. R. and Wood, W. W. 1987. Playa-lake basins on the southern High Plains of Texas and New Mexico: part I. Hydrologic, geomorphic, and geologic evidence for their development. – Geol. Soc. Am. Bull. 99: 215–223.
Owen, M. 1993. The UK shooting disturbance project. – Wader Study Grp Bull. 68: 35–46.
Pearse, A. T. et al. 2011. Changes in nutrient dynamics of midcontinent greater white-fronted geese during spring migration. – J. Wildl. Manage. 75: 1716–1723.
Pearse, A. T. et al. 2012. Spring snow goose hunting influences body composition of waterfowl staging in Nebraska. – J. Wildl. Manage. 76: 1393–1400.
Reeves, C. C., Jr. and Reeves, J. A. 1996. The Ogallala Aquifer of the southern High Plains. – Estacado Books, Lubbock, TX, USA.
Schabenberger, O. 2005. Introducing the GLIMMIX procedure for generalized linear mixed models. Paper 196-30, SUGI 30. – SAS Inst., Cary, NC, USA.
Schildman, G. and Hurt, J. 1984. Update of Rainwater Basin Wetland Survey. Survey of habitat work plan K-83. Nebraska Game and Parks Commission, Lincoln, NE, USA.

Smith, B. J. and Higgins, K. F. 1990. Avian cholera and temporal changes in wetland numbers and densities in Nebraska's Rainwater Basin area. – Wetlands 10: 1–5.
Smith, B. J. et al. 1989. Land use relationships to avian cholera outbreaks in the Nebraska Rainwater Basin Area. – Prairie Nat. 21: 125–136.
Smith, B. J. et al. 1990. Precipitation, waterfowl densities and mycotoxins: their potential effect on avian cholera epizootics in the Nebraska Rainwater Basin Area. – In: Trans. N. Am. Wildl. Nat. Resour. Conf. 55: 269–282.
Smith, L. M. 2003. Playas of the Great Plains. – Univ. of Texas Press, Austin, TX, USA.
Sokos, C. K. et al. 2013. Hunting of migratory birds: disturbance intolerant or harvest tolerant? – Wildl. Biol. 19: 113–125.
Srivastava, D. S. and Jefferies, R. L. 1996. A positive feedback: herbivory, plant growth, salinity, and the desertification of an Arctic salt-marsh. – J. Ecol. 84: 31–42.
Stewart, R. E. and Kantrud, H. A. 1971. Classification of natural ponds and lakes in the glaciated prairie region. Resource Publication 92. – Bureau of Sport Fisheries and Wildlife, US Fish and Wildlife Service, Washington, D.C., USA.
St. James E. A. et al. 2013. Effect of weekly hunting frequency on duck abundances in Mississippi Wildlife Management Areas. – J. Fish Wildl. Manage. 4: 144–150.
Thompson, J. J. 1993. Modeling the local abundance of shorebirds staging on migration. – Theor. Popul. Biol. 44: 299–315.
USFWS and Canadian Wildlife Service 1986. North American waterfowl management plan. – US Fish and Wildlife Service and Canadian Wildlife Service, Washington, D.C., USA.
USFWS 2007. Final Environmental Impact Statement: Light Goose Management. – US Fish and Wildlife Service, Washington, D.C., USA.
USFWS 2012. Waterfowl population status, 2012. – US Department of the Interior, Washington, D.C., USA.
Vrtiska, M. P. and Sullivan, S. 2009. Abundance and distribution of lesser snow and Ross's geese in the Rainwater Basin and central Platte River Valley of Nebraska. – Great Plains Res. 19: 147–155.
Webb, E. B. et al. 2010a. Effects of local and landscape variables on wetland bird habitat use during migration through the Rainwater Basin. – J. Wildl. Manage. 74: 109–119.
Webb, E. B. et al. 2010b. Community structure of wetland birds during spring migration through the Rainwater Basin. – J. Wildl. Manage. 74: 765–767.
Webb, E. B. et al. 2011. Factors influencing behavior of wetland birds in the Rainwater Basin during spring migration. – Waterbirds 34: 457–467.
Windingstad, R. M. et al. 1988. Characterization of an avian cholera epizootic in wild birds in western Nebraska. – Avian Dis. 32: 124–131.
Wobeser, G. A. 1997. Diseases of wild waterfowl, 2nd edn. – Plenum Press.
Zinkl, J. G. et al. 1977. An epornitic of avian cholera in waterfowl and common crows in Phelps County, Nebraska, in the spring, 1975. – J. Wildl. Dis. 13: 194–198.