Management Plan for Midcontinent Greater White-fronted Geese

Prepared for the:
Central Flyway Council
Mississippi Flyway Council
Pacific Flyway Council
Canadian Wildlife Service
United States Fish and Wildlife Service

March 2023

Background
This plan was prepared by members of the White-fronted Goose Subcommittee of the Central Flyway Waterfowl Technical Committee, the Arctic Goose Committee of the Mississippi Flyway Game Bird Technical Section, and the Alaska Department of Fish and Game, with assistance from representatives of the Canadian Wildlife Service and U.S. Fish and Wildlife Service (see Participants section).

Midcontinent greater white-fronted geese migrate through many jurisdictions in three nations and are of great interest to many individuals and organizations. The Central, Mississippi, and Pacific Flyway Councils solicit the cooperation of all who are responsible for and interested in the management of the international resource these geese comprise. Inquiries or comments may be addressed to:

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Population Definition

For the purposes of this management plan, the midcontinent population of greater white-fronted geese (*Anser albifrons frontalis*; MCWFG) will include all greater white-fronted geese nesting in Canada and in interior and northern Alaska that winter in the Central and Mississippi Flyways (Figure 1). These birds breed throughout tundra and taiga habitats, and important breeding areas include: the Melville Peninsula and western Hudson Bay in the eastern Canadian arctic (Nunavut), Queen Maud Gulf (Nunavut), portions of southern Victoria Island (Nunavut), coastal portions of the Northwest Territories, the North Slope (Alaska), Seward Peninsula and portions of western Alaska, and interior Alaska (Garrettson et al. 2020, VonBank et al. 2021). Prior to 2000, eastern and western components of MCWFG were managed independently, but extensive banding on the breeding grounds during the 1980s and 1990s indicated relatively little longitudinal variation in recovery distributions (AGJV 2008). This led to amalgamation and management of a single population shared by the Mississippi, Central, and Pacific Flyway Councils. Agricultural lands in Saskatchewan and Alberta are important staging areas during fall migration, and MCWFG migrate through portions of the eastern Central Flyway and western Mississippi Flyway on their way to terminal wintering grounds. Previous research indicated differential timing of migration by breeding region and some segregation on wintering grounds according to breeding affiliation (Ely et al. 2013). However, VonBank et al. (2021) found that while geese from each breeding region occurred at proportionally higher numbers in some areas, there was considerable mixing of geese from all breeding regions during winter. Both studies demonstrated earlier timing of migration by geese from interior and northwest Alaska relative to other breeding affiliations.

Figure 1. Approximate breeding range of midcontinent greater white-fronted geese.

Over the last few decades, wintering distributions of MCWFG have changed, and the primary wintering area has shifted from coastal marshes of Louisiana and Texas to the Mississippi Alluvial Valley (Figure 2), although MCWFG are highly flexible and undergo frequent regional movements (VonBank et al. 2021). Band-recovery data, midwinter survey counts (Figure 2), and total harvest estimates (Figure 3) indicate a substantial eastward distributional shift of MCWFG from the Central Flyway to the Mississippi Flyway during the past decades. For example, between 2008-2014 and 2015-2021, the proportion of adult band recoveries in Arkansas increased from 18% to 29% (Dooley 2022). The general shift in wintering areas is thought to have been driven by agricultural changes and hunting pressure.

During the most recent 5-year period (2016-17 through 2020-21 hunting seasons), total harvests of juvenile and adult MCWFG in Canada and the Central and Mississippi Flyways averaged about 250,000, with Canada, the Central Flyway, and the Mississippi Flyway composing 23%, 20%, and 57%, respectively, of the total harvest (Figure 3). Major recreational harvest areas include Saskatchewan, Alberta, Louisiana, Texas and Arkansas (Figure 4), which collectively accounted for 71% of adult pre-season band recoveries during 2015-2021 (Dooley 2022). Moderate numbers of greater white-fronted geese are harvested in Mexico and during spring-summer subsistence seasons in Alaska and Canada, although estimates are lacking for most areas. During 2016-2019, spring-summer harvest of greater white-fronted geese in Alaska averaged about 54,000 (state-wide, including Pacific greater white-fronted geese), including about 30,000 harvested on the North Slope and in Interior Alaska (primarily MCWFG; Naves et al. 2021).

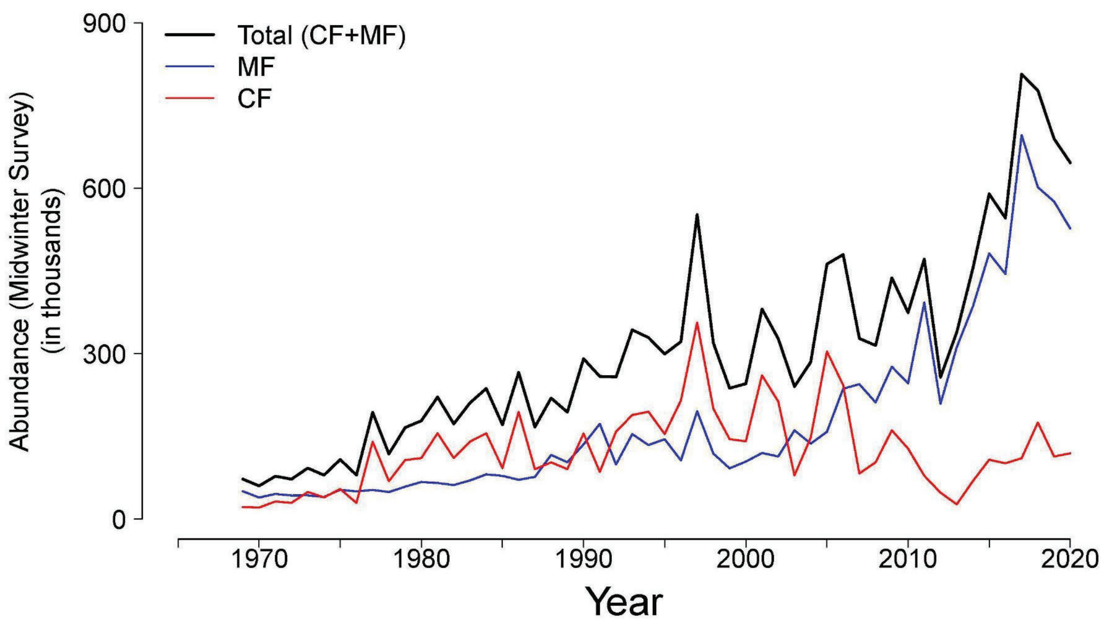

Figure 2. Midwinter survey counts of midcontinent greater white-fronted geese in the Mississippi Flyway (MF) and Central Flyway (CF), 1969-2020.

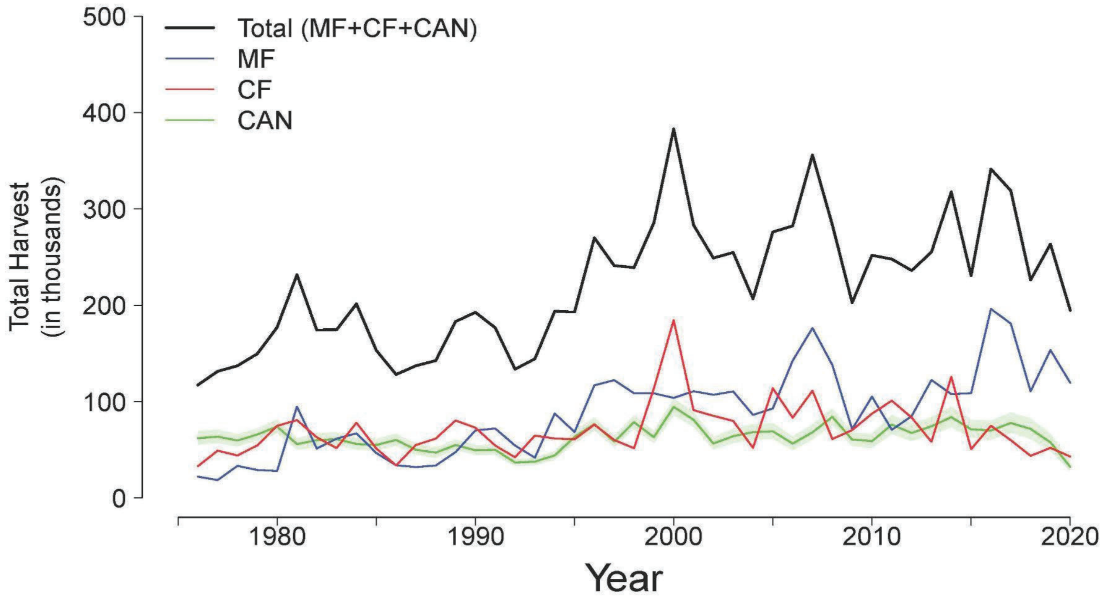

Figure 3. Total harvest estimates of juvenile and adult midcontinent greater white-fronted geese in the Mississippi Flyway (MF), Central Flyway (CF), and Canada (CAN), 1976-2020.

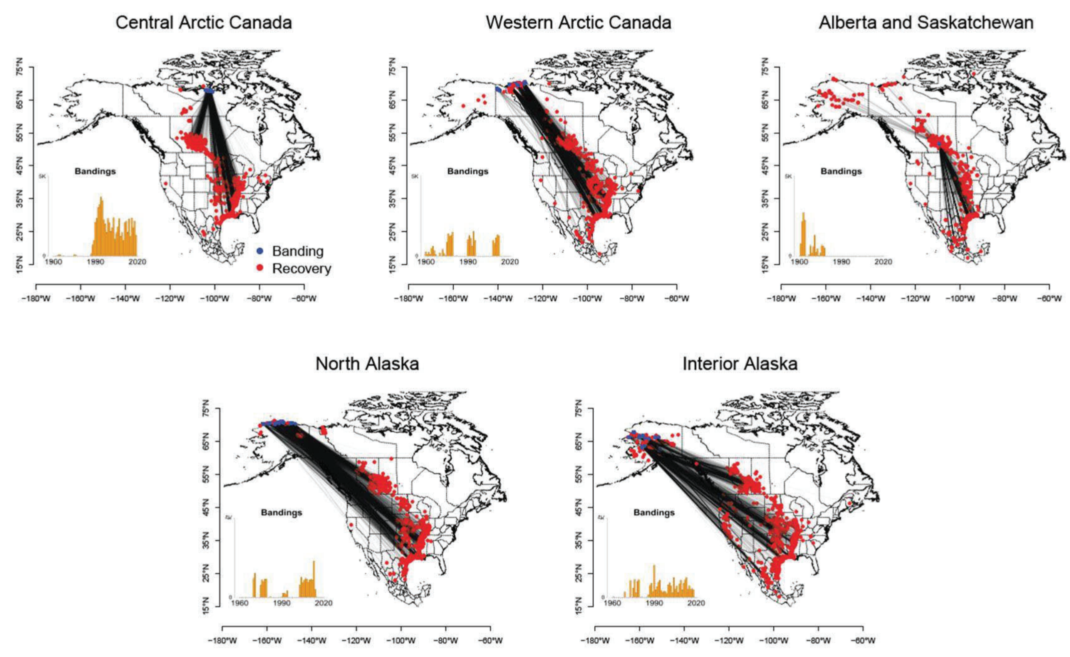

Figure 4. Banding and recovery locations of juvenile and adult midcontinent greater white-fronted geese marked in Arctic Canada, Alberta and Saskatchewan (in September and October during the 1960s and 1970s), north Alaska, and interior Alaska. Only the most recent 2,500 recoveries were shown to reduce overlap. Barplots show the number of annual bandings in each area during 1960-2020.

Population Status and Trends
Previous management plans for MCWFG determined population status based on fall staging counts conducted in Saskatchewan and Alberta. This survey was discontinued in 2020, due to methodological concerns, including lack of a sampling frame and unknown detection probability (Canadian Wildlife Service 2018). Similar to other arctic goose management plans, this plan now uses Lincoln estimates of abundance (adults) to determine population status and trends. Lincoln estimates are derived from total harvest estimates and hunter-shot recoveries of banded birds (Lincoln 1930, Alisauskas et al. 2009; Appendix 1). Lincoln estimates indicated the adult population underwent an approximate six- to seven-fold increase from the late 1970s (about 500,000) to the late 2000s (about 3.5 million), but, over the past decade, abundance has declined by about 3% per year (Figure 5). In 2020, there were 2.38 (95% CI=1.78-2.98) million adults in this population (Figure 5).

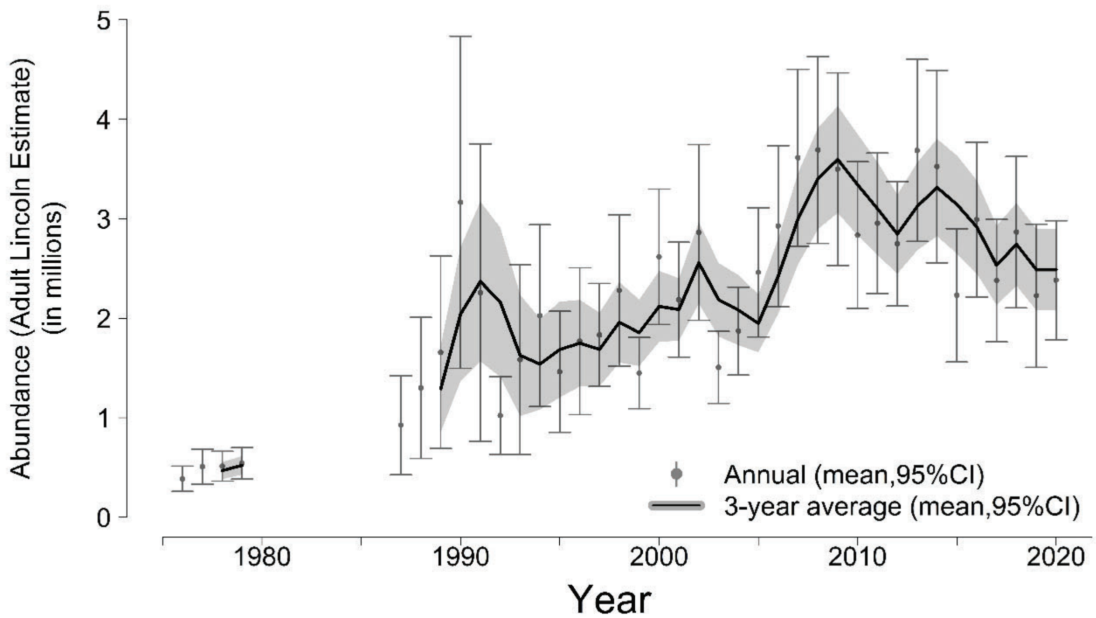

Figure 5. Lincoln estimates of adult midcontinent greater white-fronted geese, 1976-2020 (see Appendix 1).

Counts from the midwinter survey also increased approximately six- to seven-fold since the beginning of the survey, increasing from about 100,000 in the early 1970s to about 700,000 in recent years (Figure 2). MCWFG breeding in Alaska are monitored using standardized spring aerial transect surveys. Total and breeding bird indices of MCWFG from the Arctic Coastal Plain survey since 2007 averaged about 233,000 and 132,000, respectively, with no significant trend (Figure 6).

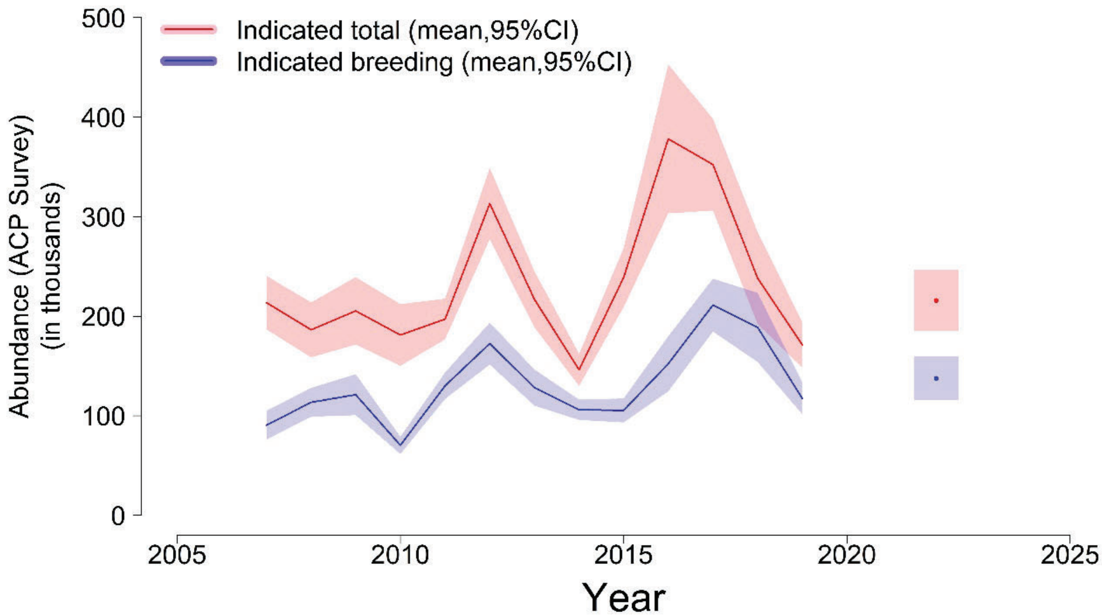

Figure 6. Indicated total and breeding bird indices of midcontinent greater white-fronted geese from the Arctic Coastal Plain Survey in north Alaska, 2007-2022.

Total and breeding bird indices of MCWFG from the Waterfowl Breeding Population and Habitat Survey in northwest and interior Alaska (strata 3-6 and 10-11) during the past ten years have averaged about 35,000 and 11,000, respectively, with no significant trend (Figure 7). In some years, large numbers of total MCWFG are estimated by this survey, likely reflecting the detection of migratory groups that have not settled at their final summering locations (Figure 7).

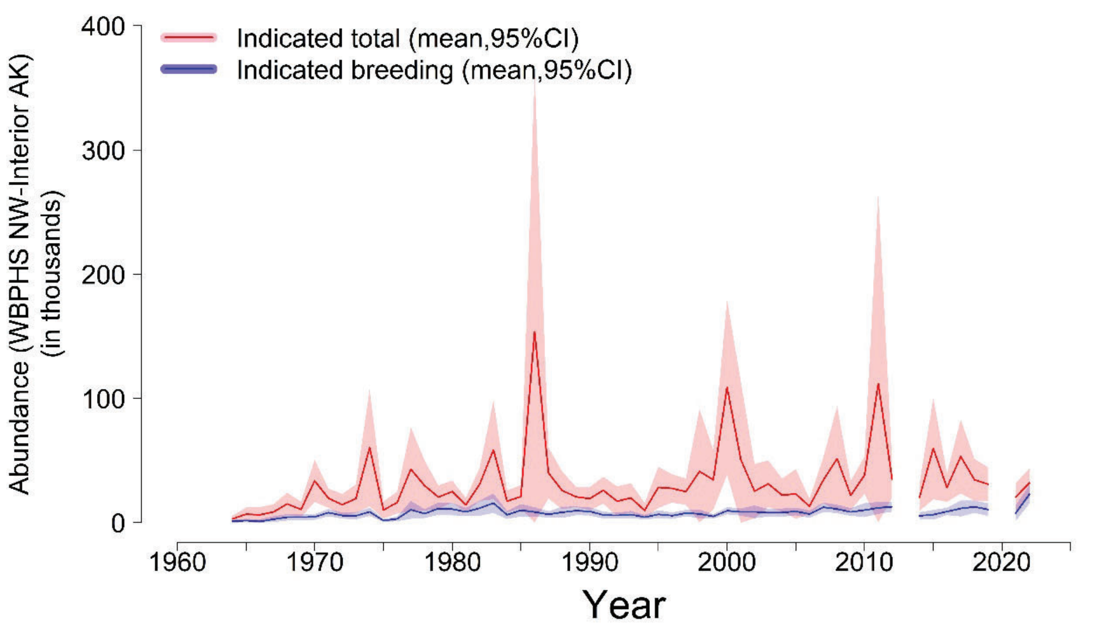

Figure 7. Indicated total and breeding bird indices of midcontinent greater white-fronted geese from the Waterfowl Breeding Population and Habitat Survey in northwest and interior Alaska (strata 3-6 and 10-11), 1964-2022.

Adult harvest rates have declined substantially, from about 10% in the mid-1970s to 4-5% in recent years (Dooley 2016). The most recent 3-year average (2019-2021) adult harvest rate (all banding areas combined) was 3.8% (Figure 8; Dooley 2022). Adult survival rates have averaged about 80% in recent years with no significant trend (Figure 8). Survival and harvest rates of MCWFG from different banding areas were relatively similar to each other during the past decade in contrast to prior analyses using band-recovery data through the late-1990s and early-2000s that found lower survival and higher harvest rates of MCWFG from interior Alaska (Ely et al. 2013, Dooley 2016). These changes in demographic rates are consistent with the recent GPS-GSM marking studies, suggesting greater degrees of inter-mixing of MCWFG among breeding and wintering areas than in the past (VonBank et al. 2021).

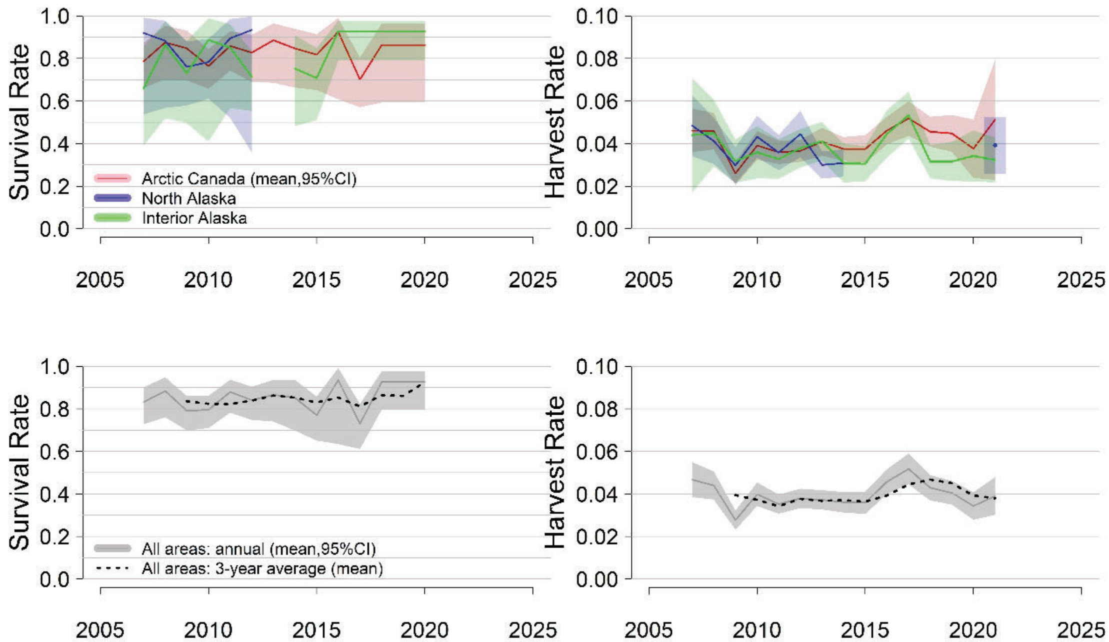

Figure 8. Survival and harvest rate estimates of adult midcontinent greater white-fronted geese banded in Arctic Canada, north Alaska, and interior Alaska (top) and all areas combined (bottom), 2007-2021 (from Dooley 2022).

Similar to other arctic nesting geese, productivity of MCWFG has declined over the long-term. The estimated ratio of juveniles to adults in Federal harvest surveys exceeded 0.70 (long-term average age ratio during 1976-2000) in only two years between 2007-2020 (Figure 9). The driver of low productivity in recent years is not fully understood, but the same pattern is occurring in other species of arctic-nesting geese.

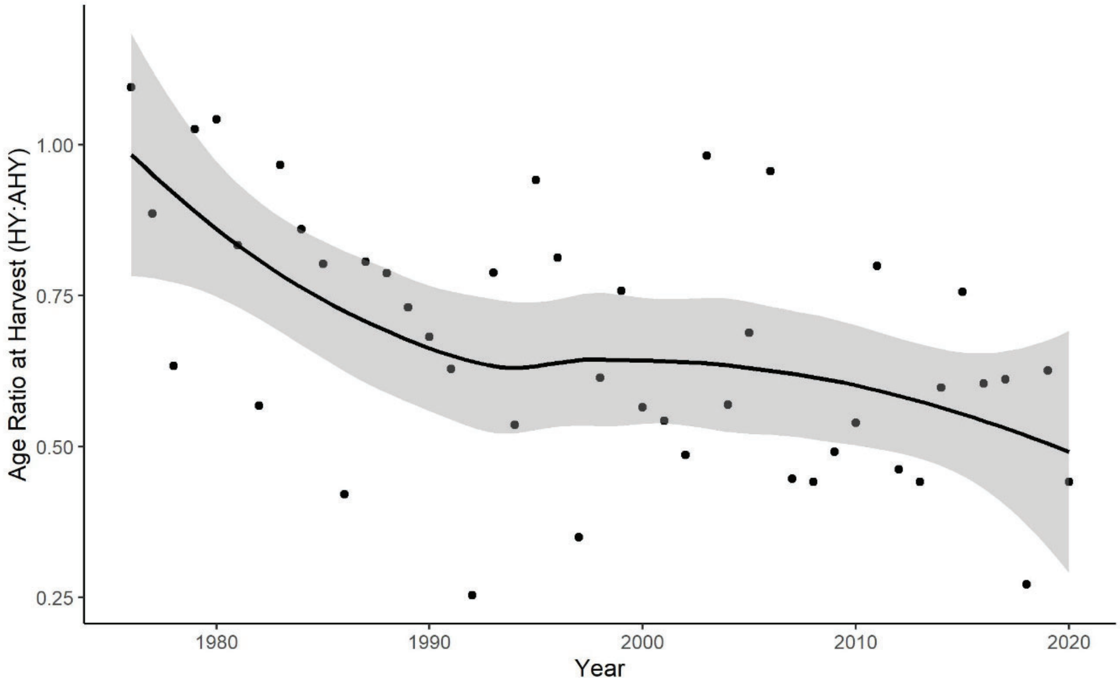

Figure 9. Age ratios (juvenile [hatch-year; HY]:adult [after-hatch-year; AHY]) and LOESS smoothed trend line of midcontinent greater white-fronted geese harvested in Canada and the Mississippi and Central Flyways,1976-2020.

Management Objective

The management objective is to maintain a midcontinent greater white-fronted goose population that allows optimum harvest opportunities in the Pacific, Central, and Mississippi Flyways and supports traditional subsistence harvest with consideration for special management options for identifiable and manageable segments or subunits within the population.

Population Monitoring Strategy

MCWFG will be monitored using estimates of adult harvest rates and Lincoln estimates of population size, similar to other arctic goose management plans (e.g., MF Canada goose, MF Cackling/CF Arctic Nesting Canada goose, MF and CF midcontinent Lesser Snow goose, MF Ross's goose; see https://www.agjv.ca/related-links/). This will require banding a representative sample of adults on the breeding grounds in Northern Canada and Alaska and deriving age-specific harvest estimates from national surveys in Canada and the United States. Band recovery data provide consistent information to assess survival and harvest rates, temporal and geographic distribution of the harvest, and population size. Banded samples should be adequate to provide statistically valid results and have sufficient distribution across breeding areas. A review of arctic goose banding programs (Calvert 2010) indicated high precision of adult survival estimates from 1996-2008, likely due at least in part to a long period of record (typically over 100 recoveries per year for over a decade). However, as in many banding programs, questions remain about what the best representative sample of banded birds should be, both geographically and by cohort. Annual pre-season banding efforts target molting, non-breeder MCWFG, which concentrate in large flocks during their flightless period. Banding occurs in three locations: the Central Arctic (Queen Maud Gulf; coordinated by CWS), the Arctic Coastal Plain of Alaska (coordinated by USGS), and in interior Alaska at the Innoko National Wildlife Refuge (NWR; coordinated by USFWS). At Innoko NWR, Bruce (2020) found that a relatively high proportion (32%) of greater white-fronted geese banded in the southwest portion of the refuge were affiliated with the Pacific Flyway. Based on this work, Dooley (2020) recommended revised spatial filters for interior Alaska to exclude banding records from the southwest portion of Innoko NWR for computing survival and harvest rates and Lincoln estimates (Appendix 1). Until the COVID-19 pandemic, adequate numbers of bandings (>1,000 adults/year) were achieved without interruption from 1970-1979, and since about 1990 (Figure 4). Maintaining continuous banding at these three sites (with annual targets of 1,000 adults/year) will be important to ensure banding data are representative of the breeding population across its entire breeding range. Multiple, independent banding sites also serves as a safeguard to ensure adequate annual bandings are achieved if environmental or logistical challenges prevent field operations at any particular location (e.g., inaccessible areas due to forest fires, pandemic induced restrictions, weather or logistical interruptions). Importantly, efforts are underway to establish approaches to incorporate indirect band recoveries into Lincoln estimates and also estimation of harvest rates in years where no banding occurs, and these efforts will improve precision around estimates. Additionally, use of indirect recoveries in future Lincoln estimates will inherently include individuals with varying breeding status, instead of only non-breeding geese, given that is the cohort targeted by banding operations (due to logistical/efficiency purposes).

Midwinter survey counts will continue to provide annual information on the abundance and distribution of MCWFG on concentration areas during the winter, and aerial transect surveys in Alaska will continue to provide annual information on the abundance and distribution of MCWFG in interior and Arctic Alaska during the summer. Experimental, aerial transect surveys in the Arctic were conducted during 2005-2011, which provided additional information about the distribution and abundance of MCWFG in areas of Arctic Canada (Garrettson et al. 2020). This survey did not become operational, principally due to operational expense and logistical challenges, but also because Lincoln estimates have become the preferred method of monitoring many Arctic-nesting goose populations in the midcontinent region. However, density and distribution estimates from these surveys provided important baseline information and could be used to assess future changes in breeding abundance or distribution or to target areas of high MCWFG concentration for future research studies or banding efforts.

Harvest Management Strategy

Although abundance of adult MCWFG has declined over the last decade, the population remains well above historical levels (Figure 5), and adult harvest rates remain relatively low (Figure 8), despite long-term increases in total harvest (Figure 3). Recent changes in harvest regulations around the 2015 Management Plan revision resulted in little change in adult harvest rates; rates slightly increased for a few years but subsequently decreased thereafter, with all 3-year average adult harvest rate estimates remaining below 5% (Figure 8). However, prior liberalizations in the Central Flyway West Tier States in the early 1990s coincided with a decline in MCWFG abundance in interior Alaska (Marks and Fischer 2015).

Managers of MCWFG have taken incremental steps to simplify and liberalize regulations, measure impacts, and adjust regulations accordingly. For example, the 2015 plan revision embraced this premise given monitoring systems were well established during the period of evaluation. Thus, a more risk-tolerant cooperative harvest management strategy was supported within a system of adaptive management. Similar to the previous plan, the current strategy will include: (1) use of a minimum population threshold approach and harvest rates to inform management decisions; (2) stable regulations whenever possible; and (3) flexibility to use an aggregate dark goose bag limit in provinces and some states with low annual harvest.

The 2015 harvest strategy used an interim threshold harvest rate of 6%, which was based on previous harvest rates of MCWFG and harvest rate objectives/harvest potential analyses of other goose populations. The 2015 plan revision also specified that a comprehensive harvest potential analysis be completed for MCWFG. This analysis was completed in 2016 (Dooley 2016) and used both Lincoln estimates and fall aerial survey counts to model maximum sustained yield kill rates (i.e., assuming 25% crippling loss). Estimated maximum sustained yield kill rates using Lincoln estimates were 9-11% (i.e., MSY harvest rates of 6.8-8.3%) depending on the model. This analysis supported use of a higher harvest rate threshold than the interim 6% threshold, and a harvest rate threshold of 7.5% was selected to reflect the midpoint of the range in maximum sustainable harvest rates. This is consistent with other midcontinent arctic-nesting goose harvest rate objectives (e.g., 10% for midcontinent cackling geese), and harvest rates higher than 7.5% have been sustainable for the management of other goose populations in North America, including some in the Mississippi Flyway (e.g., see Table 3 in Zimmerman et al. 2009).

The MCWFG harvest management strategy will use a minimum threshold of 1.2 million adult geese, calculated as the most recent three-year average of adult Lincoln estimates (Appendix 1). Previous harvest strategies for the population used a lower population threshold of 600,000, based on a running 3-year mean of counts from the fall staging survey. The threshold was reached only once since monitoring began in 1992, although there were three years where counts were less than 600,000 (Bartzen et al. 2020). With the shift towards use of Lincoln estimates in the harvest strategy, the lower threshold based on Lincoln estimates (1.2 million) continues to reflect the lowest abundance ever observed, based on a 3-year running mean of adult population size. For regulatory restrictions, 85% of the 3-year average adult Lincoln estimate distribution must be below the abundance threshold (1.2 million) and 85% of the 3-year average adult harvest rate estimate distribution must be above the harvest rate threshold (7.5%). Both conditions must occur for restrictions to be imposed. If only one condition is triggered, more restrictive regulatory changes could be considered by each Flyway but would not be predetermined. Additionally, any Flyway or State/Province could implement more restrictive regulations than those specified in this harvest strategy at any time, but regulations may not be more liberal than those specified. The use of a 3-year average estimate distribution (rather than point estimates or an average of annual confidence limits) better reflects the variance associated with a 3-year average, encourages efforts to reduce parameter estimate uncertainty (i.e., having sufficient banding sample sizes; USFWS 2017), and reduces the influence of an errant annual estimate or an annual estimate with poor precision.

Finally, there are some states in the Mississippi Flyway with very low total harvest of MCWFG each year. In the previous management plan, jurisdictions with harvest less than 500 (based on a 5-year mean) were considered ‘low harvest states’, but in this plan the threshold has been increased to less than 1,000. This was in response to a request by the Mississippi Flyway to maintain aggregate dark goose bags in states where harvest remains small, given that annual harvest estimates can be volatile (Appendix 2).

Regulatory Frameworks

States in each flyway will consider season framework dates independently, and states must choose a single framework statewide each year. Regulatory frameworks for midcontinent greater white-fronted geese are as follows:

- Canada: 107 days and 8 birds per day daily bag
  - The daily bag is an aggregate limit for Canada geese, cackling Geese, and white-fronted geese combined
  - Consider restrictions if 85% of the most recent 3-year average adult Lincoln estimate distribution was below 1.2 million AND 85% of the most recent 3-year average harvest rate estimate distribution was above 7.5%
- Alaska: 107 days and 4 birds per day daily bag
- West Tier Central Flyway (except Texas West Goose Zone): 107 days and 5 birds per day daily bag, in aggregate with dark geese
- Texas West Goose Zone: 95 days and 5 birds per day daily bag, in aggregate with dark geese
- Low-harvest Mississippi Flyway states (most recent 5-year average harvest <1,000 white-fronted geese annually): up to 107 days and 5 birds per day daily bag, in aggregate with dark geese
- Balance of Central and Mississippi Flyway states
  - *Standard Package*: 88 days and 2 birds per day daily bag OR 74 days and 3 birds per day daily bag OR 107 days and 1 bird per day daily bag
    - Offered when 85% of the most recent 3-year average adult Lincoln estimate distribution was above 1.2 million OR 85% of the most recent 3-year average harvest rate estimate distribution was below 7.5%.
  - *Restrictive Package*: 88 days and 1 bird per day daily bag OR 74 days and 2 birds per day daily bag
    - Offered when 85% of the most recent 3-year average adult Lincoln estimate distribution was below 1.2 million AND 85% of the most recent 3-year average harvest rate estimate distribution was above 7.5%
  - *Closed Season*
    - Considered jointly by all partners in this plan when 85% of the most recent 3-year average adult Lincoln estimate distribution was below 250,000

Maintenance of Plan

This plan will be reviewed at 5-year intervals by the Central, Mississippi, and Pacific Flyway Councils, their technical committees, and representatives from the Canadian Wildlife Service and U.S. Fish and Wildlife Service. Participation by Mexico in future plan revisions will also be encouraged. Each August, population status information and estimates (Lincoln estimates and harvest rates) will be updated by the USFWS, and a memo with this information will be distributed to each flyway to consider for selecting harvest regulations. Necessary modifications to this plan will be developed and presented to all three Flyway Councils for consideration and appropriate action. Annual status and other information relevant to MCWFG will be distributed through appropriate contacts before the Flyway Council meetings. These updates will be provided by the Chair of the Pacific Flyway Midcontinent White-fronted Goose Subcommittee, the Chair of the Central Flyway White-fronted Goose Subcommittee, and the Chair of the Mississippi Flyway Arctic Goose Committee.

Information Needs

Over the last decade, there have been substantial improvements in our collective understanding of MCWFG population status. Improved analytical methods have made monitoring programs more efficient and improved estimation precision, and new tracking technology has permitted insight into migratory strategies, distribution, energetics, and habitat use. Despite these advances, we remain strongly reliant on historical banding, harvest, and population survey data, and maintaining or improving these programs should be paramount among the respective agencies responsible for their delivery. However, there remain some key uncertainties and knowledge gaps, which we advocate for resolving in the coming years. These include:

- addressing uncertainty in data used to calculate Lincoln estimates of abundance (including dealing with missing years of banding data, and years with restricted banding distribution)
- investigating the utility of a coordinated two season banding program (pre-season winter) for partitioning survival into seasons and use of marked individuals to evaluate environmental and cross-seasonal effects on demographic rates
- improving knowledge of pre-breeding habitat use in subarctic and Arctic staging areas
- continuation of harvest surveys and pilot fall productivity surveys in Prairie Canada, such that long-term trends in age ratios can continue to be monitored (especially considering banding is focused on adults only)
- understand the cause of recent declines in productivity/age ratios
- investigating climate/weather and other factors driving productivity in Alaska and the Canadian arctic

Appendix 1. Band-recovery filters and methodology to calculate Lincoln estimates

Alisauskas et al. (2009) showed that the Lincoln estimator (Lincoln 1930) could be used to estimate population size of several species of arctic-nesting geese for which age-specific band-recovery data and harvest estimates were available. This method can be used to estimate population size at the time of banding in the summer (typically Jul-Aug). A general summary of the band-recovery filters used for midcontinent greater white-fronted geese (MCWFG) and the methodology to calculate Lincoln estimates is provided below.

Band-recovery filters

Dooley (2020) provided details of U.S. Geological Survey Bird Banding Laboratory codes and accompanying R code for the band-recovery data filters used for MCWFG survival and harvest rate analyses and annual memos. Information is summarized below.

Banding filters - spatial:

Based on Dooley (2016), which showed negligible difference between demographic rates of MCWFG from western and central Arctic Canada, and Bruce (2020), which provided updated spatial filters for interior Alaska that reduced the number of geese recovered in the Pacific Flyway, filters for the 3 banding areas are:

1) Arctic Canada: summer (Jun-Aug; banding month = 6-8) bandings in Canada (flyway code = 6) >60°N (banding latitude [or longitude, below] decimal degrees = >60.0).
2) North Alaska: summer (Jun-Aug) bandings in Alaska (flyway code = 5) >68°N.
3) Interior Alaska: summer (Jun-Aug) bandings in Alaska (flyway code = 5) between 169°-159°W and 68°-64°N, east of 159°W and between 68°-63.13°N, and east of 158.5°W and between 63.13-61°N.

Banding filters - additional:

For banding data, records with the following codes are included: greater white-fronted goose (species code = 1710), non-juvenile age (age code = 1, 5-8 [after hatch year, second year, after second year, third year, after third year]), known and unknown sex (sex code = 0 and 4-7 [unknown, male, female]), original banded (band status code = 0), normal, wild bird (bird status = 3), and metal or control leg band only (extra info code = 0 and 4).

Recovery filters:

For recovery data (in addition to the banding filters above), records with the following codes are included: shot or found dead (how obtained code = 0 and 1) during September–March and inexact month codes for fall, winter, and hunting seasons (encounter month code = 9-12, 1-3, and 93, 92, 94) in areas outside of Canada and Alaska (flyway code = 0-4, 7-9) and during all months and inexact month codes for fall, winter, spring, summer, and hunting seasons (encounter month code = 1-12, 93, 92, 83, 82, 94) in Alaska and Canada (flyway code = 5-6) to include recoveries from spring-summer harvests. Inexact month/year records are excluded (HSS [hunting seasons survived] = 99). Recoveries are categorized as direct (recovered in the first hunting season of the initial banding year] or indirect [recovered ≥1 hunting season after the initial banding year]). To do this, a separate encounter year field is created (e.g., "hunting season"), where recoveries during January-May and inexact month codes for winter and spring (encounter month = 1-5, 92, 93) are indexed as the prior year to reflect the hunting season (indexed by the first year [e.g., 2020] of a combined, two calendar year hunting season [2020-21 hunting season]). For example, if a goose was initially banded in July 2020 and then shot in the first hunting season in January 2021, this would be a direct recovery (hunting season code = 2020 and banding year code = 2020).

Lincoln estimates

In simplest form, Lincoln estimates of population size (N) are calculated as: N=H/h, where H = total harvest (estimated from Federal harvest surveys) and h = harvest rate (estimated from band-recovery data). Harvest rate can be calculated as *h* = DRR/r, where DRR is direct recovery rate and *r* is band reporting rate (typically estimated from reward banding studies). As a simple example, if 100 geese were banded in July 2020, and 2 of those geese were recovered that same hunting season (2020-21 hunting season), the direct recovery rate would be 0.02 (2/100). If the band reporting rate was 0.50 (50% of geese killed with a band are reported), then the direct harvest rate would be 0.04 (0.02/0.50). Thus, if the total harvest was 10,000 geese, the population size (N) would be 250,000 (10,000/0.04).

MCWFG band-recovery data:

The filters described above are used to create a timeseries of annual total adult bandings (from all three banding areas combined) and resulting direct recoveries, except that direct recoveries are only included from the three Canadian prairie provinces (encounter region = AB[04], SK[79], and MB[45]) and the Central and Mississippi Flyways (flyway code = 2-3). This spatial area is used to match the same spatial area for the total harvest estimates (below).

MCWFG band reporting rates:

Dooley (2020) provided analyses and details of the annual band reporting rates used for MCWFG to expand recovery rates to harvest rates, which are summarized below. Reporting rates (mean and standard deviation) prior to 2010 are from Arnold et al. (2020; Appendix A [mallard/non-trophy species]). Since their analyses ended in 2010, linear predicted values are used for years after 2010 (using the estimates during 2000-2010 for the regression). For the variances on the out-year predictions, the average percent coefficient of variation (% CV) observed during 2000-2010 (3.6%) is used. Arnold et al. (2020), as well as other studies, showed little difference between band reporting rates between commonly harvested geese and ducks in the midcontinent region. A recent reward band study was initiated on midcontinent mallards in 2017 (S. Boomer, USFWS, unpubl. data). Once results are finalized from that study, those reporting rates will be used for MCWFG, rather than linear predicted values based on Arnold et al. (2020).

MCWFG total harvest estimates:

Total harvest estimates are derived from the national harvest surveys conducted by the CWS and USFWS. In Canada, a Bayesian modeling approach is used to derive harvest estimates (posterior means and credible intervals) from 1979 to present (Smith et al. 2022). Annual adult MCWFG total harvest estimates from the three prairie provinces (Alberta, Saskatchewan, and Manitoba) are used. Because the Bayesian posterior credible intervals are asymmetric, an average standard error is calculated based on the lower and upper credible interval and used to calculate an annual variance estimate (var = SE^2). In the United States., species-specific harvest estimates are not reported with variance estimates. Annual adult MCWFG total harvest estimates from the Central and Mississippi Flyways are used, and a 10% CV is used to calculate annual standard errors and variances. The harvest estimates (and variances) from Canada (AB, SK, MB) and the United States (MF and CF) are then combined to create the final annual timeseries of the adult MCWFG total harvest estimates. A final step involves reducing the total harvest estimates and variances by the bias correction factors for geese (Padding and Royle 2012; 0.67 before 1999 and 0.61 after 1999). This final adjusted annual timeseries of total adult MCWFG harvest estimates is then used in the Lincoln estimator calculations (below).

Lincoln estimator calculations - annual estimates:
Methods to calculate Lincoln estimates follow Alisauskas et al. (2014) and are summarized below. Lincoln estimates (N) are calculated using the bias-adjusted estimator of Chapman (1951):

$$\widehat{N} = \frac{(b+1)(\widehat{H}+1)\widehat{p}}{(r+1)} - 1 \qquad (1)$$

where,
b = number of bandings
r = number of direct recoveries
$\widehat{p}$ = band reporting rate
$\widehat{H}$ = total harvest estimate

Variance is calculated using the delta method (Powell 2007) using the equations detailed in Alisauskas et al. (2014, eq. 5–8).

Lincoln estimator calculations - 3-year average:
A 3-year average is calculated by generating 5,000 randomly drawn samples of each annual Lincoln estimate based on the mean and standard deviation from the prior step (e.g., rnorm[5,000, mean=$mean_{year=x}$, sd=$sd_{year=x}$]). For the 3 applicable years, an average is calculated of the first 3 randomly drawn samples, the second 3 randomly drawn samples, etc. (up to the 5,000th randomly drawn samples), and these 5,000 averages are retained. Summary statistics (mean, standard deviation, and 95% confidence intervals [using 1.96*standard deviation]) are calculated from the 5,000 retained averages to represent the 3-year average Lincoln estimate. The proportion of the 3-year average Lincoln estimate distribution below a given numerical threshold is found by calculating the cumulative distribution at that threshold value (e.g., in Excel using function: NORMDIST("Threshold Value", mean=$mean_{3\text{-yr ave=x}}$, sd=$sd_{3\text{-yr ave=x}}$, TRUE).

Appendix 2. Redefining low harvest states in the Mississippi Flyway.

The below table includes average total harvest estimates of MCWFG in states in the Mississippi Flyway for the 5-year periods before (2011-15) and after (2016-2020) the last Management Plan revision in 2015. If a <500 bird threshold was maintained, IA, IN, and MN would switch to high harvest states. In order to keep the same designations as the current regulations, the threshold would need to be increased to <2,300 to include IN, which had the largest increase in harvest between the two periods. Using a threshold of <1,000 allows MN and IA to remain as low harvest states and maintain an aggregate bag of 5 in a 107-day dark goose season, but IN would switch to a high harvest state.

STATE	2011-15 AVE	2016-20 AVE	ALL YEAR (2011-20) AVE	CURRENT REGS (Low/High)	500 2016-20 AVE <500 (Low/High)	2300 2016-20 AVE <2,300 (Low/High)	1000 2016-20 AVE <1,000 (Low/High)
AL	0	0	0	L	L	L	L
AR	51,177	77,819	64,498	H	H	H	H
IA	321	516	419	L	H	L	L
IL	4,599	4,436	4,518	H	H	H	H
IN	106	2,246	1,176	L	H	L	H
KY	1,791	2,998	2,394	H	H	H	H
LA	28,592	39,004	33,798	H	H	H	H
MI	55	0	27	L	L	L	L
MN	97	900	499	L	H	L	L
MO	1,776	4,778	3,277	H	H	H	H
MS	9,894	14,196	12,045	H	H	H	H
OH	0	171	86	L	L	L	L
TN	677	5,108	2,893	H	H	H	H
WI	51	93	72	L	L	L	L

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