Minnesota Breeding Trumpeter Swan Survey 2022

Final Performance Report

DEPARTMENT OF NATURAL RESOURCES

Minnesota Breeding Trumpeter Swan Survey 2022

Final Performance Report

Federal Grant Award ID: F20AP12279

Reporting Agency: Minnesota Department of Natural Resources

Grant Period of Performance: October 1, 2020 – September 30, 2022

Performance Reporting Period: October 1, 2020 – September 30, 2022

Authors

Andrew Herberg, Regional Nongame Specialist, Minnesota Department of Natural Resources

Spencer Rettler, Nongame Specialist, Minnesota Department of Natural Resources

Contents

Summary

This grant funds an aerial survey for breeding swans in northeastern Minnesota to produce estimates of the abundance and distribution of adult Trumpeter Swans for the northeast third of Minnesota. The survey contributes data from the forested region of the state to complement data collected in the prairie from the annual Waterfowl Breeding Population Survey (WBPS); these data then contribute to the North American Trumpeter Swan Survey which has been completed at five-year intervals since 1975. The first aerial survey of northeastern Minnesota was conducted in 2015 and was intended to be completed again in 2020. However, in 2020 and 2021, the annual waterfowl surveys were cancelled due to COVID-19. The surveys were flown in spring of 2022. This report summarizes the results of the 2022 breeding swan survey and provides population estimates based on Northeast Breeding Swan Survey (NBSS; 2015, 2022) and the WBPS (2000-2022). Swan populations appear to remain increasing in Minnesota. The report also compares data from National Audubon Society Christmas Bird Counts and North American Breeding Bird Survey Counts. All objectives for this grant were met and are reported in detail below.

Objectives

- Conduct an aerial survey for breeding trumpeter swans within the northeast third of MN
- Combine results of aerial effort with annual Waterfowl Production Surveys that take place in the in the transition and prairie region of the state
- Produce an estimate of the adult trumpeter swan population abundance and precision within MN to update the USFWS 5 year monitoring estimates for the North American population of trumpeter swans.
- Produce a map delineating the estimated current summer range of trumpeter swans in the surveyed region

Introduction

The North American Trumpeter Swan Survey is the official status assessment for this species. It was first conducted in 1968 and has been completed at five-year intervals since 1975 (Groves 2012). The survey includes cooperators from federal, state, and provincial agencies across the northern United States and Canada, as well as volunteers from non-governmental organizations and the general public. Originally planned for 2020, this Minnesota effort represents an extension of the original planned official assessment.

When trumpeter swans (*Cygnus buccinator*) were being reintroduced to Minnesota, collaborators knew the locations of most nesting pairs and counted known pairs as well as incidentally observed birds from the ground or air, or solicited observations from the public. As the population grew, this survey was conducted during winter months as it was believed that most of the population concentrated at a limited number of wintering locations in Minnesota. Beginning in 2015, the U.S. Fish and Wildlife Service has requested that current and future surveys be conducted during the breeding season. Swan observations have been recorded as part of the annual Waterfowl Breeding Population Survey (WBPS) conducted by Minnesota Department of Natural Resources (MNDNR), but few trumpeter swans were

detected before 2000. This survey provides an estimate of swans primarily in the prairie and transition zones of Minnesota.

Given the lack of detailed information on swans in the northeast forest zone, a pilot study was initiated in 2015 to collect baseline data on the distribution of breeding swans and to identify potential habitat associations that could be used to improve the sampling design (e.g., via sampling-frame delineation or stratification). This extensive aerial transect survey was able to provide a reasonable estimate of breeding swans in the northeastern portion of Minnesota and was found to be a cost-effective means of supplementing the annual Waterfowl Breeding Population Survey to count swans. Building off the results of the 2015 pilot effort, the MN DNR once again flew an extensive aerial transect survey in the spring of 2022 to estimate the number of breeding swans in the northeastern portion of the state. This report summarizes the results of the 2022 breeding swan survey and provides population estimates based on Northeast Breeding Swan Survey (NBSS; 2015, 2022) and the WBPS (2000-2022). We also present data from National Audubon Society Christmas Bird Counts (CBC; National Audubon Society 2022) and North American Breeding Bird Survey Counts (BBS; U.S. Geological Survey 2022) for comparison to this statewide breeding surveys of trumpeter swans.

Methods

Northeast Breeding Swan Survey

Following the methodology used by Herwig & Giudice (2015), we conducted an extensive aerial transect survey in Northeast Minnesota (16 counties; Figure 1). The sampling frame into East-West transects that were 10-30 mi long and 0.25 mi wide. The choice of transect dimensions reflected tradeoffs examined in 2015 such as survey costs, efficiency, sample size (number of transects), and the spatial distribution of the sample. For the 2022 NBSS, 1st and 3rd quantiles (25% and 75% of ordered observations) of total open-water habitat (Gap Analysis Program data – open water habitats) were used as breakpoints to form 3 strata denoting the relative amount of "potential" swan habitat in each transect (low, medium, high).

The survey was conducted using a Cessna 185 and an American Champion Scout with an observer and pilot. Only the observer counted swans. The airplane traveled 0.25 miles north or south of the transect center line depending on the direction of flight, so that the observer could view the entire transect width (0.25 mi). Transects were flown at approximately 120 mph at 800-1200 feet above ground level. When birds were encountered that may be another species (e.g., American white pelicans [*Pelecanus erythrorhynchos*]), we descended to a lower altitude, and circled one or more times until accurate species information was obtained. We flew on days with good visibility and light winds. The survey was conducted in early June due to the late ice out in the spring of 2022 and staff capacity limitations. The pilot and observer were able to view 0.25 mi transect boundaries and aerial photography in real-time using both the pilot's navigation equipment. As swans were observed, the observer recorded a global positioning system location and the observer recorded if the swan was single, paired, flocked (along with the number of swans in the flock) and/or if a nest was present.

Waterfowl Breeding Population Survey

The MNDNR Waterfowl Breeding Population Survey is a long-running annual survey that uses east- west aerial transects (0.25-mi wide) stratified by historic wetland/lake density (Figure 1). The survey is conducted using a fixed-wing aircraft and 2 observers (pilot and a primary observer) and is seasonally timed to be optimal for breeding mallard (*Anas platyrhynchos*) ducks (although all waterfowl species are recorded). Standard procedures for the survey generally follow those outlined in "Standard Operating Procedures for Aerial Waterfowl Breeding Ground Populations and Habitat Surveys in North America" (USFWS/CWS 1987). The sampling design and survey protocols are briefly described in annual MNDNR reports (e.g., Cordts 2022). Since 2005, swan observations have been recorded by total count rather than by social category (single, flocked, etc.). Thus, we could not decompose the population estimate of swans by breeding status or social category. It should be noted that the WBPS is a parallel effort to the NBSS, with separate objectives and funding sources. Both datasets were used to generate a statewide estimate of trumpeter swans.

Analytical methods

We used a ratio estimator (Cochran 1977) to estimate the total number of swans in the stratified sampling frames, because transects varied in length (and thus area) in both the NBSS and WBPS. We used the R package "survey" (Lumley 2021, R Core Team 2022) to compute ratio-based estimates of population size and sampling variance. We explored both combined and separate ratio estimators (for stratified sampling designs). The estimators produced very similar population estimates in both surveys; therefore, we only report the results of the combined ratio estimator.

We also reviewed National Audubon Society Christmas Bird Counts (CBC; National Audubon Society 2022) and North American Breeding Bird Survey Counts (BBS; U.S. Geological Survey 2022) for comparison to our statewide breeding surveys of trumpeter swans. Christmas Bird Count Data included states in the Mississippi Flyway only (Alabama, Arkansas, Iowa, Illinois, Indiana, Louisiana, Michigan, Minnesota, Missouri, Mississippi, Ohio, Tennessee, and Wisconsin) plus Kansas. We assumed birds from Minnesota would either remain in Minnesota or migrate south primarily within this flyway. Wolfson et al. (2021) has shown that marked birds from Minnesota migrate using a variety of strategies and to a variety of Mississippi Flyway states as well as Kansas (Wolfson et al. 2021). To compare Christmas Bird Count data for Minnesota to the rest of the Mississippi Flyway, we first divided the total number of swans observed in an individual survey site by the total number of party hours (hours spent surveying - both car and on foot combined) to give us the rate of swans detected in each survey site (each year). We then averaged those rates within each state to provide an annual state average rate. From there, we grouped the other Mississippi Flyway states together and calculated a flyway annual average rate and compared that to Minnesota annual rates. We also examined BBS data within Minnesota from 2000-2021. We ran a log-linear hierarchical mixed regression model with random year-effects that allowed the trend trajectory to depart from a smooth regression line. This is a standard approach used by USGS to analyze BBS data (Link and Sauer 2002, Sauer and Link 2011, Smith et al. 2014). We allowed for a heavy tailed distribution that accounts for extra Poisson variation (i.e., overdispersion). For each of 3 Markov chain Monte Carlo (MCMC) chains, we used a 40,000 sample burn-in period, a 20-sample thinning rate, and 1,500 posterior samples for making inferences on index and trend parameters.

Convergence for all MCMC chains was confirmed by assessing the Gelman-Rubin R-hat criterion for all monitored parameters (less <1.1).

Results

Northeast Breeding Swan Survey

Total acres of open-water habitats (GAP data) per transect ranged from 0 to 3,292 ac. The sampling frame consisted of 933 transects (0.25-mi wide) in the low stratum, 1,859 transects in the medium stratum, and 931 transects in the high stratum. Our sample consisted of 75 transects (22, 36, and 17 transects in the low, medium, and high strata, respectively). Transects were well distributed across the northeastern sampling frame (Figure 1).

Transects were flown on June 2-3, 6, and 8-9, 2022 for a total of 31.8 hours of flight time. The air crew surveyed an average of 393 mi of transects per day (range: 277 - 577 mi/day). The total survey time was 17.57 hr, (does not include transit or refueling times). Survey time per transect ranged from 4 to 33 min and it varied linearly as a function of transect length (R-squared = 0.965).

We observed 687 swans and 146 nests on 68 (90.7%) of the 75 0.25-mi wide transects. Most (67.8%) swan observations were single or paired birds; only 15 observations involved flocked swans (mean = 14.7; median = 4; range = 3-137). One observation of 137 swans was removed from population estimate analyses due to the large impact this observation had both the point estimate and the standard error. This observation was included in all other summary statistics. Counts on transects where we observed at least 1 swan ranged from 1 to 141 swans (mean = 10.1; median = 7). For transects with swans, swans per mile of transect surveyed ranged from 0.033 to 4.7 (mean = 0.394, median = 0.26). Swan counts per transect were not strongly correlated with transect length (Figure 2a) or amount of open-water habitat (Figure 2b). Likewise, the probability of observing at least one swan per transect was not correlated with open-water habitat (z-value = 1.051, P =0.293). The proportion of transects with at least one swan observation were high across all strata, ranging from lowest 86.4% in the low strata to 100% in the high strata, whereas the proportion of transects in the medium stratum with at least one swan observation was 88.9%. GAP open-water habitat data was found not to be a good stratification variable (i.e., the design effect was negligible, which means that precision of the estimate was not improved via stratification). We generally observed swans in small open-water wetlands and on lakes that had small bays with wild rice (*Zizania palustris*), cattails (*Typha* sp.) and other emergent vegetation suitable for nesting. They were also observed in meandering rivers and streams that were bordered by emergent vegetation. We also observed swans in open-water ditches that were created in peatland areas in an attempt to drain and farm these areas; these ditches often do not show up on GAP or other geographic information system data layers.

The combined ratio estimate for the NBSS based on 0.25-mi wide transects was 0.279 swans per mile (SE=0.025), which produced a population estimate of 26,750 swans (90% CI: 22,850 – 30,650; Table 1). The breakdown by social category was approximately 15,488 (57.9%) paired swans, 3,237 (12.1%) single swans, and 8,025 (30%) flocked birds.

Waterfowl Breeding Population Survey

The WBPS observed 503 swans on 81 (70.4%) of the 115 transects surveyed. Counts on transects where at least 1 swan was observed ranged from 1 to 22 swans (mean = 2; median = 2). Swan counts per transect were not strongly correlated with transect length (Figure 3). For transects with swans, swans per mile of transect surveyed ranged from 0.045 to 2.261 (mean = 0.37, median = 0.2608). The combined ratio estimate for the WBPS produced population estimates that ranged from 150 (2001; 90% CI: 2-320) to 25,110 (2022; 90% CI: 20,120-30,100) (Table 1). The estimated number of trumpeter swans based on this survey has increased steadily since 2000 (Figure 4). The results of the 2022 survey have been published online (Minnesota Waterfowl Breeding Population Survey 2022).

Statewide Trumpeter Swan Population Estimate

The statewide population estimate for 2022 was 51,860 swans (90% CI: 45,530 – 58,190). Of the 190 transects surveyed in the two separate surveys (WBPS & NBSS), 149 (78.4%) transects had swans observed. For transects with swans, swans per mile of transect surveyed ranged from 0.033 to 4.7 (mean = 0.38, median = 0.261). Highest concentrations of swans were observed west of the metropolitan area, north-central, and the east-central part of the state (Figure 5). Percent change and annual growth have been reported in the North American Trumpeter Swans Survey report for the Interior Population. We provided similar calculations using Waterfowl Breeding Population Survey data for which we have breeding counts since 2000 (Table 2).

Reviewing Christmas Bird Count data from the Mississippi Flyway (plus Kansas) since 2000, when looking at individual state averages, we see that Minnesota has consistently had one of the highest number of swans per party hour with Missouri close behind (Figure 6). Illinois and Iowa are the other two Mississippi Flyway states that had high rates of swans per party hour. When comparing the Mississippi Flyway as a whole to Minnesota, we see dissimilar patterns (Figure 7). These data indicate a period of increasing wintering swan counts in Minnesota in the early 2000s followed by relatively steady and high wintering counts for the past decade plus. In the remainder of the flyway states (plus Kansas), numbers of trumpeter swans observed were relatively stable in the early 2000s, followed by large increases since ~2010 (Figure 7). Note that the high average rate for the 2018 survey year in Minnesota was driven by several surveys with high counts within a few survey hours. Examining Breed Bird Survey data from Minnesota since 2000 indicates a strong increasing trend in the index of annual abundance of trumpeter swans, with an annual 23.25% estimated increase in abundance between 2000-2021 (95% Credible Interval = 15.19% - 32.86%; Figure 7). This translates to an overall percentage increase between 2000-2021 of 7,966.26% (95% Credible Interval = 1,849% - 38,942%). These percent increases trends are expressed as a geometric mean rate of change (%/year) between 2000 and 2021.

Discussion

The trumpeter swan population in Minnesota has increased steadily since the early 2000s. We do not know exactly how quickly the population has grown outside of the Waterfowl Breeding Population Survey sampling frame, but results from the 2022 Northeast Breeding Swan Survey suggest that the swan population in the Northeast portion of Minnesota has grown rapidly since 2015. Similar to the

Waterfowl Breeding Population Surveys, sampling variance likely plays a significant role in the substantial population estimate difference observed between 2015 and 2022 in Northeast Minnesota. Similar to 2015, no cygnets were observed in 2022 and thus did not contribute to the stark increase in the number of observed swans during the Northeast Breeding Swan Survey in 2022. During the early years of Waterfowl Breeding Population Survey (pre-2010) swan growth in the prairie/agricultural region was exponential at times and we may be observing a similar pattern of growth in Northeast Minnesota. We expect that the swan population will continue to grow, but we are less certain about the rate of growth. Although it was too early to count cygnets during 2022 surveys, past estimates indicated that cygnet production for the Interior Population was stable (Groves 2012, Groves 2017). Swans were detected on 78.4% of transects in 2022, a large increase from 43% in 2015, indicating that the population is utilizing much more of the available aquatic habitat than in 2015. The 2022 results continue to point to the population not yet having saturated available aquatic habitat.

When reintroduction efforts began in 1987, the goal for Minnesota was 15 breeding pairs. This goal was later revised to 500 individuals by 2001 (Ad hoc drafting committee for the interior population of trumpeter swans 1998), but the population goals from the 1998 management plan for the interior population of trumpeter swans were not reassessed or updated as reintroduction efforts continued. Many states met or exceeded the population goals from this plan during the 2000 North American Trumpeter Swan Survey and discontinued reintroduction efforts (Groves 2012). The Waterfowl Breeding Population Survey has documented swans annually during the breeding season since 2000. For the first 10 years, swans were increasing at a rate of about 500 swans per year. Around 2010, this rate increased to closer to 1,000 swans per year. Since 2015, this rate again increased to closer to 1,800 swans per year. However, estimates since 2011 have been quite variable, fluctuating at times by more than 5,000 swans annually (average annual change 2010-2022 = 3338.89). Much of the annual variability in population estimates is likely due to sampling variance (vs. true annual variation in population size), which can only be reduced by increasing sample sizes or making the design more efficient. However, focusing on trends over time rather than individual population estimates, the Waterfowl Breeding Population Survey provides a reasonable estimate of population trends and status (Figure 4).

We believe that previous population estimates should be interpreted cautiously. Counts conducted in Minnesota for the North American Trumpeter Swan Survey from 2000-2010 relied on a variety of labor-intensive techniques (often during winter) and were believed to represent the best counts of the population in Minnesota, although it is difficult to assess the accuracy of these counts (Herwig and Giudice 2015). In 2000, data were collected May through January and used a combination of aerial and ground counts (Caithamer 2001). In 2005, an estimate was provided based on data collected spring through mid- winter as a formal count was not conducted (Moser 2006). The 2010 count was conducted in January and was believed to represent birds from Minnesota and southwestern Ontario (Groves 2012). This count took place during a narrow window and the organizers believed the conditions were ideal (i.e, deep snow forced birds into few open water locations) for documenting swans. The count comprised of an actual count of 5,470 trumpeter swans found in Minnesota and an estimated 600 swans that migrated from or through the state (Herwig and Giudice 2015). Data collected in winter months closely tracked the data collected for the Waterfowl Breeding Population Survey; however, this survey only represents about 39% of the state. Furthermore, we may also have expected higher winter counts due to the addition of annual production, particularly with this population experiencing rapid growth.

Bird movements in and out of Minnesota make it challenging to monitor this population in winter. While it was believed that winter counts conducted for the North American Trumpeter Swan Survey 2000-2010 represented a complete census of the population in Minnesota, trumpeter swan movements in and out of Minnesota have been well documented since. Wolfson et al. (2021) observed that most marked swans in Minnesota migrated south starting in November and exhibited a variety of migration strategies. Some swans remained near their breeding locations while others traveled as far as Arkansas, Kansas, Missouri and other Mississippi Flyway states. Continuing efforts by Wolfson et al. (2021) seek to better our understanding of trumpeter swan movement ecology and habitat use. Christmas Bird Counts continue to indicate that the proportion of swans wintering outside of Minnesota is increasing as well (Figure 6).

The relative precision of our survey estimates for swans in both the Waterfowl Breeding Population (20%) and Northeast Breeding Swan surveys (15%) were within the MN DNR's normal target level of 25% or less for the bound relative to the estimate. While the estimate uncertainty for these estimates have improved over time, there are still ways we could improve the precision of these surveys. To do so we would need to: a) increase sample size (increase the number of transects surveyed and reduce the number of transects with zero swan observations), and/or b) improve the sampling design with auxiliary information (e.g., on spatial distribution of breeding swans and their habitat association). Similar to the findings in 2015, stratifying by the amount of water using GAP data in 2022 did not improve the precision of our estimates (i.e., the design effect was negligible). Alternate sources of available aquatic habitat data may be necessary to assess any habitat associations more accurately.

The Northeast Breeding Swan Survey was the second transect survey flown for swans in northeastern Minnesota. While flights were flown on days with good visibility and low winds, we did encounter isolated storms north of Grand Marais that prevented 2 transects from being flown in the far Northeast of the sampling area (they were replaced with 2 transects further west). The late timing (early-June) may have also increased the number of single and flocked swans observed and thus increased the population estimate for 2022. More flocks and in greater numbers were observed in 2022 (n = 15) compared to 2015 (n = 3), but still represented a small proportion of swans observed (Herwig and Giudice 2015). One observation of 137 swans on a small lake within the Fond Du Lac Reservation was removed as an outlier; failure to remove this observation would have increased the population estimate by 6,205 swans and the SE by 269%. However, it is important to acknowledge that large congregations of trumpeter swans are becoming more common in Minnesota. Other statewide bird surveys (e.g., Breeding Bird Survey) indicate that the population continues to rapidly increase statewide as well (Figure 8). To better understand the growth rate and population size in Northeast Minnesota, future surveys should be flown with greater frequency (i.e. <7 years). Ultimately, cost and staff limitations may support the sole use of the WBPS as the proxy for the statewide estimate of breeding Trumpeter Swans.

Given the data from this and other surveys, we still believe that spring counts will provide more accurate estimates of population size and trends. We found that aerial transects are an efficient, cost-effective way to collect data on these large and easily observed birds. Additionally, it was cost effective to supplement the annual Waterfowl Breeding Population Survey to count swans. We acknowledge that we are still missing portions of the state (far northwest and southeast) that may have breeding trumpeter swans but given the best information we have on the distribution of the species and funding

limitations, we believe we have a reasonable estimate of breeding trumpeter swans for Minnesota. We also acknowledge that our estimates have relatively wide confidence intervals. Given the current distribution of this population, improved precision would likely be more expensive to obtain. Going forward, having a clearer understanding of population goals and survey objectives will help us optimize the survey needs.

Acknowledgements

We would like to thank Steve Cordts and other FAW staff that collected survey data for the Waterfowl Breeding Population Survey. Many thanks to the MNDNR pilots that assisted with this survey, particularly Jason Jensen and Tim Gray. Thank you to John Giudice for the assistance with the data analysis. Thank you to Alison Cariveau and Cynthia Osmundson for their review of drafts of this report. Thank you to Chris Jennelle for assistance with analyzing the North American Breeding Bird Survey data. The Northeast Breeding Swan Survey was funded by the MNDNR Nongame Wildlife Program and the U.S. Fish and Wildlife Service. The Waterfowl Breeding Population Survey was funded in part by the Wildlife Restoration (Pittman-Robertson) Program and the MNDNR Section of Wildlife.

Literature Cited

Ad hoc drafting committee for the interior population of trumpeter swans. 1998. Mississippi and Central Flyway Management Plan for the interior population of trumpeter swans.

Mississippi and Central Flyway Councils, Twin Cities, MN. Unpublished report. 51 pp.

Caithamer, D. F. 2001. The 2000 North American Trumpeter Swan Survey. U.S. Fish and Wildlife Service. 15 pp. https://mrwa.org/wp-content/uploads/repository/trumpeter_swan_population_status_2000.pdf.

Cochran, W. G. 1977. Sampling techniques, third edition. John Wiley & Sons, New York. Cordts, S.

Groves, D.J. 2012. The 2010 North American Trumpeter Swan Survey. U.S. Fish and Wildlife Service. 29 pp. https://swansg.org/wp-content/uploads/2018/01/North-American-TRUS-Survey-2010-Rept.pdf.

Groves, D.J. 2017. The 2015 North American Trumpeter Swan Survey: A Cooperative North American Survey. U.S. Fish and Wildlife Service. 28 pp. https://nwswans.org/wp-content/uploads/2020/08/NATrumpeterSwanSurvey_2015.pdf.

Herwig, C. and J.H. Giudice. 2015. North American Trumpeter Swan Survey 2015 – Minnesota. Unpublished report, Division of Ecological and Water Resources, Minnesota Department of Natural Resources, St. Paul, Minnesota.

Kincaid, T. M. and A. R. Olsen. 2021. spsurvey: Spatial Survey Design and Analysis. R package version 5.4. https://cran.r-project.org/web/packages/spsurvey/index.html.

Minnesota Department of Natural Resources. 2022. Waterfowl Breeding Population Survey Minnesota. Unpublished report, Division of Fish and Wildlife, Minnesota Department of Natural Resources, St. Paul, Minnesota. 19 pp. https://files.dnr.state.mn.us/recreation/hunting/waterfowl/waterfowl_survey.pdf.

Kincaid, T. M. and A. R. Olsen. 2021. spsurvey: Spatial Survey Design and Analysis. R package version 5.4. https://cran.r-project.org/web/packages/spsurvey/index.html.

Link, W.A. and J.R. Sauer. 2002. A Hierarchical Analysis of Population Change with Application to Cerulean Warblers. Ecology 83 (10): 2832–40. https://doi.org/10.1890/0012-9658(2002)083[2832:AHAOPC]2.0.CO;2.

Moser, T. J. 2006. The 2005 North American Trumpeter Swan Survey. U.S. Fish and Wildlife Service. 23 pp. https://www.arlis.org/docs/vol1/C/720357554.pdf.

National Audubon Society. 2020. The Christmas Bird Count Historical Results [Online]. Available http://www.christmasbirdcount.org. Accessed 6 January 2022.

R Core Team. 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.r-project.org/.

Sauer, J.R. and W.A. Link. 2011. Analysis of the North American Breeding Bird Survey Using Hierarchical Models. The Auk 128 (1): 87–98. https://doi.org/10.1525/auk.2010.09220.

Smith, A.C., M.R. Hudson, C.D., and C.M. Francis. 2014. Estimating Breeding Bird Survey Trends and Annual Indices for Canada: How Do the New Hierarchical Bayesian Estimates Differ from Previous Estimates? The Canadian Field-Naturalist 128 (2): 119. https://doi.org/10.22621/cfn.v128i2.1565.

United States Fish and Wildlife Service/Canadian Wildlife Service. 1987. Standard operating procedures for aerial waterfowl breeding ground population and habitat surveys in North America. U.S. Fish and Wildlife Service and Canadian Wildlife Service.

Wolfson, D.W., D.E. Anderson, and J.R. Fieberg. 2021. Annual Report 2021. Unpublished report, Minnesota Cooperative Fish and Wildlife Research Unit, Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota, St. Paul, Minnesota. https://trumpeterswan.netlify.app/tabbed_annual_reports.html.

Ziolkowski Jr., D.J., M. Lutmerding, V.I. Aponte, and M-A.R. Hudson. 2022. North American Breeding Bird Survey Dataset 1966 - 2021: U.S. Geological Survey data release, https://doi.org/10.5066/P97WAZE5.

Tables

Table 1. Population estimates of trumpeter swans in Minnesota based on aerial transect surveys (2000-2015). Also included are standard errors (SE), 90% upper and lower confidence intervals (CI) and relative bound, which provides a measure of the confidence interval relative to the point estimate.

Survey[1]	Year	Estimate	SE	Lower CI	Upper CI	Relative Bound (%)
WBPS	2000	230	132	10	450	94%
WBPS	2001	150	103	2	320	113%
WBPS	2002	230	179	5	520	128%
WBPS	2003	2,030	1,038	320	3,740	84%
WBPS	2004	860	231	480	1,240	44%
WBPS	2005	2,400	1,147	510	4,290	79%
WBPS	2006	3,850	1,257	1,780	5,920	54%
WBPS	2007	2,070	635	1,030	3,110	51%
WBPS	2008	2,820	852	1,420	4,220	50%
WBPS	2009	5,330	2,223	1,670	8,990	69%
WBPS	2010	5,150	1,391	2,860	7,440	44%
WBPS	2011	10,620	4,880	2,590	18,650	76%
WBPS	2012	6,610	1,589	4,000	9,220	40%
WBPS	2013	11,450	2,517	7,310	15,590	36%
WBPS	2014	7,680	1,366	5,430	9,930	29%
WBPS	2015	12,570	2,439	8,560	16,580	32%
NEBSS	2015	4,420	867	2,990	5,840	32%
WBPS	2016	13,410	2,951	8,560	18,260	36%
WBPS	2017	17,230	3,085	12,160	22,300	29%
WBPS	2018	22,850	5,652	13,550	32,150	41%
WBPS	2019	23,190	4,438	15,890	30,490	31%
WBPS	2022	25,110	3,033	20,120	30,100	20%
NEBSS	2022	26,750	2,370	22,850	30,650	15%

[1] WBPS = Waterfowl Breeding Population Survey; NBSS = Northeast Breeding Swan Survey

Table 2. Percent change and average annual growth rates from Waterfowl Breeding Population Surveys (2000-2022) and the Interior Population (2000-2015; Moser 2006, Groves 2012, Groves 2017).

	Waterfowl Breeding Population Survey		Interior Population	
Years	Total Percent Change	Annual Growth Rate	Total Percent Change	Annual Growth Rate
2000-2005	943%	33%	91%	13%
2005-2010	115%	14.6%	111%	16.1%
2010-2015	144%	16.8%	278%	*
2015-2022	100%	15.5%	-	-

*The annual growth rate of the Interior Population from 2000-2015 was 19.9%

Figures

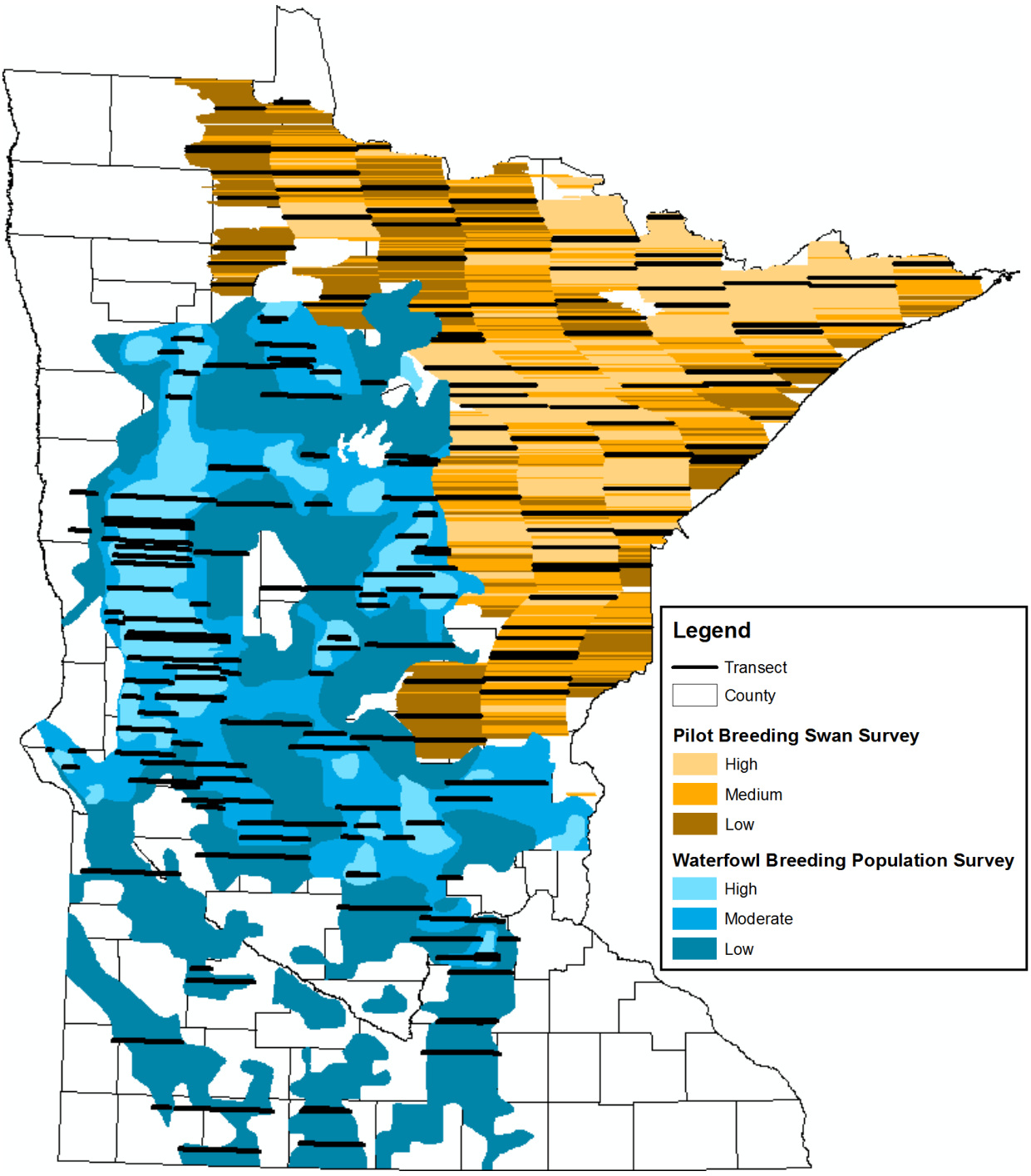

Figure 1. Map of the Waterfowl Breeding Population Survey and Northeast Breeding Swan Survey strata and associated transects.

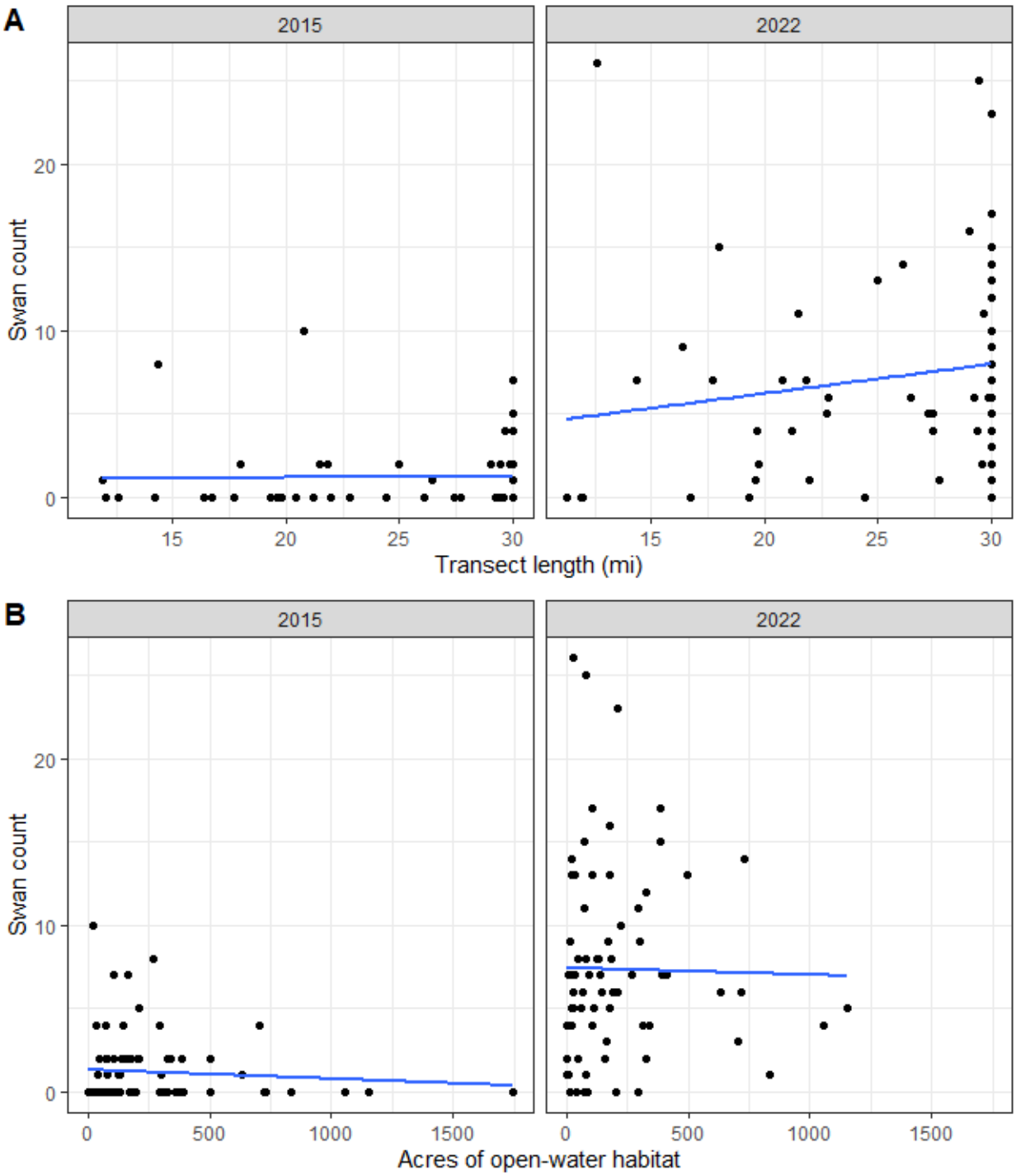

Figure 2. Scatterplots of swan counts versus A) transect length (mi) and B) acres of open-water habitat from the Northeast Breeding Swan Survey, May 2015 vs. June 2022.

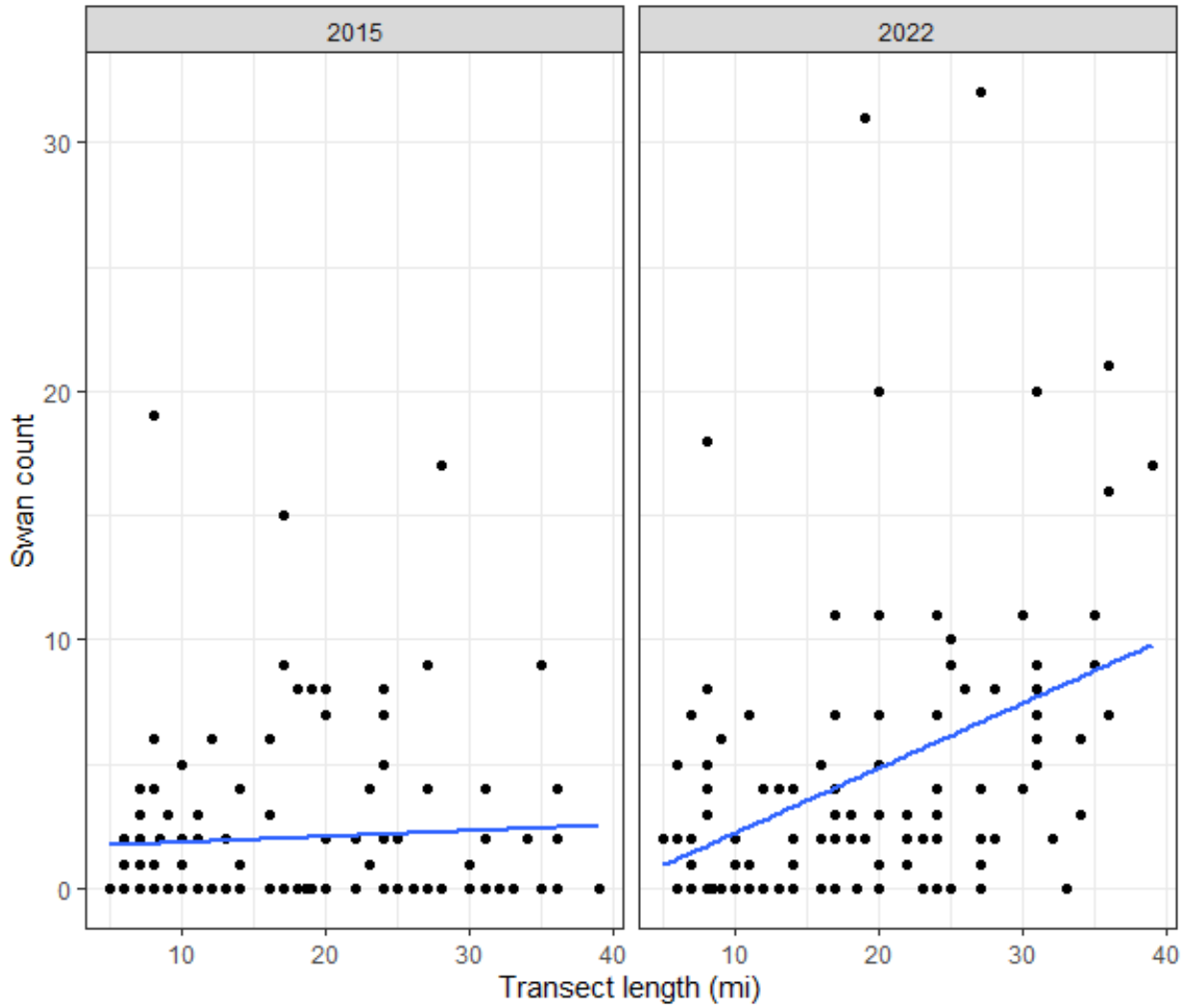

Figure 3. Scatterplot of swan counts versus transect length (mi) from the Waterfowl Breeding Population Survey, May 2015 vs. May 2022.

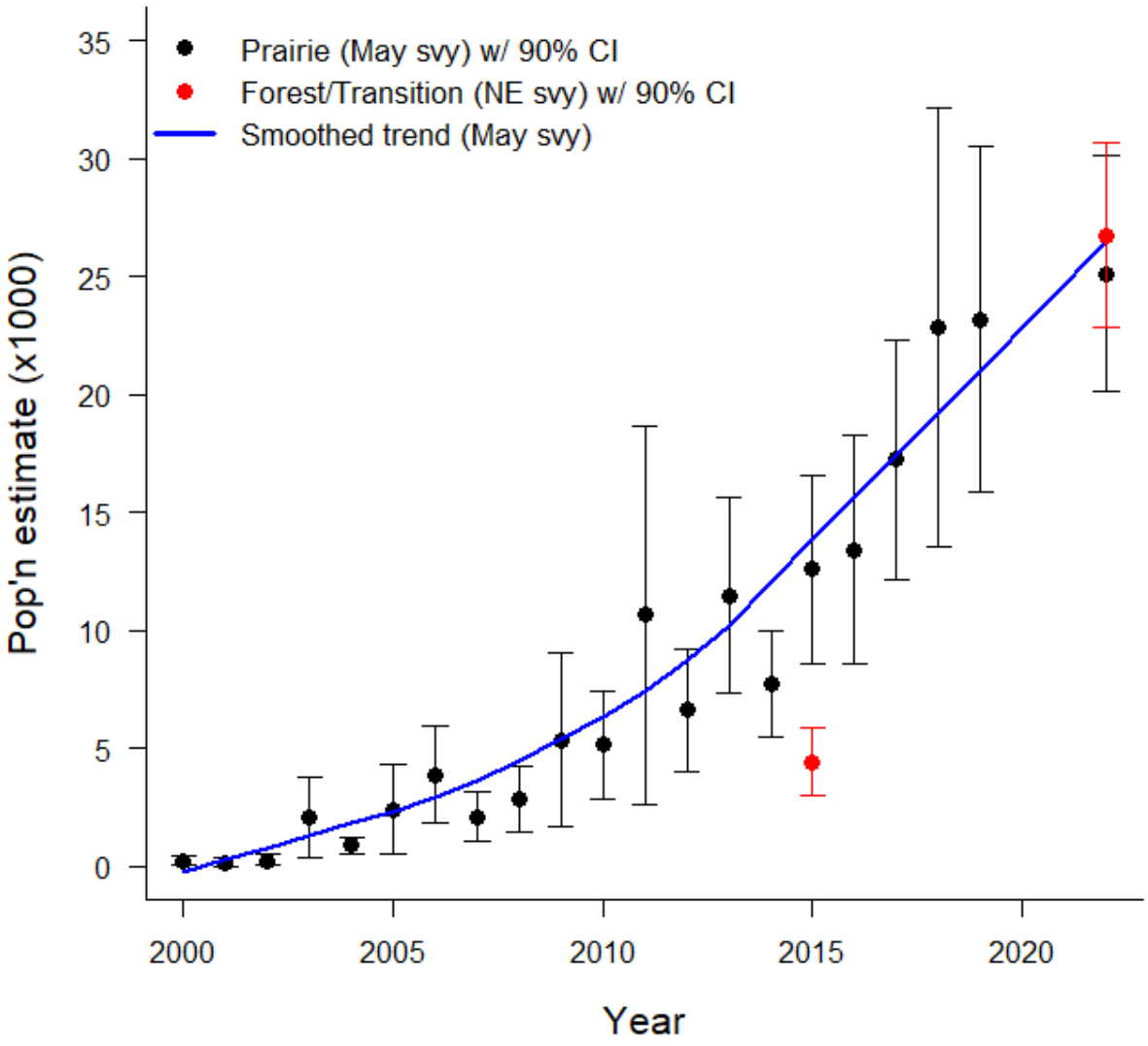

Figure 4. Population estimates of trumpeter swans with 90% confidence intervals in Minnesota based on aerial transect surveys. Waterfowl Breeding Population Survey (2000-2022, black) along with the smoothed trend (blue) and Northeast Breeding Swan Survey (2015, 2022, red) are shown.

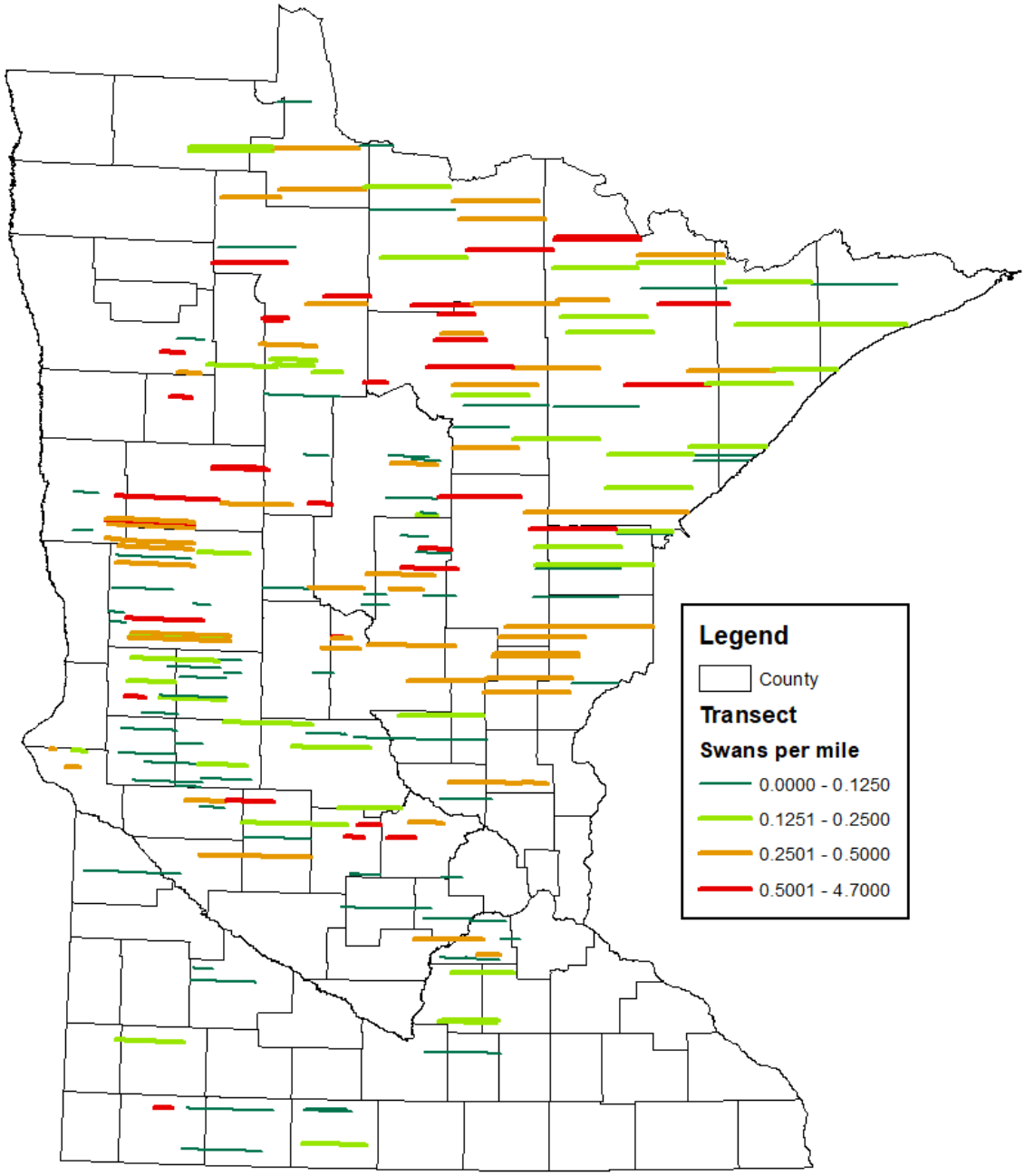

Figure 5. Number of swans per mile along surveyed transects from the Waterfowl Breeding Population and Northeast Breeding Swan surveys, May-June 2022.

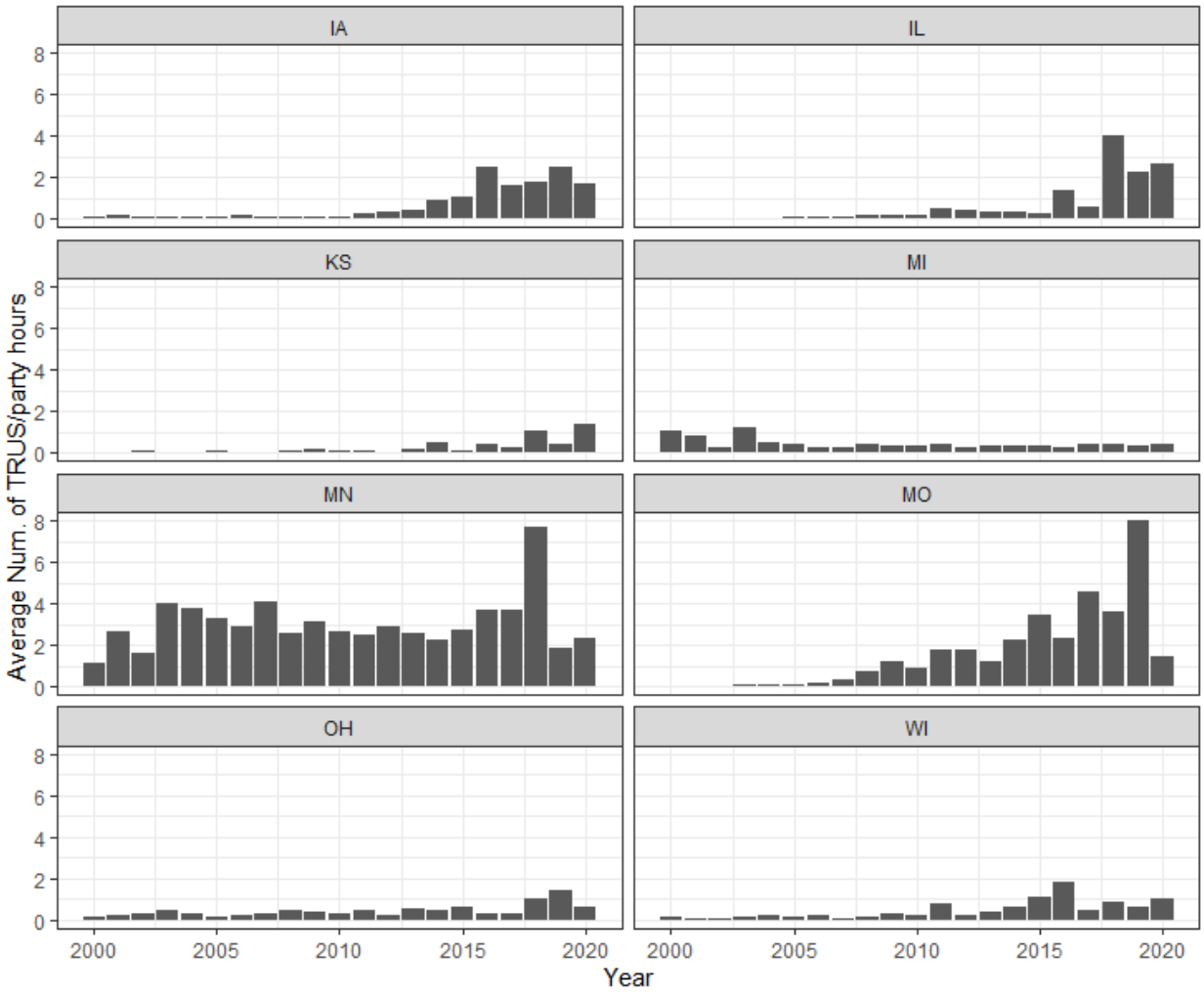

Figure 6. Christmas Bird Count data for trumpeter swans in Minnesota along with the remaining Mississippi Flyway states from 2000 to 2020 (National Audubon Society 2022). Four states (Arkansas, Indiana, Mississippi, and Tennessee) were excluded from this figure as they had an average number of swans per party hour less than 1 TRUS/party hours.

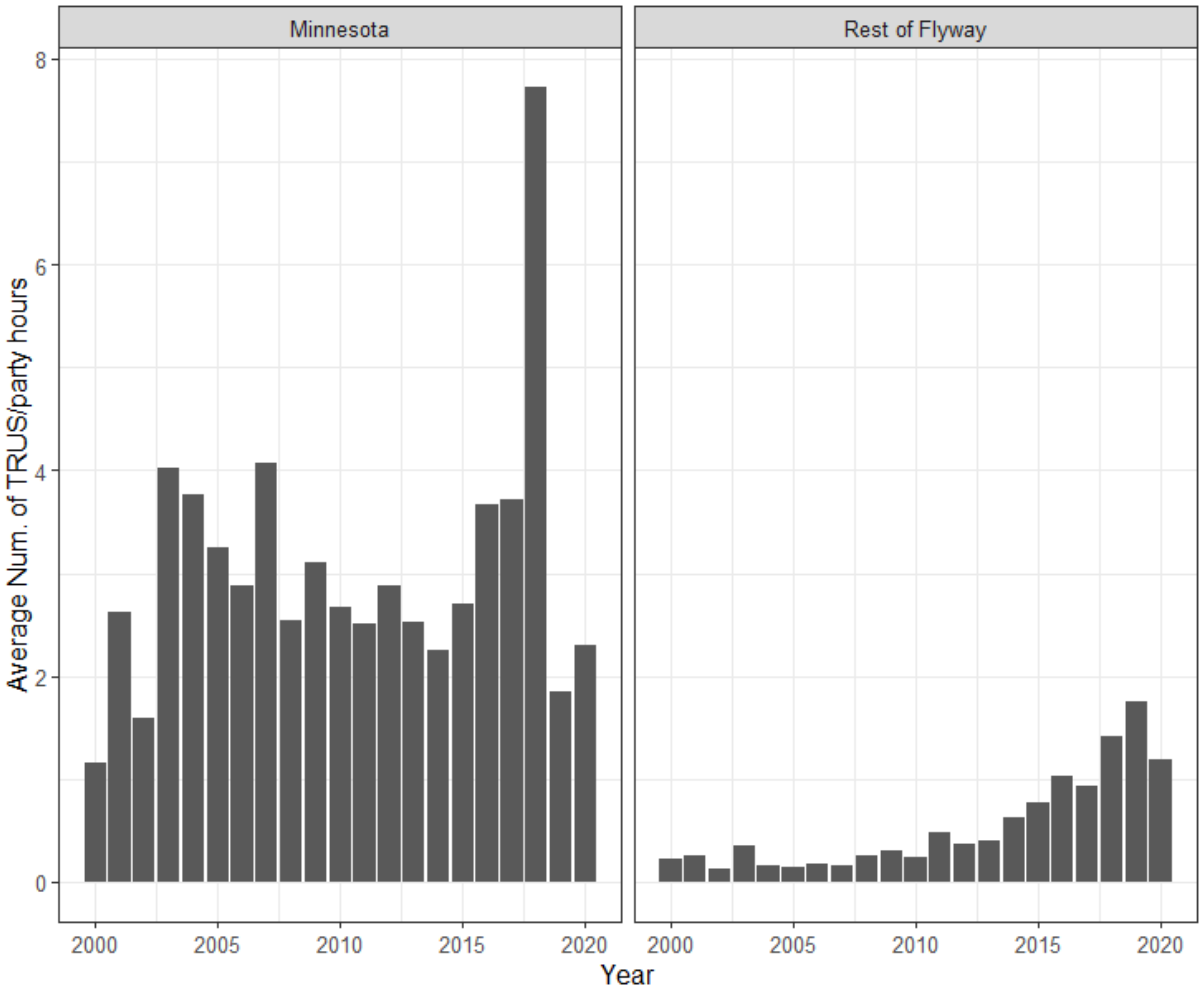

Figure 7. Christmas Bird Count data for trumpeter swans in Minnesota compared to the other Mississippi Flyway states grouped together from 2000 to 2020 (National Audubon Society 2022). All Mississippi Flyway states (plus Kansas) were included in the "Rest of the Flyway" grouping.

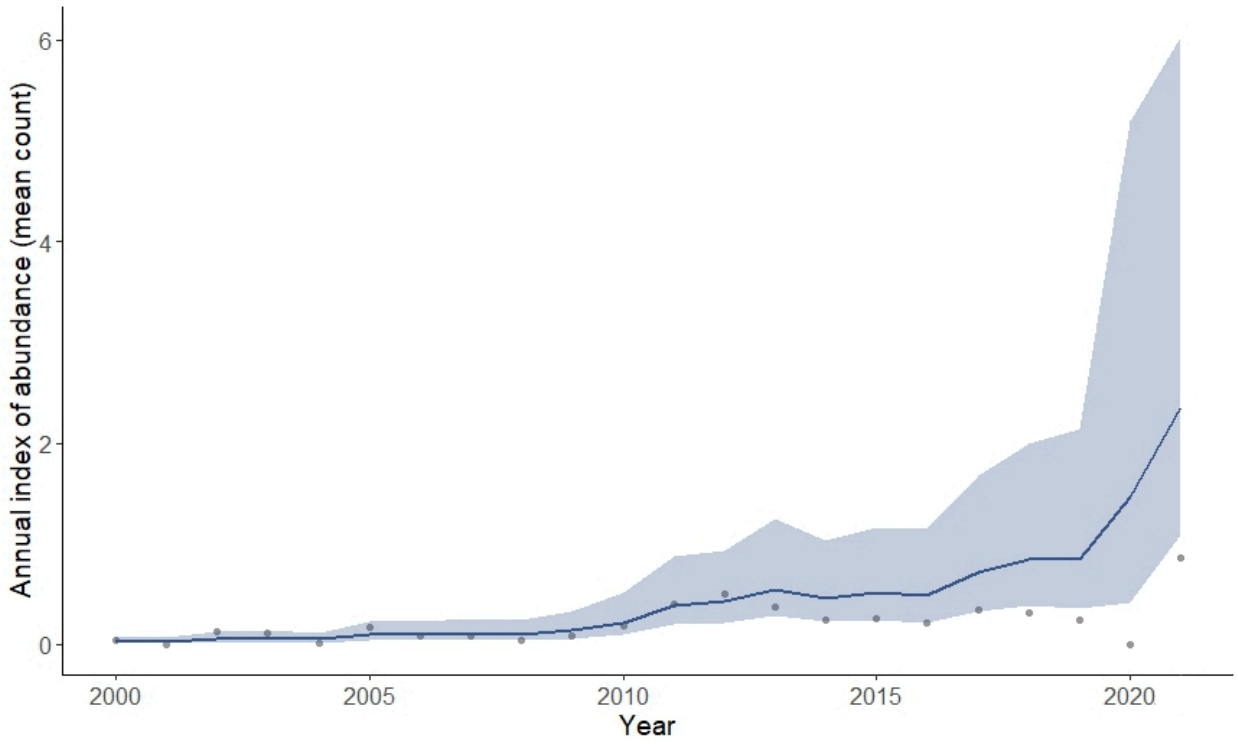

Figure 8. Index of annual abundance for trumpeter swans with 95% credible intervals in Minnesota based on the North American Breeding Bird Survey Count from 2000-2021 (U.S. Geological Survey 2022).

500 Lafayette Road
St. Paul, MN 55155-4040
888-646-6367 or 651-296-6157
mndnr.gov