WISCONSIN DEPARTMENT OF NATURAL RESOURCES
Waterfowl Breeding Population Survey For Wisconsin, 1973–2023

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Abstract

The 2023 Waterfowl Breeding Population Survey for Wisconsin was conducted from April 24–May 10 and followed methods of the North American Waterfowl Breeding Population and Habitat Survey. The information from this survey is used as part of the overall survey of breeding waterfowl in North America as well as in making state-level waterfowl management decisions. This survey has been conducted annually since 1973 (except for 2020), and data on Wisconsin waterfowl breeding populations and wetland counts are best interpreted as trends over several years rather than as year-to-year fluctuations.

Total non-linear basins were down 3.5% from 2022 in the Southeast Central (SEC) region and up 104.2% from the long-term, 50-year mean. In the Northern High Density (NHI) region, total non-linear basins were up 8.8% from 2022 and up 118.6% from the long-term mean. Non-linear basins were down 6.6% from 2022 in the Northern Low Density (NLO) region and up 191.2% from the long-term mean. Non-linear basins were up 38.4% from 2022 in the Southwest Driftless (SWD) region and up 78.4% compared to this region's long-term (26-year) mean. Total linear basins were down 6.2% from 2022 in the SEC region and up 47.3% from the long-term mean. In the NHI region, linear basins were down 23.3% from 2022 and up 66.8% from the long-term mean. NLO region linear basins were down 8.6% from 2022 and up 86.9% from the long-term mean. Linear basins were up 45.0% from 2022 in the SWD region and up 64.7% from the long-term mean.

The 2023 total breeding duck modeled population estimate of 545,065 was 3.5% lower than the 2022 modeled estimate of 564,738, and was 22.8% higher than the long-term mean. Overall, the total duck population estimate for 2023 was higher than what we have experienced over the last few years (2015–2019) and above the total duck numbers experienced in the prior 10 years. The mallard modeled breeding population estimate of 175,895 was 0.6% lower than the 2022 estimate of 176,977 and was 1.5% lower than the

long-term mean. The blue-winged teal modeled breeding population estimate of 96,271 was 6.2% higher compared to the 2022 estimate of 90,638, but remains 8.4% lower than the long-term mean. At 102,381 the 2023 population estimate for wood ducks was 29.0% lower than the 2022 estimate of 144,254 and 19.4% higher than the long-term mean. The modeled Canada goose population estimate of 169,447 was 1.3% lower compared to the 2022 estimate of 171,667, and 56.0% higher than the long-term mean. The population estimate of "other ducks" was 153,295, which was 1.8% lower than the 2022 estimate of 156,095 and was 128.7% higher than the long-term mean.

Introduction

Decisions regarding hunting season structure and harvest limits in waterfowl management are based in part upon spring breeding pair surveys. The U.S. Fish and Wildlife Service's (USFWS) Waterfowl Breeding Population and Habitat Survey (BPOP) has been conducted for 69 years across the traditional survey area of the north-central United States, Canada and Alaska. The Wisconsin Waterfowl Breeding Population Survey–which is modeled after the BPOP–has been conducted since 1973 and provides a long-term record of waterfowl breeding trends and wetland counts in Wisconsin. These data are used at the national- and state-level for monitoring waterfowl populations and making management decisions. Wisconsin's breeding waterfowl survey data are included in the Waterfowl Population Status report published annually by the USFWS on continental waterfowl populations. In addition, mallard data from Wisconsin, Minnesota, and Michigan are combined with data from the traditional survey area as a basis for the USFWS's Adaptive Harvest Management report that is used to establish federal waterfowl season frameworks. At the state-level, waterfowl breeding survey data are used to inform annual hunting season regulations, identify long-term changes in population trends, and evaluate the impacts of habitat changes and management. This report provides a summary and analysis of the 2023 survey data in support of these efforts.

Methods

Study area and survey timing

The Wisconsin Waterfowl Breeding Population Survey employs a stratified sampling scheme modeled after the BPOP survey (Platte 1987) but modified for local conditions (March et al. 1973). The state is divided into four strata based on regional waterfowl densities and habitat attributes: the Southeast Central region (SEC), Northern High Density region (NHI), Northern Low Density region (NLO), and Southwest Driftless region (SWD; Figure 1). Fifty-five east-west oriented transects, each 30 mi in length and 1/4 mi-wide, were randomly selected in 1973 within the SEC (n = 29), NHI (n = 13), and NLO (n = 13) regions; transects in the SWD region (n = 11) were not added until 1997 due to low wetland density. Surveys have been conducted every year since 1973, except in 2020 due to the COVID-19 pandemic.

Transects are typically surveyed from May 1–20 to obtain accurate estimates of *local* breeding pairs. However, the start date may be adjusted to accommodate inter-annual variation in the timing of spring (i.e., to exclude migratory individuals and minimize the effects of leaf-out on observer visibility). To account for latitudinal differences in leaf-out and waterfowl breeding phenology, surveys are generally initiated in southern Wisconsin and northern transects are the last to be completed.

Data collection

Two observers–each experienced in waterfowl identification and waterfowl census procedures–performed the aerial surveys. To minimize problems with observer bias, the same aerial observers are used for a minimum five-year period. In addition, surveys do not take place when winds exceed 25 mph or if other adverse weather conditions exist (e.g., snow, rain, fog, and smoke). Fixed-wing aerial surveys were conducted from a Cessna 182 aircraft, flying at 90–100 mph and 100–150 ft above ground level. During each transect flight, an observer recorded all observations of ducks, geese, coots, cranes, and swans within a 1/8-mile strip from either side of the aircraft, while the observer on the north side of the plane recorded the number and type of unoccupied wetland basins containing surface water. All wetlands within the 1/4-mile transect width on which breeding waterfowl are observed (i.e., occupied wetlands) are also recorded by the observer counting waterfowl.

Given the challenges of detecting and counting waterfowl from the air, 27 segments of selected aerial transects are censused by ground crews to obtain a 'complete' count of all waterfowl present and calculate visibility (air-to-ground) correction factors (VCFs). Ground crews (2–4 individuals) cover every wetland basin within a transect segment on foot or by boat on the same day or within 2 days after the air count. Ground observers record waterfowl observations according to the same instructions for the aerial survey.

Data preparation

The Waterfowl Breeding Population Survey focuses on four priority waterfowl species: mallards (*Anas platyrhynchos*), blue-winged teal (*A. discors*), wood ducks (*Aix sponsa*) and Canada geese (*Branta canadensis*). All other duck species that are likely breeders in Wisconsin are pooled into a category of "other ducks" ("total ducks" combines these four priority species and "other ducks"). By 2004, wood duck populations had increased to a level where we were able to estimate them as a separate group rather than as part of "other ducks." Lesser scaup (*Aythya affinis*) and bufflehead (*Bucephala albeola*) are not included in population estimates because they rarely breed in Wisconsin and when counted are assumed to be in migration to more northern breeding areas. We also tallied counts for several other species of interest: American coots (*Fulica americana*), whooping cranes (*Grus americana*), sandhill cranes (*Antigone canadensis*), and trumpeter swans (*Cygnus buccinator*).

We note that this survey was not originally designed for surveying Wisconsin's resident Canada goose population due to their earlier breeding phenology. However, aerial counts of geese increased steadily from the mid-1980s through the early 2000s, making survey estimates useful indices of population trends. Human-goose conflicts resulting from a growing goose population increase the importance of tracking the population status of breeding geese in Wisconsin, and have been included in this report since 1986.

Prior to analysis, we calculated the total numbers of "indicated" birds for each transect based on the observation type (i.e., pairs, lone drakes, flocked drakes [males in groups

of 2–4], and groups [$\geq$ 5 drakes or mixed flocks that cannot be separated into pairs or sexes]) and each species' breeding biology. In general, lone drakes, flocked drakes, and pairs are adjusted by a multiplier of two, while groups are not adjusted.

Statistical analysis

Visibility correction factors

The VCF (also referred to as *R*; see below) is the ratio of individuals counted by ground crews to the number of individuals counted by aerial crews from the same set of transect segments. VCFs are used as a multiplier to the aerial survey counts and yield statewide, corrected abundance estimates. VCFs were calculated independently for all priority waterfowl species and "other ducks" by pooling data from all 27 air/ground transect segments. To quantify VCF precision, we calculated the coefficient of variation (CV), which provides a standardized measure of dispersion. We iteratively added prior years of survey data until a CV value $\leq$ 0.20 (and a robust VCF) was achieved.

Population estimates

To calculate species-specific and visibility-corrected abundance estimates in each region, we used the traditional formula developed by Smith (1995):

$$N = B \times A \times R \tag{1}$$

where B is the bird density per mi^2, A is the area of the survey region, and R is the visibility correction factor. We note that this procedure was only conducted for the four priority waterfowl species and "other ducks" (VCF-corrected estimates were summed across these groups to estimate "total duck" abundance).

Because these abundance estimates are imperfect counts (i.e., some combination of true population size and detection error), we elected to model annual trends using a Bayesian state-space modeling approach (Kéry and Schaub 2012). State-space models are hierarchical models that simultaneously account for process error (true population size change) and measurement error (survey biases), and are increasingly used to model ecological time series (Auger-Méthé et al. 2021). State-space models offer at least two important advantages. First, modeled survey estimates smooth out drastic annual changes in population estimates that are biologically unrealistic (e.g., mallard abundance changing from roughly 250,000 in 1999, 450,000 in 2000, and then 180,000 in 2001). Second, a Bayesian state-space model allows for prediction, even when counts are unavailable (e.g., when surveys were canceled in 2020 due to the COVID-19 pandemic). Therefore, in the following waterfowl summaries we reference abundance and percent changes in state-space estimates rather than the raw population estimates. However, for comparison and continuity with previous reports, we provide both estimate types in the associated tables and figures (state-space modeling was first implemented for the 2021 report). We report the mean population estimate and 95% credible

interval (CI), which can be interpreted as saying '*the true population size has a 95% probability of falling within this range, given the observed data*.'

Results

Survey timing

We initiated the 2023 Waterfowl Breeding Population Survey on April 24. As in the past, the survey was initiated in the southern part of Wisconsin, progressing northward to account for the differences in phenology from south to north. The timing of the breeding waterfowl survey is always a challenge because variables such as weather, waterfowl phenology, and tree leaf-out all impact the timing, visibility and accuracy of the survey. Weather conditions were wetter and cooler than average during the survey statewide. Conditions in the south were slightly drier than the north but similar to last year we had above average wet conditions and late ice out in much of the north with some lakes retaining ice during the survey time period in late April/early May.

Aerial surveys were completed in 10 days from April 24 to May 10. The ground survey was completed in 7 days from April 26 to May 6. Paired aerial and ground surveys occurred within 2 days of each other, except for one transect segment where aerial/ground surveys occurred within 3 days.

Wetland counts

In the SEC region, total non-linear basins were down 3.5% from 2022 and were up 104.2% from the long-term (50-year) mean. Linear basins in the SEC region were down 6.2% from 2022 and up 47.3% from the long-term mean (Table 1). In the NHI region, total non-linear basins were up 8.8% from 2022 and up 118.6% from the long-term mean. Linear basins in the NHI region were down 23.3% from 2022 and up 66.8% from the long-term mean (Table 2). In the NLO region, total non-linear basins were down 6.6% from 2022 and up 191.2% from the long-term mean. Linear basins in the NLO region were down 8.6% from 2022 and up 86.9% from the long-term mean (Table 3). In the SWD region, total non-linear basins were up 38.4% from 2022 and up 78.4% from this region's long-term, 26-year mean. Linear basins in the SWD region were up 45.0% from 2022 and up 64.7% from the long-term mean (Table 4). Long-term wetland counts for each survey region are shown in Figure 2.

Waterfowl population estimates

2023 VCF and population estimate summary statistics for mallards, blue-winged teal, wood ducks, "other ducks", and Canada geese are provided in Table 5.

Mallards

The 2023 modeled mallard population estimate was **175,895 (95% credible interval [CI] = 131,956–227,236 individuals)**. This estimate is 0.6% lower compared to the previous year's modeled estimate and 1.5% lower than the long-term, 50-year mean (Table 6; Figure 3). As in previous years, the SEC still represented the largest portion of the breeding mallard population (41%) and was similar to that of 2022.

Blue-winged teal

The 2023 modeled population estimate for blue-winged teal was **96,271 (95% CI = 58,301–151,996 individuals)**. This estimate was 6.2% higher compared to the previous year's modeled estimate but remains 8.4% lower than the long-term mean (Table 6; Figure 4).

Wood ducks

The 2023 population estimate for wood ducks was **102,381 (95% CI = 64,730–173,810 individuals)**. This estimate was 29.0% lower compared to the previous year and was 19.4% higher than the long-term mean (Table 6; Figure 5).

Other ducks

The 2023 modeled population estimate for "other ducks" was **153,295 (95% CI = 76,590–277,462 individuals)**. This estimate was 1.8% lower compared to the previous year and was 128.7% higher than the long-term mean (Table 6; Figure 6). Species considered as "other ducks" and their percent composition in the 2023 uncorrected aerial count were: American black duck (*A. rubripes*; 1%), northern pintail (*A. acuta*; 0%), gadwall (*Mareca strepera*; 2%), American wigeon (*M. americana*; 3%), northern shoveler (*Spatula clypeata*; 1%), green-winged teal (*A. carolinensis*; 2%), canvasback (*A. valisineria*; 4%), redhead (*A. americana*; 1%), ring-necked duck (*A. collaris*; 39%), common goldeneye (*B. clangula*; 1%), hooded merganser (*Lophodytes cucullatus*; 3%), common merganser (*Mergus merganser*; 36%), red-breasted merganser (*M. serrator*; 0%), and ruddy duck (*Oxyura jamaicensis*; 8%).

Total ducks

The 2023 population estimate for all breeding ducks was **545,065 (95% CI = 411,225–708,254 individuals)**. This estimate was 3.5% lower compared to the previous year and is 22.8% higher than the long-term mean (Table 6; Figure 7).

Canada geese

Based on the most recent harvest derivations, the proportion of the Wisconsin Canada goose harvest that consists of temperate breeding (formerly 'giant') Canada geese is about 60%, with most of those birds representing Canada geese that breed in Wisconsin

(Dooley 2017). This proportion indicates the continued importance of in-state breeding Canada geese in our overall fall harvest. The 2023 population estimate for Canada geese was **169,447 (95% CI = 124,907–229,885 individuals)**. This estimate was 1.3% lower than the previous year's modeled estimate and was 56.0% higher than the long-term, 37-year mean (Table 6; Figure 8). The long-term trend in goose numbers suggests a continued, gradual increase in their population.

American coots, cranes, and trumpeter swans

In 2023, observers counted a total of 242 coots, one pair of whooping cranes, and 112 sandhill cranes (Figure 9). Excluding groups of five or more, 102 trumpeter swans were recorded and the 2023 population estimate for swans (accounting for bird density and survey region area, but lacking VCF-correction) was **13,643 (95% CI = 6,682–25,297 individuals)**; Table 7; Figure 10).

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Tables

Table 1: Type and number of wetlands per square mile observed during the last 10-year period (2013–2023; surveys were not conducted in 2020 due to the COVID-19 pandemic), SEC region.

	Wetland type							
Year	**I, II, VI**	**III**	**IV, V**	**VII, VIII**	**Non-linear**	**Stream**	**Ditch**	**Linear**
2013	2.5	1.0	3.2	0.6	7.3	1.8	2.5	4.2
2014	3.0	1.0	3.1	1.2	8.3	1.7	2.8	4.5
2015	1.3	0.8	2.7	0.7	5.6	1.8	2.4	4.2
2016	2.1	0.9	3.0	1.0	6.8	1.5	2.2	3.7
2017	9.2	1.1	3.6	1.9	15.8	1.9	3.2	5.1
2018	6.5	0.8	3.3	1.6	12.2	1.9	3.1	4.9
2019	7.7	2.1	4.7	2.3	16.9	1.5	3.8	5.4
2021	2.9	0.9	5.0	1.8	10.6	2.6	2.8	5.4
2022	9.3	2.3	5.1	3.1	19.9	2.7	4.2	6.8
2023	9.0	2.6	5.7	1.8	19.2	2.5	3.9	6.4
% Change from previous year	-4.0%	16.0%	11.3%	-41.1%	-3.5%	-5.7%	-6.6%	-6.2%
Long-term mean	4.0	1.0	3.1	1.2	9.2	1.8	2.5	4.3
% Change from long-term mean	124.4%	174.7%	87.7%	55.4%	108.7%	41.8%	53.6%	48.7%
10-Year mean (2013-2023)	5.4	1.4	3.9	1.6	12.2	2.0	3.1	5.1

Notes: Wetland classification system from March et al. (1973). I, II, VI = temporary, wet meadow, and shrub swamps; III = seasonal wetlands, IV, V = semi-permanent and permanent/open water wetlands; VII, VIII = wooded swamp and bog wetlands. Non-linear wetlands include type I-VIII wetlands, and linear wetlands include streams and ditches.

Table 2: Type and number of wetlands per square mile observed during the last 10-year period (2013–2023; surveys were not conducted in 2020 due to the COVID-19 pandemic), NHI region.

	Wetland type							
Year	**I, II, VI**	**III**	**IV, V**	**VII, VIII**	**Non-linear**	**Stream**	**Ditch**	**Linear**
2013	2.9	2.1	4.0	0.6	9.6	2.8	0.6	3.3
2014	6.4	1.8	5.7	2.4	16.3	2.9	0.6	3.5
2015	2.6	1.3	3.5	1.7	9.1	2.1	0.6	2.7
2016	2.4	1.2	3.4	1.9	8.9	1.9	0.6	2.5
2017	3.5	1.8	3.6	3.4	12.3	1.8	0.9	2.7
2018	1.5	1.2	4.5	1.5	8.6	2.4	0.5	2.9
2019	2.4	2.6	5.5	1.7	12.2	2.8	0.4	3.2
2021	1.4	1.1	5.8	5.3	13.5	3.2	0.3	3.6
2022	3.2	3.3	5.1	11.4	23.0	4.8	1.4	6.2
2023	5.5	2.5	11.5	5.6	25.1	3.6	1.1	4.7
% Change from previous year	71.1%	-25.2%	124.2%	-51.0%	8.8%	-25.4%	-15.8%	-23.3%
Long-term mean	3.4	1.4	4.1	2.3	11.2	2.3	0.5	2.8
% Change from long-term mean	63.2%	78.4%	183.1%	136.9%	124.1%	53.1%	150.6%	69.1%
10-Year mean (2013-2023)	3.2	1.9	5.3	3.5	13.9	2.8	0.7	3.5

Notes: Wetland classification system from March et al. (1973). I, II, VI = temporary, wet meadow, and shrub swamps; III = seasonal wetlands, IV, V = semi-permanent and permanent/open water wetlands; VII, VIII = wooded swamp and bog wetlands. Non-linear wetlands include type I-VIII wetlands, and linear wetlands include streams and ditches.

Table 3: Type and number of wetlands per square mile observed during the last 10-year period (2013–2023; surveys were not conducted in 2020 due to the COVID-19 pandemic), NLO region.

	Wetland type							
Year	**I, II, VI**	**III**	**IV, V**	**VII, VIII**	**Non-linear**	**Stream**	**Ditch**	**Linear**
2013	3.4	1.0	2.5	0.7	7.6	3.8	0.8	4.6
2014	8.8	0.5	2.0	2.7	14.1	4.6	1.7	6.2
2015	1.7	0.6	1.8	1.1	5.2	3.0	0.9	3.9
2016	1.8	0.8	2.1	1.2	5.9	2.8	0.8	3.6
2017	4.7	0.8	2.1	2.9	10.6	2.9	1.4	4.2
2018	2.8	0.8	2.9	2.6	9.1	5.0	1.3	6.2
2019	5.6	1.7	3.5	1.9	12.6	4.0	1.2	5.2
2021	3.0	1.2	3.8	4.7	12.7	4.9	1.3	6.3
2022	13.7	1.5	3.4	13.1	31.7	5.6	3.7	9.2
2023	13.7	2.1	8.9	4.9	29.6	5.3	3.2	8.4
% Change from previous year	-0.4%	43.2%	161.4%	-62.5%	-6.6%	-5.3%	-13.5%	-8.6%
Long-term mean	4.3	0.8	2.3	2.3	9.8	3.6	0.9	4.4
% Change from long-term mean	217.1%	159.5%	287.7%	109.5%	203.1%	48.1%	263.2%	90.2%
10-Year mean (2013-2023)	5.9	1.1	3.3	3.6	13.9	4.2	1.6	5.8

Notes: Wetland classification system from March et al. (1973). I, II, VI = temporary, wet meadow, and shrub swamps; III = seasonal wetlands, IV, V = semi-permanent and permanent/open water wetlands; VII, VIII = wooded swamp and bog wetlands. Non-linear wetlands include type I-VIII wetlands, and linear wetlands include streams and ditches.

Table 4: Type and number of wetlands per square mile observed during the last 10-year period (2013–2023; surveys were not conducted in 2020 due to the COVID-19 pandemic), SWD region.

	Wetland type							
Year	**I, II, VI**	**III**	**IV, V**	**VII, VIII**	**Non-linear**	**Stream**	**Ditch**	**Linear**
2013	1.4	0.5	1.3	0.4	3.6	3.6	0.8	4.4
2014	2.3	0.6	1.7	0.5	5.1	3.4	1.3	4.7
2015	0.7	0.2	1.3	0.3	2.6	2.8	0.7	3.5
2016	0.3	0.3	1.1	0.3	2.0	2.5	0.8	3.3
2017	3.4	0.5	1.9	0.7	6.5	3.6	1.2	4.8
2018	1.8	0.3	1.5	0.3	3.9	3.2	0.8	4.1
2019	3.2	1.0	1.8	0.7	6.7	3.6	1.4	5.0
2021	0.8	0.4	2.0	0.2	3.4	4.8	0.6	5.4
2022	2.0	0.6	1.2	0.9	4.7	3.4	1.1	4.5
2023	2.8	0.5	2.3	0.8	6.6	5.0	1.6	6.6
% Change from previous year	40.1%	-4.3%	90.1%	-7.9%	38.4%	45.9%	42.4%	45.0%
Long-term mean	1.4	0.3	1.5	0.3	3.6	3.2	0.7	3.9
% Change from long-term mean	104.4%	60.5%	50.7%	189.3%	83.9%	55.3%	132.3%	68.9%
10-Year mean (2013-2023)	1.9	0.5	1.6	0.5	4.5	3.6	1.0	4.6

Notes: Wetland classification system from March et al. (1973). I, II, VI = temporary, wet meadow, and shrub swamps; III = seasonal wetlands, IV, V = semi-permanent and permanent/open water wetlands; VII, VIII = wooded swamp and bog wetlands. Non-linear wetlands include type I-VIII wetlands, and linear wetlands include streams and ditches.

Table 5: Statewide and stratum-specific population estimates for the 2023 Waterfowl Breeding Population Survey population estimates.

Stratum*	Area of stratum (mi^2)	Bird density seen from the air (birds/mi^2)	Aerial visibility correction factor†	Survey estimate	Standard error
Mallard					
SEC	17,949	3.595	1.050	67,754	12,090
NHI	9,431	3.897	1.050	38,591	7,797
NLO	15,979	2.810	1.050	47,146	15,521
SWD	12,311	1.018	1.050	13,160	4,095
Statewide total				**166,651**	**21,555**
Blue-winged teal					
SEC	17,949	0.520	4.904	45,732	15,593
NHI	9,431	1.323	4.904	61,193	20,149
NLO	15,979	0.092	4.904	7,233	4,480
SWD	12,311	0.048	4.904	2,927	2,011
Statewide total				**117,085**	**25,947**
Wood duck					
SEC	17,949	0.749	3.015	40,562	9,259
NHI	9,431	0.205	3.015	5,834	3,244
NLO	15,979	0.226	3.015	10,872	4,479
SWD	12,311	0.436	3.015	16,199	6,999
Statewide total				**73,467**	**12,857**
Other duck species[a]					
SEC	17,949	0.782	4.168	58,467	15,851
NHI	9,431	1.610	4.168	63,290	22,055
NLO	15,979	0.338	4.168	22,539	9,555
SWD	12,311	0.061	4.168	3,110	3,110
Statewide total				**147,406**	**28,959**
Canada goose					
SEC	17,949	2.915	1.590	83,206	12,747
NHI	9,431	1.497	1.590	22,459	8,067
NLO	15,979	1.056	1.590	26,845	8,526
SWD	12,311	1.164	1.590	22,782	9,892
Statewide total				**155,292**	**19,953**

* SEC = Southeast Central, NHI = Northern High, NLO = Northern Low, SWD = Southwest Driftless Strata.

† Aerial Visibility Correction Factor = ratio of number of species-specific individuals seen from the ground divided by the number seen from the air on air-ground segments, pooled across strata. To achieve a desirable coefficient of variation (CV) value in the aerial visibility correction factor, previous years of air-ground data were iteratively added until CV was <20%. In 2023, aerial visibility correction factors for mallards, blue-winged teal, wood ducks, Canada geese, and "other ducks" were derived using 1, 14, 5, 1, and 12 years of air-ground data, respectively.

[a] Lesser scaup, bufflehead, and all non-duck/goose waterbirds are excluded from analysis. Common duck species categorized as "other ducks" include: ring-necked duck, common goldeneye, northern shoveler, hooded merganser, common merganser, gadwall, green-winged teal, and canvasback.

Table 6: Statewide breeding waterfowl population survey estimates and corresponding Bayesian state-space modeled estimates (highlighted in bold) in Wisconsin, 1973–2023.

Year	Mallard		Blue-winged teal		Wood ducks		Other ducks		Total ducks		Canada geese	
1973	106,956	**103,106**	185,361	**209,437**	6,636	**9,687**	113,753	**86,448**	412,706	**406,702**		
1974	94,322	**101,965**	254,440	**216,175**	15,442	**15,098**	70,978	**66,083**	435,182	**407,322**		
1975	120,460	**104,756**	237,426	**207,800**	26,520	**21,809**	42,472	**48,489**	426,878	**393,977**		
1976	109,862	**100,603**	200,649	**190,347**	26,164	**23,440**	42,851	**40,402**	379,526	**364,364**		
1977	91,657	**93,219**	195,737	**171,935**	21,475	**21,962**	14,411	**29,579**	323,280	**330,451**		
1978	61,646	**86,209**	134,205	**146,583**	17,811	**21,281**	57,686	**40,869**	271,348	**301,350**		
1979	78,600	**91,796**	120,892	**129,761**	31,697	**27,517**	34,541	**36,869**	265,730	**290,361**		
1980	116,488	**103,769**	69,404	**115,576**	29,261	**27,875**	32,920	**35,490**	248,073	**289,471**		
1981	142,831	**111,431**	258,054	**130,107**	40,817	**29,222**	63,336	**38,800**	505,038	**318,437**		
1982	89,472	**105,669**	98,641	**103,882**	9,524	**15,839**	21,081	**24,018**	218,718	**260,887**		
1983	119,462	**108,593**	60,465	**85,921**	10,642	**16,515**	11,727	**16,871**	202,296	**237,906**		
1984	104,759	**106,362**	64,951	**80,728**	28,294	**26,572**	11,991	**15,050**	209,995	**234,191**		
1985	73,909	**103,599**	84,199	**81,396**	25,757	**32,862**	8,929	**14,521**	192,794	**240,646**		
1986	110,763	**116,229**	51,266	**78,280**	82,747	**63,084**	17,237	**19,332**	262,013	**276,550**	11,129	**12,701**
1987	136,947	**131,762**	124,021	**89,540**	98,349	**76,139**	30,518	**26,477**	389,835	**324,112**	14,519	**15,360**
1988	148,901	**146,216**	67,580	**87,611**	54,260	**61,352**	16,333	**28,941**	287,074	**336,189**	15,339	**18,879**
1989	180,676	**161,120**	125,062	**94,355**	59,676	**63,744**	97,099	**55,568**	462,513	**384,333**	53,040	**32,725**
1990	151,356	**168,061**	70,169	**89,659**	67,065	**70,153**	40,040	**55,569**	328,630	**390,952**	22,840	**26,354**
1991	172,423	**183,200**	67,023	**93,615**	69,349	**77,277**	126,986	**83,307**	435,781	**439,889**	23,931	**27,330**
1992	249,727	**205,344**	179,125	**113,104**	145,118	**108,108**	109,834	**81,053**	683,804	**501,559**	34,668	**32,949**
1993	174,531	**209,578**	98,859	**109,128**	73,866	**83,863**	32,115	**56,057**	379,371	**473,970**	34,386	**35,959**
1994	283,400	**234,316**	144,041	**112,312**	63,078	**80,867**	80,710	**68,721**	571,229	**516,326**	36,125	**40,618**
1995	242,166	**240,006**	117,945	**103,027**	153,658	**116,557**	78,650	**69,396**	592,419	**529,174**	59,240	**53,525**
1996	314,413	**246,667**	69,960	**89,217**	76,475	**94,613**	75,457	**62,271**	536,305	**509,779**	55,888	**59,617**
1997	180,968	**226,461**	70,795	**84,975**	119,410	**113,676**	38,140	**45,598**	409,313	**474,241**	78,566	**73,463**
1998	186,891	**229,405**	75,975	**86,376**	121,713	**119,080**	28,219	**37,755**	412,798	**475,637**	74,712	**80,516**
1999	248,446	**254,329**	84,418	**90,272**	113,898	**119,756**	29,869	**37,832**	476,631	**511,914**	101,183	**98,050**
2000	453,979	**287,169**	117,338	**95,955**	141,882	**132,947**	31,191	**41,798**	744,390	**575,232**	129,508	**114,308**
2001	183,453	**259,909**	77,310	**91,494**	131,051	**131,253**	48,312	**56,765**	440,126	**550,293**	94,066	**109,531**
2002	378,542	**282,939**	66,033	**92,763**	135,129	**130,087**	161,087	**92,678**	740,791	**605,758**	118,476	**129,199**
2003	261,332	**266,343**	90,136	**107,786**	110,109	**118,411**	71,888	**80,437**	533,465	**588,930**	241,930	**176,613**
2004	229,175	**254,064**	213,755	**136,542**	114,550	**120,245**	94,014	**84,443**	651,494	**610,942**	149,003	**149,988**
2005	317,224	**255,696**	195,239	**140,582**	141,152	**130,228**	70,655	**75,964**	724,270	**613,106**	123,836	**134,678**
2006	219,494	**231,819**	108,701	**126,457**	121,650	**120,006**	72,726	**73,682**	522,571	**558,899**	134,683	**134,467**
2007	210,219	**217,861**	124,093	**124,120**	87,875	**104,659**	48,427	**68,997**	470,614	**529,859**	125,195	**130,102**
2008	188,429	**205,955**	179,549	**123,304**	126,440	**118,214**	132,506	**90,527**	626,924	**543,070**	116,715	**128,952**
2009	200,497	**201,708**	112,793	**103,018**	113,523	**114,595**	75,602	**75,569**	502,416	**506,253**	148,293	**144,663**
2010	199,107	**197,862**	50,188	**83,790**	103,769	**112,814**	32,757	**61,512**	385,821	**470,878**	157,622	**154,061**
2011	187,862	**193,262**	90,803	**84,700**	146,471	**127,297**	88,610	**84,465**	513,746	**489,760**	176,095	**161,074**
2012	196,950	**190,180**	105,791	**81,738**	106,626	**109,340**	111,712	**105,757**	521,079	**492,076**	145,386	**148,913**
2013	181,200	**183,392**	73,483	**69,854**	91,516	**98,734**	181,141	**125,851**	527,340	**478,493**	138,925	**140,452**
2014	158,747	**176,495**	34,337	**57,744**	104,140	**98,944**	97,875	**102,906**	395,099	**436,191**	126,299	**132,046**
2015	176,200	**177,348**	59,083	**58,216**	68,142	**83,971**	69,415	**89,696**	372,840	**418,269**	119,212	**129,481**
2016	164,147	**177,603**	37,936	**56,489**	89,775	**93,401**	98,640	**96,689**	390,498	**423,854**	129,562	**137,234**
2017	180,930	**183,837**	85,526	**63,938**	102,397	**101,603**	110,246	**98,375**	479,099	**449,761**	158,023	**152,577**
2018	216,652	**192,317**	45,130	**61,230**	100,055	**104,512**	77,560	**85,259**	439,397	**454,083**	157,950	**159,117**
2019	204,296	**189,572**	61,946	**66,225**	100,027	**111,663**	47,392	**75,864**	413,661	**462,936**	171,407	**167,102**
2020		**181,932**		**73,360**		**144,265**		**98,281**		**502,660**		**171,530**
2021	147,373	**173,015**	75,256	**80,145**	240,293	**179,989**	122,036	**122,499**	584,958	**543,374**	170,125	**171,075**
2022	185,616	**176,977**	105,116	**90,638**	157,621	**144,254**	198,745	**156,095**	647,098	**564,738**	171,125	**171,667**
2023	166,651	**175,895**	117,085	**96,271**	73,467	**102,381**	147,406	**153,295**	504,609	**545,065**	155,292	**169,447**
Mean (1973–2022)	182,315	**178,621**	110,616	**105,224**	86,182	**85,388**	68,784	**65,309**	447,897	**441,802**	106,083	**106,943**
Mean (2014–2023)	177,846	**180,499**	69,046	**70,426**	115,102	**116,498**	107,702	**107,896**	469,695	**480,093**	150,999	**156,128**
% change from previous year	-10.2%	**-0.6%**	11.4%	**6.2%**	-53.4%	**-29.0%**	-25.8%	**-1.8%**	-22.0%	**-3.5%**	-9.3%	**-1.3%**
% change from 1973–2022	-8.6%	**-1.5%**	5.8%	**-8.5%**	-14.8%	**19.9%**	114.3%	**134.7%**	12.7%	**23.4%**	46.4%	**58.4%**

Table 7: Annual statewide estimates of breeding Trumpeter swan abundance in Wisconsin, 2010–2023. Survey estimates (corrected for bird density and survey region area, but not visibility) and model-predicted estimates from a Bayesian state-space model are shown. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

Year	Survey estimate	Modeled estimate
2010	1,237	1,199
2011	1,408	1,480
2012	1,999	1,896
2013	2,292	2,318
2014	2,979	2,891
2015	3,679	3,564
2016	5,029	4,447
2017	4,833	5,012
2018	5,677	5,873
2019	6,106	6,894
2020		8,882
2021	11,197	10,521
2022	11,919	12,044
2023	11,078	13,643

Figures

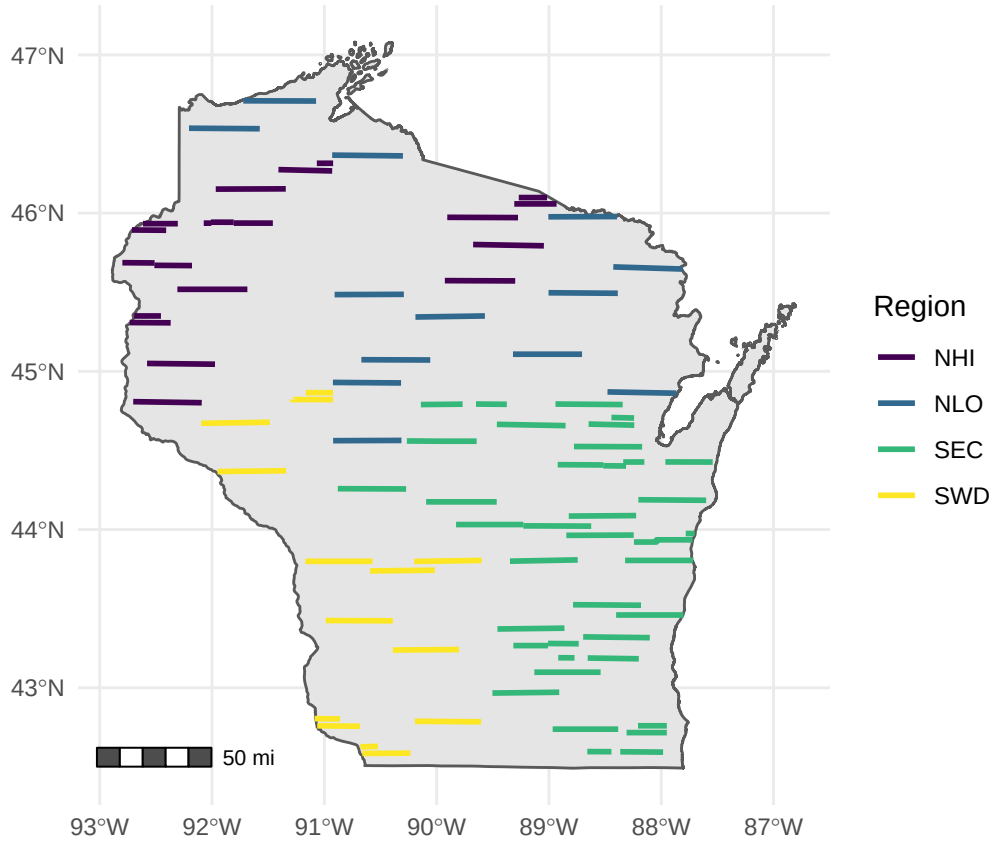

Figure 1: Wisconsin Waterfowl Breeding Population Survey aerial transects (*n* = 66) labeled by survey region. The four regions surveyed are the Northern High Density region (NHI), Northern Low Density region (NLO), Southeast Central region (SEC), and Southwest Driftless region (SWD).

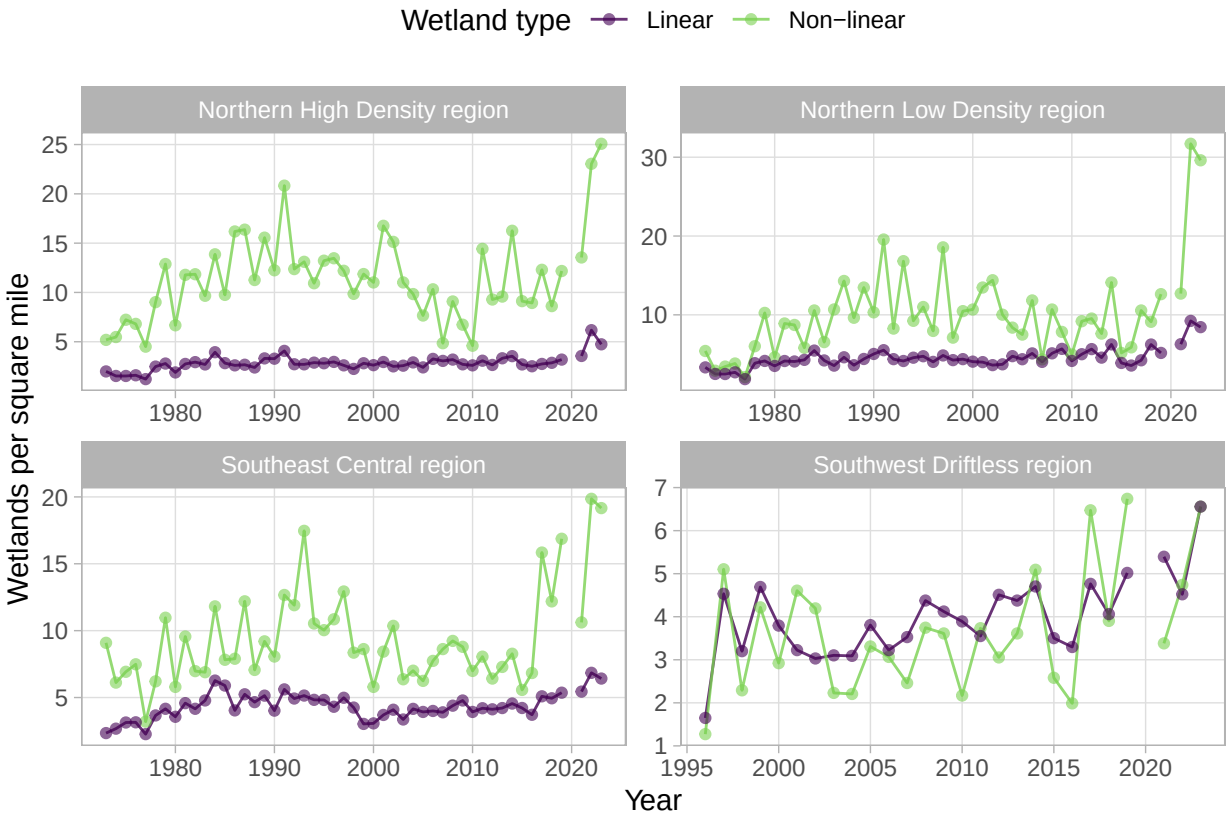

Figure 2: Annual variability in total linear and non-linear wetlands per square mile by survey region. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

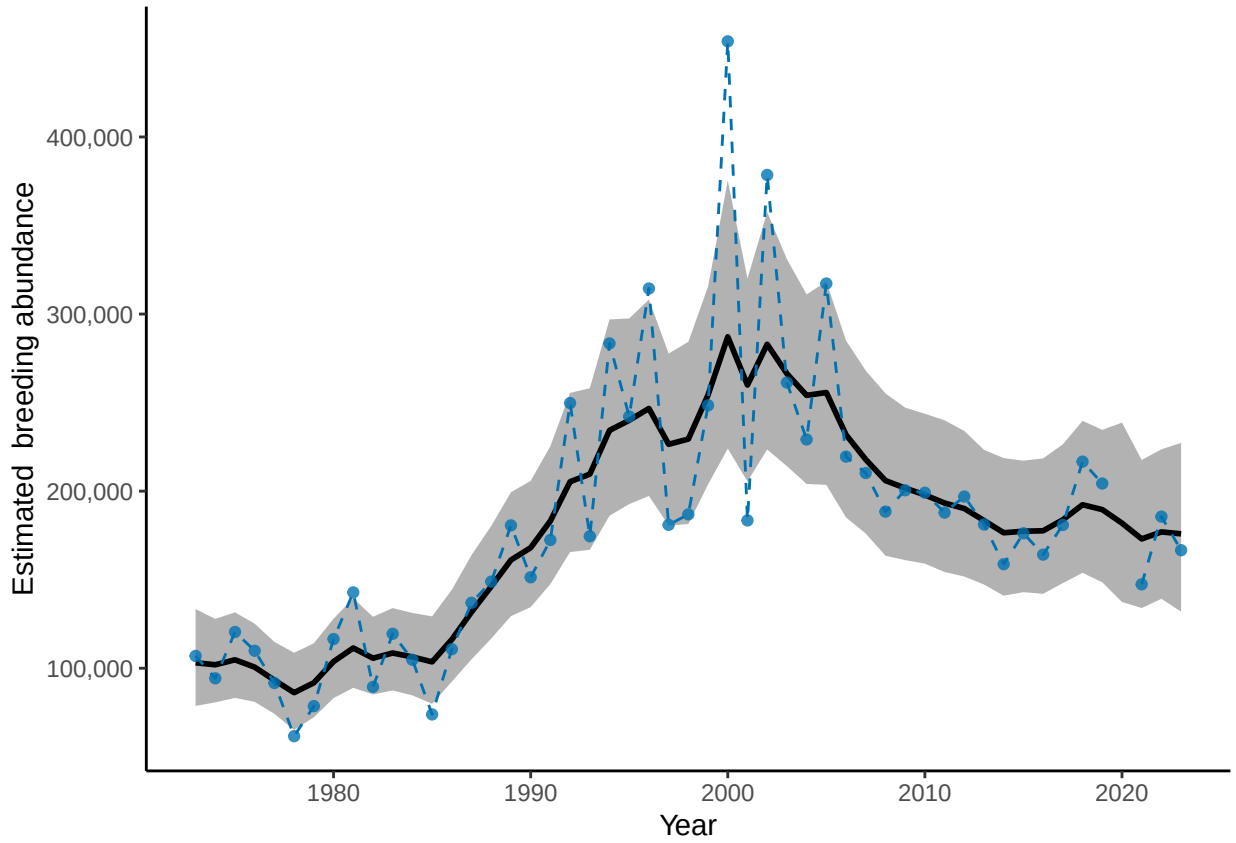

Figure 3: Annual statewide estimates of breeding mallard population size in Wisconsin, 1973–2023. Black line and gray shaded region are the mean and 95% credible interval estimates for the state-space population trend, and blue points and dashed line show the annual survey counts. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

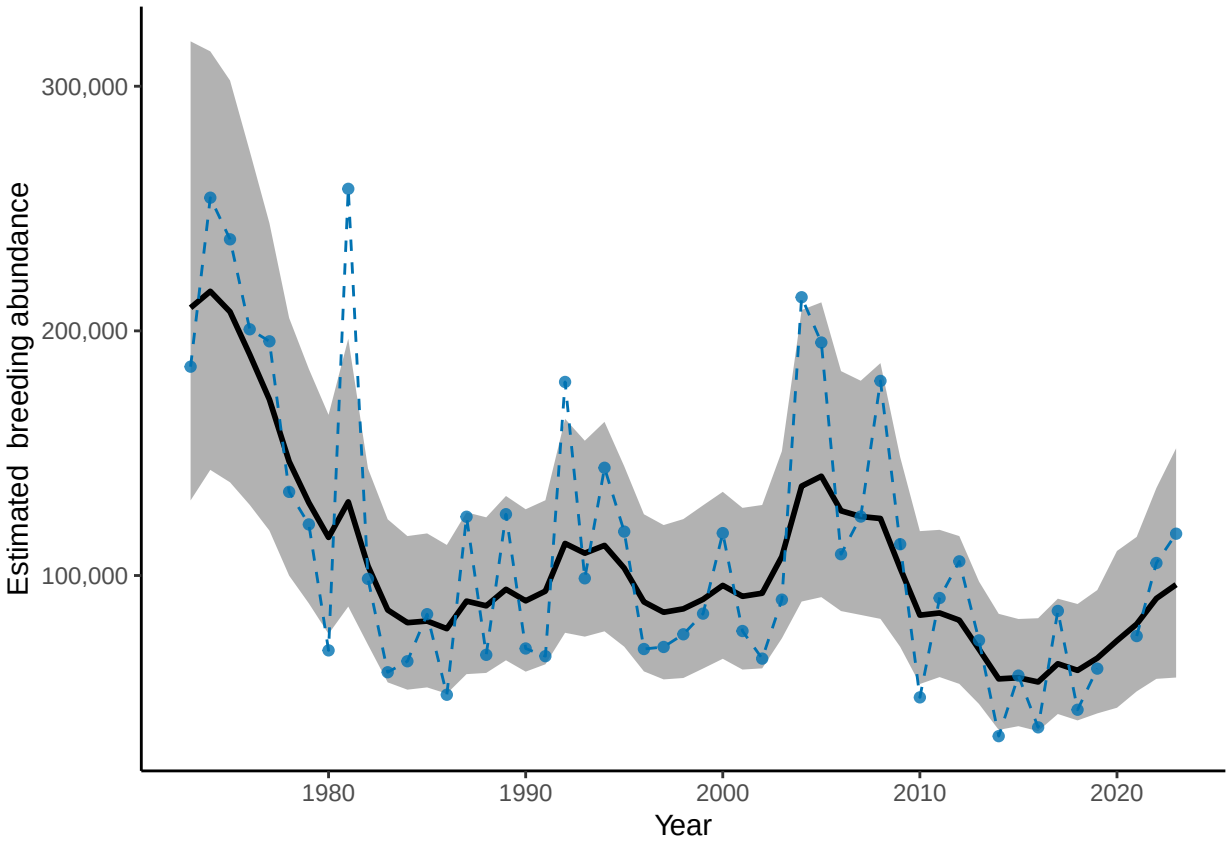

Figure 4: Annual statewide estimates of breeding blue-winged teal abundance in Wisconsin, 1973–2023. Black line and gray shaded region are the mean and 95% credible interval estimates for the state-space population trend, and blue points and dashed line show the annual survey counts. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

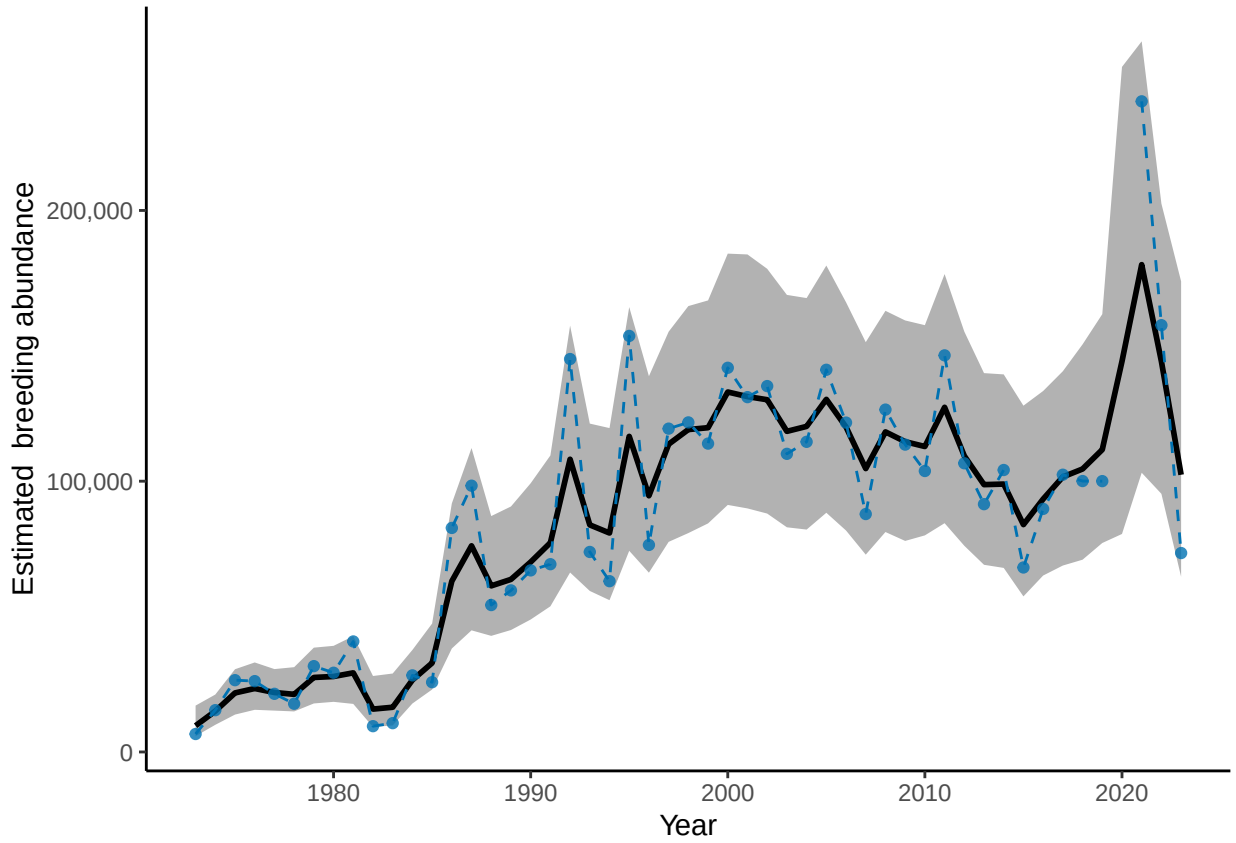

Figure 5: Annual statewide estimates of breeding wood duck abundance in Wisconsin, 1973–2023. Black line and gray shaded region are the mean and 95% credible interval estimates for the state-space population trend, and blue points and dashed line show the annual survey counts. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

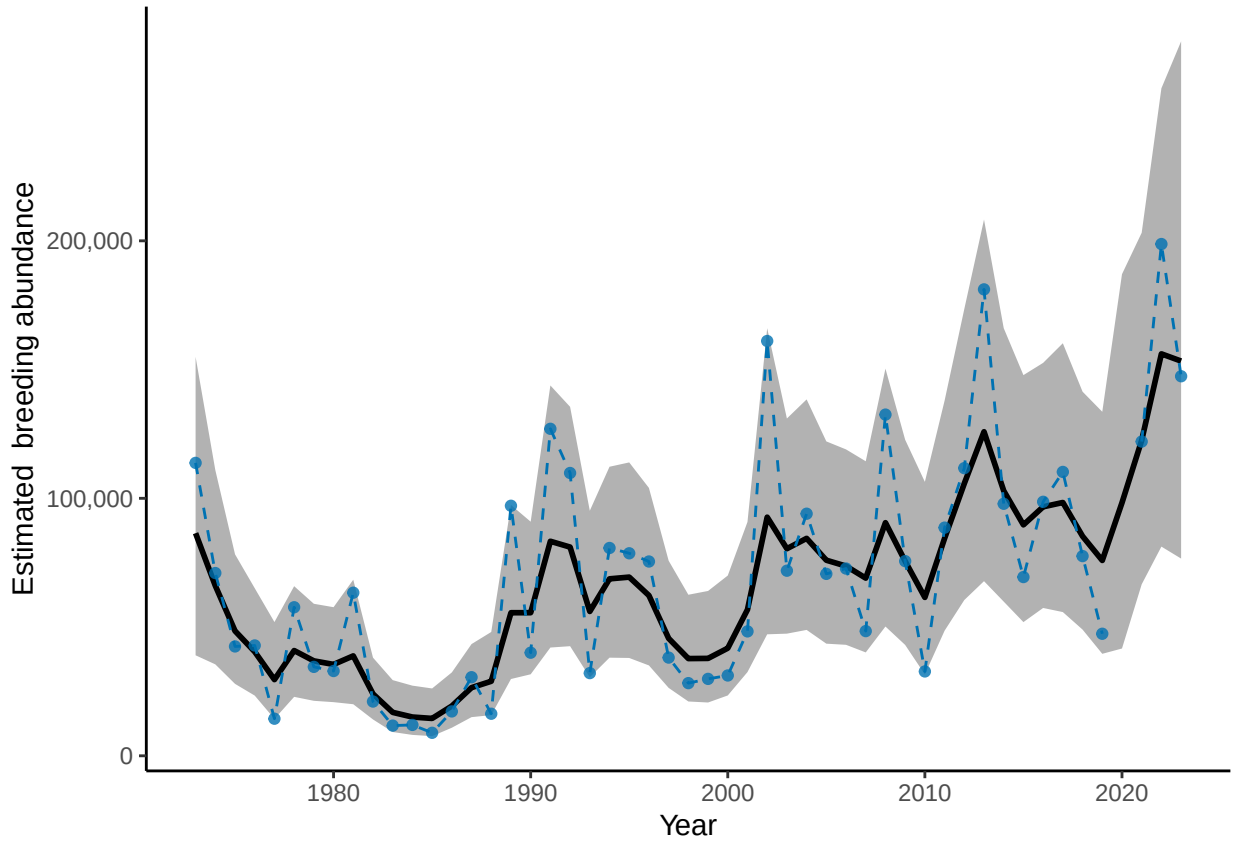

Figure 6: Annual statewide estimates of breeding 'other duck' abundance in Wisconsin, 1973–2023. Black line and gray shaded region are the mean and 95% credible interval estimates for the state-space population trend, and blue points and dashed line show the annual survey counts. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

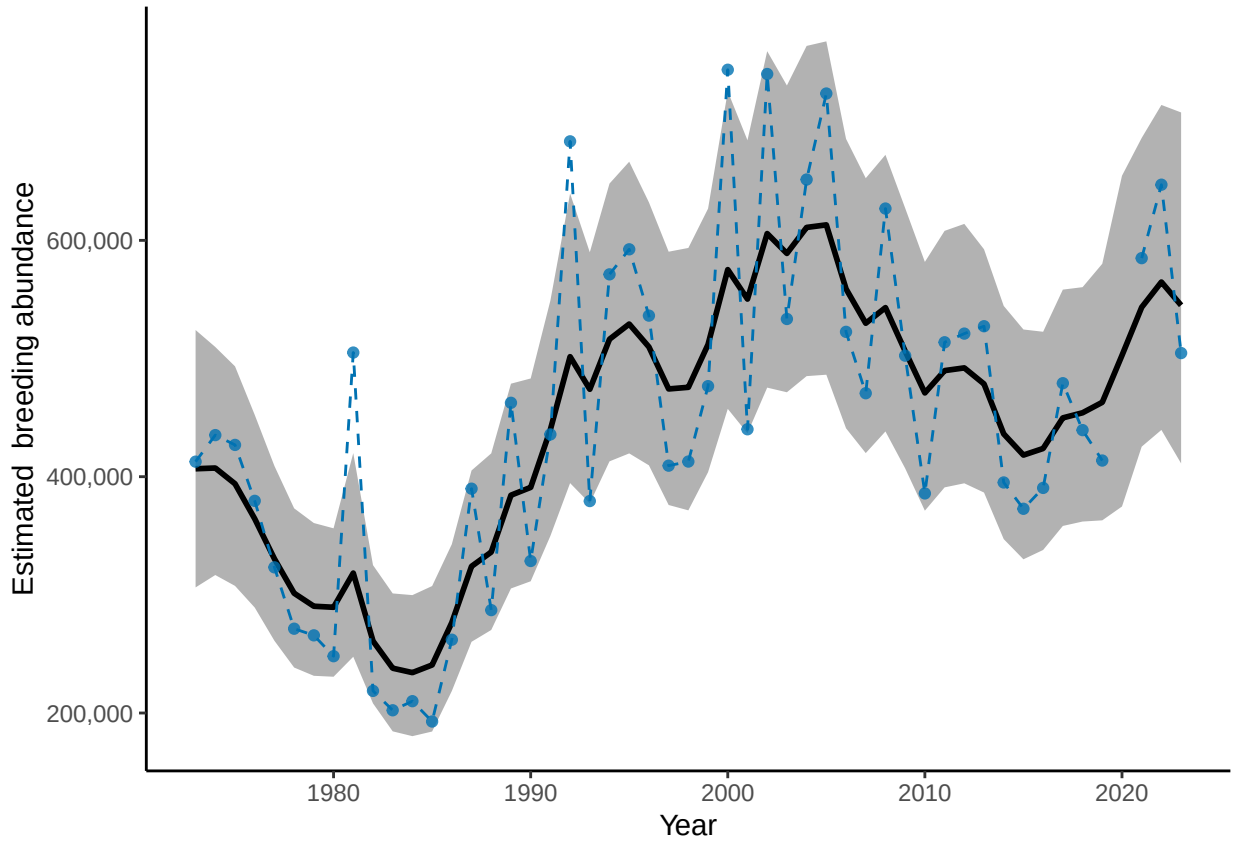

Figure 7: Annual statewide estimates of total breeding duck abundance in Wisconsin, 1973–2023. Black line and gray shaded region are the mean and 95% credible interval estimates for the state-space population trend, and blue points and dashed line show the annual survey counts. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

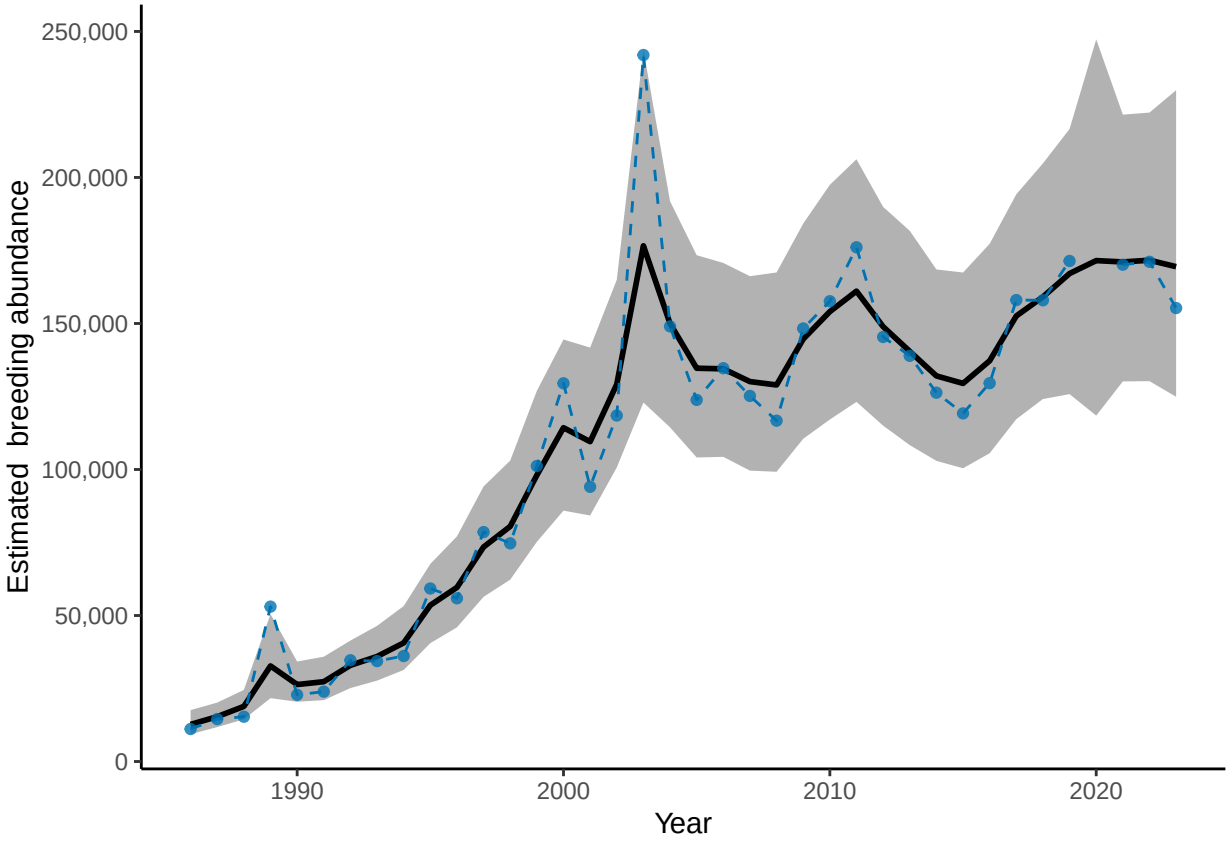

Figure 8: Annual statewide estimates of breeding Canada goose abundance in Wisconsin, 1986–2023. Black line and gray shaded region are the mean and 95% credible interval estimates for the state-space population trend, and blue points and dashed line show the annual survey counts. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

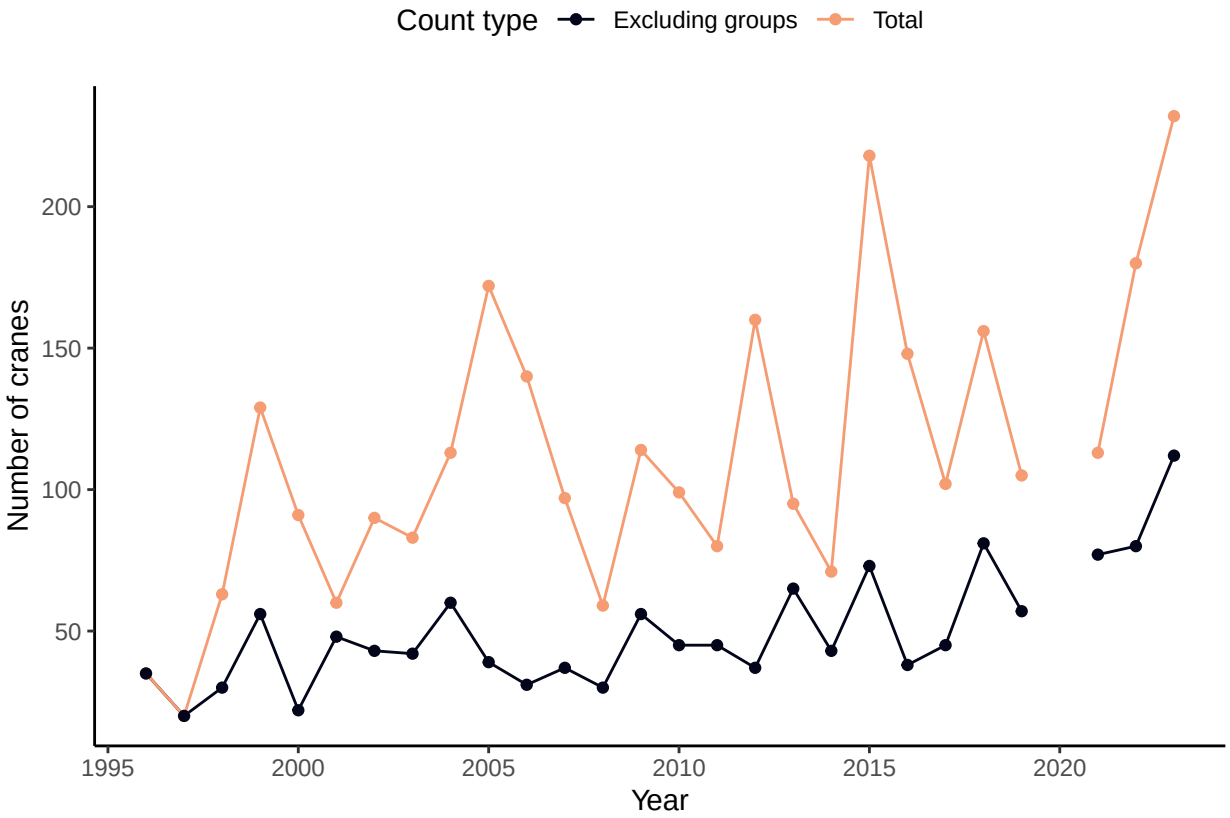

Figure 9: Annual counts of sandhill cranes (raw estimates) observed from the air during the Waterfowl Breeding Population Survey, 1996–2023. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

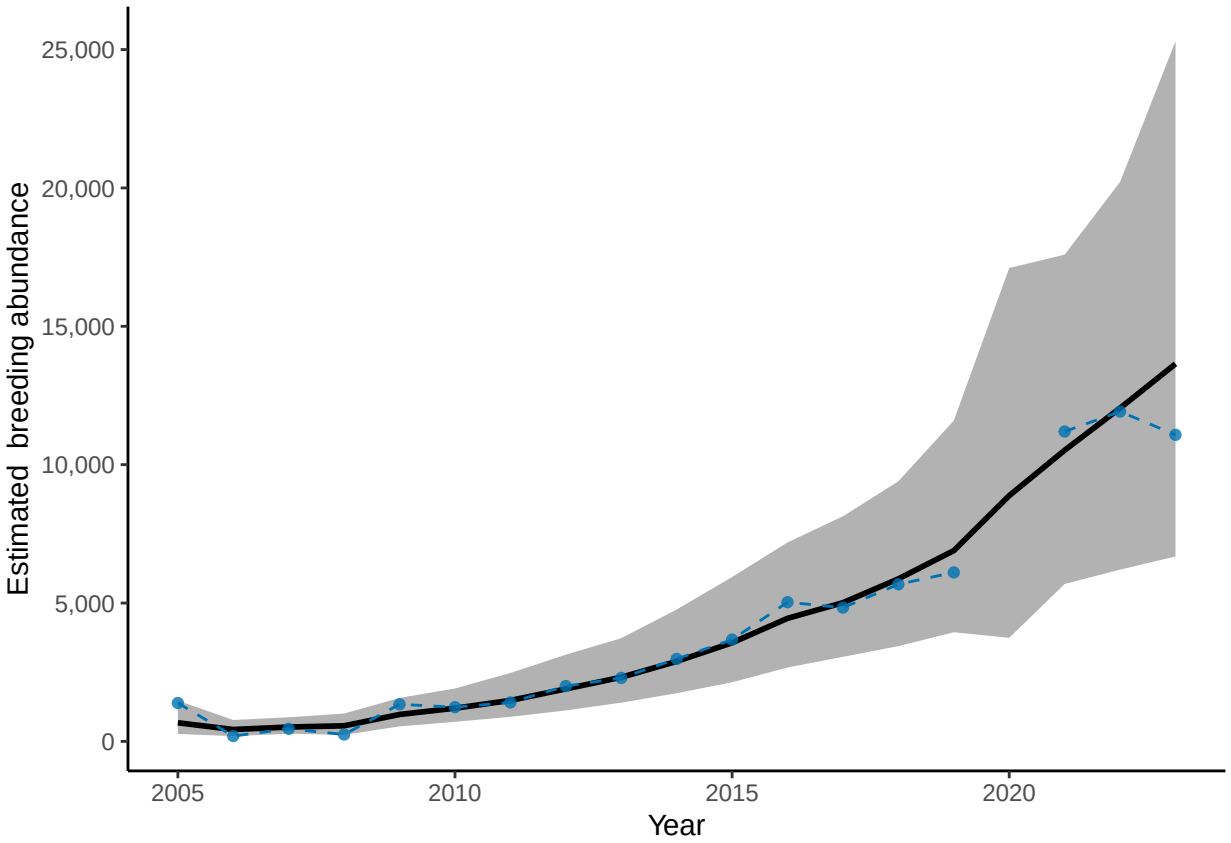

Figure 10: Annual statewide estimates of trumpeter swan abundance in Wisconsin, 2005–2023. Black line and gray shaded region are the mean and 95% credible interval estimates for the state-space population trend, and blue points and dashed line show the annual survey counts. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.