Waterfowl Breeding Population Survey For Wisconsin, 1973–2022

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1 Abstract

The 2022 Waterfowl Breeding Population Survey for Wisconsin was conducted from April 25–May 6 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, 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 up 87.1% from 2021 in the Southeast Central (SEC) region and up 116.2% from the long-term, 49-year mean. In the Northern High Density (NHI) region, total non-linear basins were up 70.1% from 2021 and up 105.9% from the long-term mean. Non-linear basins were up 149.7% from 2021 in the Northern Low Density (NLO) region and up 224.5% from the long-term mean. Non-linear basins were up 40.1% from 2021 in the Southwest Driftless (SWD) region and up 32.9% compared to this region's long-term (25-year) mean. Total linear basins were up 25.8% from 2021 in the SEC region and up 58.6% from the long-term mean. In the NHI region, linear basins were up 73.5% from 2021 and up 120.3% from the long-term mean. NLO region linear basins were up 47.1% from 2021 and up 108.0% from the long-term mean. Linear basins were down 16.2% from 2021 in the SWD region and up 16.4% from the long-term mean.

The 2022 total breeding duck modeled population estimate of 591,762 was 6.3% higher than the 2021 modeled estimate of 556,507, and was 33.6% higher than the long-term mean. Overall, the total duck population estimate for 2022 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 181,686 was 3.3% higher than the 2021 estimate of 175,819 and was 1.5% higher than the long-term mean. The blue-winged teal modeled breeding population estimate of 81,359 was 9.0% higher compared to the 2021 estimate of 74,653, but remains 22.1% lower than the long-term mean. At 174,526 the 2022 population estimate for wood ducks was 8.4% lower than the 2021 estimate of 190,551 and 102.2% higher than the long-term mean. The modeled Canada goose population estimate of 180,340 was 3.3% higher compared to the 2021 estimate of 174,515, and 68.2% higher than the long-term mean. The population estimate of "other ducks" was 156,330, which was 26.4% higher than the 2021 estimate of 123,648 and was 138.8% higher than the long-term mean.

2 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 68 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 2022 survey data in support of these efforts.

3 Methods

3.1 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.

3.2 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.

3.3 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.

3.4 Statistical analysis

3.4.1 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.

3.4.2 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.*'

4 Results

4.1 Survey timing

We initiated the 2022 Waterfowl Breeding Population Survey on April 25. 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 was a slight issue leading up to and during the survey, with extremely wet conditions across most of the state and cold conditions in the north, resulting in northern Wisconsin lakes retaining some ice into late April/early May. Significant rainfall events likely contributed to the high number of temporary and other wetland types recorded across much of the state.

Aerial surveys were completed in 9 days from April 25 to May 5. The ground survey was completed in 10 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.

4.2 Wetland counts

In the SEC region, total non-linear basins were up 87.1% from 2021 and were up 116.2% from the long-term (49-year) mean. Linear basins in the SEC region were up 25.8% from 2021 and up 58.6% from the long-term mean (Table 1). In the NHI region, total non-linear basins were up 70.1% from 2021 and up 105.9% from the long-term mean. Linear basins in the NHI region were up 73.5% from 2021 and up 120.3% from the long-term mean (Table 2). In the NLO region, total non-linear basins were up 149.7% from 2021 and up 224.5% from the long-term mean. Linear basins in the NLO region were up 47.1% from 2021 and up 108.0% from the long-term mean (Table 3). In the SWD region, total non-linear basins were up 40.1% from 2021 and up 32.9% from this region's long-term, 25-year mean. Linear basins in the SWD region were down 16.2% from 2021 and up 16.4% from the long-term mean (Table 4). Long-term wetland counts for each survey region are shown in Figure 2.

4.3 Waterfowl population estimates

2022 VCF and population estimate summary statistics for mallards, blue-winged teal, wood ducks, "other ducks", and Canada geese are provided in Table 5.

4.3.1 Mallards

The 2022 modeled mallard population estimate was **181,686 (95% credible interval [CI] = 136,200–237,762 individuals)**. This estimate is 3.3% higher compared to the previous year's modeled estimate and 1.5% higher than the long-term, 49-year mean (Table 6; Figure

3). As in previous years, the SEC still represented the largest portion of the breeding mallard population (46%) and was similar to that of 2021.

4.3.2 Blue-winged teal

The 2022 modeled population estimate for blue-winged teal was **81,359 (95% CI = 48,810–129,071 individuals)**. This estimate was 9.0% higher compared to the previous year's modeled estimate but remains 22.1% lower than the long-term mean (Table 6; Figure 4).

4.3.3 Wood ducks

The 2022 population estimate for wood ducks was **174,526 (95% CI = 111,751–262,979 individuals)**. This estimate was 8.4% lower compared to the previous year and was 102.2% higher than the long-term mean (Table 6; Figure 5). The breeding wood duck population showed significant gains in the 1980s and early 1990s and appears to be leveling off around 100,000 after peaking about 10 years ago but has shown an increasing trend over the past five years.

4.3.4 Other ducks

The 2022 modeled population estimate for "other ducks" was **156,330 (95% CI = 73,792–285,474 individuals)**. This estimate was 26.4% higher compared to the previous year and was 138.8% higher than the long-term mean (Table 6; Figure 6). Species considered as "other ducks" and their percent composition in the 2022 uncorrected aerial count were: American black duck (*A. rubripes*; 0%), northern pintail (*A. acuta*; 3%), gadwall (*Mareca strepera*; 0%), American wigeon (*M. americana*; 0%), northern shoveler (*Spatula clypeata*; 10%), green-winged teal (*A. carolinensis*; 4%), canvasback (*A. valisineria*; 2%), redhead (*A. americana*; 0%), ring-necked duck (*A. collaris*; 36%), common goldeneye (*B. clangula*; 10%), hooded merganser (*Lophodytes cucullatus*; 7%), common merganser (*Mergus merganser*; 24%), red-breasted merganser (*M. serrator*; 0%), and ruddy duck (*Oxyura jamaicensis*; 3%).

4.3.5 Total ducks

The 2022 population estimate for all breeding ducks was **591,762 (95% CI = 440,343–767,764 individuals)**. This estimate was 6.3% higher compared to the previous year and is 33.6% higher than the long-term mean (Table 6; Figure 7).

4.3.6 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 2022 population estimate for Canada geese was **180,340 (95% CI = 132,921–245,447 individuals)**. This estimate was 3.3% higher than the previous year's modeled estimate and was 68.2% higher than the long-term, 36-year mean (Table 6; Figure 8). The long-term trend in goose numbers suggests a continued, gradual increase in their population.

4.3.7 American coots, sandhill cranes, and trumpeter swans

In 2022, observers counted a total of 422 coots, one pair of whooping cranes, and 80 sandhill cranes (Figure 9). Excluding groups of five or more, 115 trumpeter swans were recorded and the 2022 population estimate (accounting for bird density and survey region area, but lacking VCF-correction) was **13,320 (95% CI = 6,582–23,888 individuals)**; Table 7; Figure 10).

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7 Tables

Table 1: Type and number of wetlands per square mile observed during the last 10-year period, 2012–2022, SEC region.

	Wetland type							
Year	**I, II, VI**	**III**	**IV, V**	**VII, VIII**	**Non-linear**	**Stream**	**Ditch**	**Linear**
2012	2.1	0.6	3.1	0.7	6.4	1.6	2.6	4.1
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
% Change from previous year	222.0%	147.5%	2.8%	72.8%	87.1%	1.4%	48.8%	25.8%
Long-term mean	4.0	1.0	3.1	1.2	9.2	1.8	2.5	4.3
% Change from long-term mean	133.8%	136.9%	68.6%	163.8%	116.2%	50.3%	64.4%	58.6%
10-Year mean (2012-2022)	4.7	1.1	3.7	1.5	11.0	1.9	3.0	4.8

Notes: Wetland classification system from March et al. (1973). I, II, VI = temporary, wet meadow, and 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, 2012–2022, NHI region.

	Wetland type							
Year	**I, II, VI**	**III**	**IV, V**	**VII, VIII**	**Non-linear**	**Stream**	**Ditch**	**Linear**
2012	3.4	1.0	3.8	1.0	9.3	2.3	0.3	2.6
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
% Change from previous year	131.6%	200.9%	-11.5%	116.2%	70.1%	49.4%	303.0%	73.5%
Long-term mean	3.4	1.4	4.1	2.3	11.2	2.3	0.5	2.8
% Change from long-term mean	-4.6%	138.6%	26.3%	383.8%	105.9%	105.2%	197.6%	120.3%
10-Year mean (2012-2022)	3.0	1.7	4.5	3.1	12.3	2.7	0.6	3.3

Notes: Wetland classification system from March et al. (1973). I, II, VI = temporary, wet meadow, and 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, 2012–2022, NLO region.

	Wetland type							
Year	**I, II, VI**	**III**	**IV, V**	**VII, VIII**	**Non-linear**	**Stream**	**Ditch**	**Linear**
2012	5.0	0.5	2.4	1.7	9.5	4.8	0.8	5.7
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
% Change from previous year	353.2%	29.2%	-11.2%	179.8%	149.7%	12.9%	173.8%	47.1%
Long-term mean	4.3	0.8	2.3	2.3	9.8	3.6	0.9	4.4
% Change from long-term mean	218.3%	81.3%	48.3%	459.2%	224.5%	56.4%	319.8%	108.0%
10-Year mean (2012-2022)	5.1	0.9	2.6	3.3	11.9	4.1	1.4	5.5

Notes: Wetland classification system from March et al. (1973). I, II, VI = temporary, wet meadow, and 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, 2012–2022, SWD region.

	Wetland type							
Year	**I, II, VI**	**III**	**IV, V**	**VII, VIII**	**Non-linear**	**Stream**	**Ditch**	**Linear**
2012	1.0	0.2	1.9	0.0	3.1	3.6	1.0	4.5
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
% Change from previous year	142.0%	34.3%	-37.3%	442.9%	40.1%	-28.9%	84.0%	-16.2%
Long-term mean	1.4	0.3	1.5	0.3	3.6	3.2	0.7	3.9
% Change from long-term mean	45.9%	67.6%	-20.7%	214.1%	32.9%	6.5%	63.2%	16.4%
10-Year mean (2012-2022)	1.7	0.5	1.6	0.4	4.2	3.4	1.0	4.4

Notes: Wetland classification system from March et al. (1973). I, II, VI = temporary, wet meadow, and 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 2022 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	3.899	1.210	84,668	15,307
NHI	9,431	3.179	1.210	36,279	6,960
NLO	15,979	2.421	1.210	46,795	10,943
SWD	12,311	1.200	1.210	17,874	4,038
Subtotal				**185,616**	**20,465**
Blue-winged teal					
SEC	17,949	0.566	5.443	55,253	15,708
NHI	9,431	0.431	5.443	22,114	12,724
NLO	15,979	0.226	5.443	19,626	12,599
SWD	12,311	0.121	5.443	8,123	6,600
Subtotal				**105,116**	**24,717**
Wood duck					
SEC	17,949	1.255	2.793	62,926	15,568
NHI	9,431	1.108	2.793	29,179	7,778
NLO	15,979	0.646	2.793	28,838	10,873
SWD	12,311	1.067	2.793	36,678	14,336
Subtotal				**157,621**	**25,032**
Other duck species[a]					
SEC	17,949	0.961	3.807	65,655	18,406
NHI	9,431	2.533	3.807	90,947	23,752
NLO	15,979	0.646	3.807	39,303	11,928
SWD	12,311	0.061	3.807	2,840	1,992
Subtotal				**198,745**	**32,392**
Canada goose					
SEC	17,949	3.113	1.676	93,623	14,953
NHI	9,431	1.579	1.676	24,962	5,719
NLO	15,979	1.159	1.676	31,034	8,834
SWD	12,311	1.042	1.676	21,506	7,757
Subtotal				**171,125**	**19,862**

* 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 2022, aerial visibility correction factors for mallards, blue-winged teal, wood ducks, Canada geese, and "other ducks" were derived using 1, 14, 4, 1, and 11 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, 1973–2022.

Year	Mallard		Blue-winged teal		Wood ducks		Other ducks		Total ducks		Canada geese	
1973	106,956	**103,069**	185,361	**208,627**	6,636	**9,775**	113,753	**87,580**	412,706	**406,167**		
1974	94,322	**101,784**	254,440	**213,215**	15,442	**14,951**	70,978	**66,567**	435,182	**407,851**		
1975	120,460	**104,645**	237,426	**205,289**	26,520	**21,447**	42,472	**49,071**	426,878	**395,222**		
1976	109,862	**100,722**	200,649	**187,930**	26,164	**23,416**	42,851	**40,417**	379,526	**364,864**		
1977	91,657	**93,178**	195,737	**170,196**	21,475	**22,215**	14,411	**29,944**	323,280	**330,295**		
1978	61,646	**85,781**	134,205	**145,456**	17,811	**21,691**	57,686	**40,473**	271,348	**300,150**		
1979	78,600	**91,477**	120,892	**129,312**	31,697	**27,344**	34,541	**36,903**	265,730	**287,986**		
1980	116,488	**104,163**	69,404	**115,596**	29,261	**27,631**	32,920	**35,835**	248,073	**288,296**		
1981	142,831	**111,602**	258,054	**127,636**	40,817	**28,164**	63,336	**38,416**	505,038	**321,242**		
1982	89,472	**105,259**	98,641	**104,383**	9,524	**16,211**	21,081	**24,064**	218,718	**260,338**		
1983	119,462	**108,384**	60,465	**87,594**	10,642	**16,773**	11,727	**17,034**	202,296	**236,258**		
1984	104,759	**106,225**	64,951	**81,993**	28,294	**26,227**	11,991	**15,217**	209,995	**233,835**		
1985	73,909	**103,071**	84,199	**82,017**	25,757	**33,042**	8,929	**14,768**	192,794	**239,341**		
1986	110,763	**116,045**	51,266	**79,493**	82,747	**60,397**	17,237	**19,582**	262,013	**275,724**	11,129	**12,649**
1987	136,947	**132,308**	124,021	**89,842**	98,349	**73,144**	30,518	**26,406**	389,835	**323,542**	14,519	**15,340**
1988	148,901	**146,422**	67,580	**87,999**	54,260	**61,277**	16,333	**29,254**	287,074	**335,140**	15,339	**18,818**
1989	180,676	**161,279**	125,062	**95,076**	59,676	**63,499**	97,099	**54,962**	462,513	**384,374**	53,040	**32,672**
1990	151,356	**167,342**	70,169	**90,535**	67,065	**69,611**	40,040	**55,572**	328,630	**389,481**	22,840	**26,193**
1991	172,423	**182,671**	67,023	**94,084**	69,349	**77,219**	126,986	**81,919**	435,781	**440,541**	23,931	**27,165**
1992	249,727	**206,017**	179,125	**111,263**	145,118	**103,469**	109,834	**79,010**	683,804	**505,617**	34,668	**33,041**
1993	174,531	**209,629**	98,859	**108,234**	73,866	**83,946**	32,115	**56,476**	379,371	**473,274**	34,386	**36,030**
1994	283,400	**235,823**	144,041	**111,549**	63,078	**82,094**	80,710	**68,488**	571,229	**516,628**	36,125	**40,617**
1995	242,166	**241,247**	117,945	**102,764**	153,658	**114,147**	78,650	**68,838**	592,419	**532,076**	59,240	**53,529**
1996	314,413	**248,368**	69,960	**89,596**	76,475	**95,856**	75,457	**61,826**	536,305	**507,841**	55,888	**59,273**
1997	180,968	**226,560**	70,795	**85,641**	119,410	**113,156**	38,140	**45,308**	409,313	**470,130**	78,566	**73,245**
1998	186,891	**229,336**	75,975	**86,678**	121,713	**118,734**	28,219	**38,052**	412,798	**472,997**	74,712	**80,056**
1999	248,446	**255,518**	84,418	**90,595**	113,898	**120,551**	29,869	**37,814**	476,631	**511,084**	101,183	**97,504**
2000	453,979	**289,300**	117,338	**95,919**	141,882	**132,687**	31,191	**42,477**	744,390	**577,468**	129,508	**113,692**
2001	183,453	**260,321**	77,310	**91,722**	131,051	**131,030**	48,312	**56,865**	440,126	**549,324**	94,066	**108,687**
2002	378,542	**283,449**	66,033	**93,618**	135,129	**129,631**	161,087	**92,051**	740,791	**607,645**	118,476	**128,850**
2003	261,332	**266,693**	90,136	**107,515**	110,109	**119,391**	71,888	**81,721**	533,465	**590,276**	241,930	**177,107**
2004	229,175	**254,612**	213,755	**133,259**	114,550	**120,976**	94,014	**84,450**	651,494	**614,367**	149,003	**149,542**
2005	317,224	**256,664**	195,239	**137,560**	141,152	**129,170**	70,655	**76,904**	724,270	**618,069**	123,836	**134,005**
2006	219,494	**232,642**	108,701	**125,826**	121,650	**118,984**	72,726	**74,065**	522,571	**560,999**	134,683	**134,412**
2007	210,219	**217,859**	124,093	**123,415**	87,875	**105,552**	48,427	**69,933**	470,614	**532,626**	125,195	**129,678**
2008	188,429	**206,185**	179,549	**121,168**	126,440	**117,960**	132,506	**90,317**	626,924	**544,484**	116,715	**129,134**
2009	200,497	**201,839**	112,793	**102,963**	113,523	**115,791**	75,602	**76,141**	502,416	**504,730**	148,293	**145,177**
2010	199,107	**197,565**	50,188	**84,109**	103,769	**113,191**	32,757	**61,597**	385,821	**468,296**	157,622	**153,860**
2011	187,862	**192,949**	90,803	**83,706**	146,471	**125,200**	88,610	**84,007**	513,746	**489,523**	176,095	**160,724**
2012	196,950	**190,364**	105,791	**80,989**	106,626	**109,728**	111,712	**104,739**	521,079	**492,936**	145,386	**148,308**
2013	181,200	**183,222**	73,483	**69,884**	91,516	**99,415**	181,141	**125,914**	527,340	**478,437**	138,925	**140,216**
2014	158,747	**175,816**	34,337	**58,088**	104,140	**98,897**	97,875	**103,760**	395,099	**436,365**	126,299	**132,346**
2015	176,200	**176,752**	59,083	**58,238**	68,142	**84,898**	69,415	**89,920**	372,840	**419,012**	119,212	**129,060**
2016	164,147	**177,809**	37,936	**56,220**	89,775	**93,850**	98,640	**96,713**	390,498	**426,914**	129,562	**136,932**
2017	180,930	**184,545**	85,526	**62,260**	102,397	**102,611**	110,246	**98,330**	479,099	**451,343**	158,023	**152,529**
2018	216,652	**193,550**	45,130	**60,281**	100,055	**106,837**	77,560	**86,210**	439,397	**454,147**	157,950	**159,248**
2019	204,296	**191,517**	61,946	**64,598**	100,027	**116,286**	47,392	**77,528**	413,661	**463,912**	171,407	**168,727**
2020		**183,728**		**69,998**		**152,129**		**99,976**		**510,252**		**174,039**
2021	147,373	**175,819**	75,256	**74,653**	240,293	**190,551**	122,036	**123,648**	584,958	**556,507**	170,125	**174,515**
2022	185,616	**181,686**	105,116	**81,359**	157,621	**174,526**	198,745	**156,330**	647,098	**591,762**	171,125	**180,340**
Mean (1973–2022)	182,315	**179,056**	110,616	**104,399**	86,182	**86,306**	68,784	**65,468**	447,897	**442,994**	106,083	**107,223**
Mean (2013–2022)	179,462	**182,444**	64,201	**65,558**	117,107	**122,000**	111,450	**105,833**	472,221	**478,865**	149,181	**154,795**
% change from previous year	25.9%	**3.3%**	39.7%	**9.0%**	-34.4%	**-8.4%**	62.9%	**26.4%**	10.6%	**6.3%**	0.6%	**3.3%**
% change from 1973–2022	1.8%	**1.5%**	-5.0%	**-22.1%**	82.9%	**102.2%**	188.9%	**138.8%**	44.5%	**33.6%**	61.3%	**68.2%**

Table 7: Annual statewide estimates of breeding Trumpeter swan abundance in Wisconsin, 2010–2022. 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	1,203
2011	1,408	1,468
2012	1,999	1,883
2013	2,292	2,315
2014	2,979	2,906
2015	3,679	3,582
2016	5,029	4,469
2017	4,833	5,076
2018	5,677	6,019
2019	6,106	7,147
2020		9,303
2021	11,197	11,160
2022	11,919	13,320

8 Figures

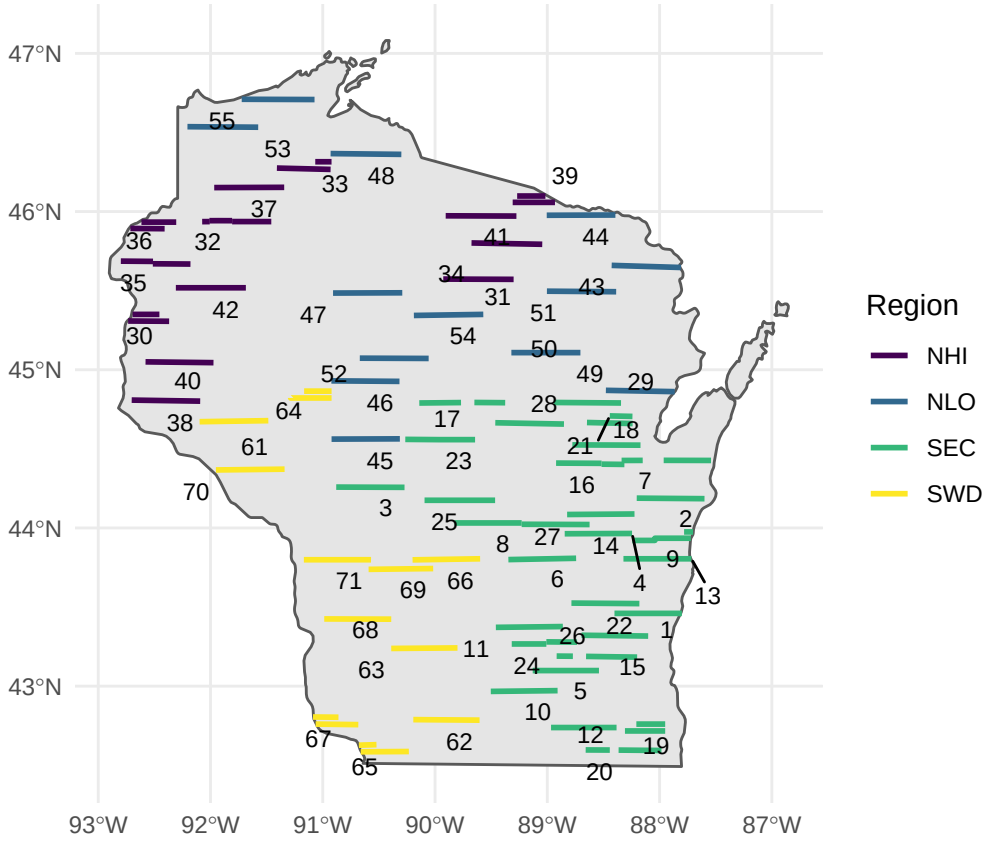

Figure 1: Wisconsin Waterfowl Breeding Population Survey aerial transects ($n = 66$) labeled by transect number and survey region. The four regions surveyed are the Northern High Density region (NHI), Northern Low Density region (NLO), Southeast Central region (SEC), and Southwest Driftless region (SWD).

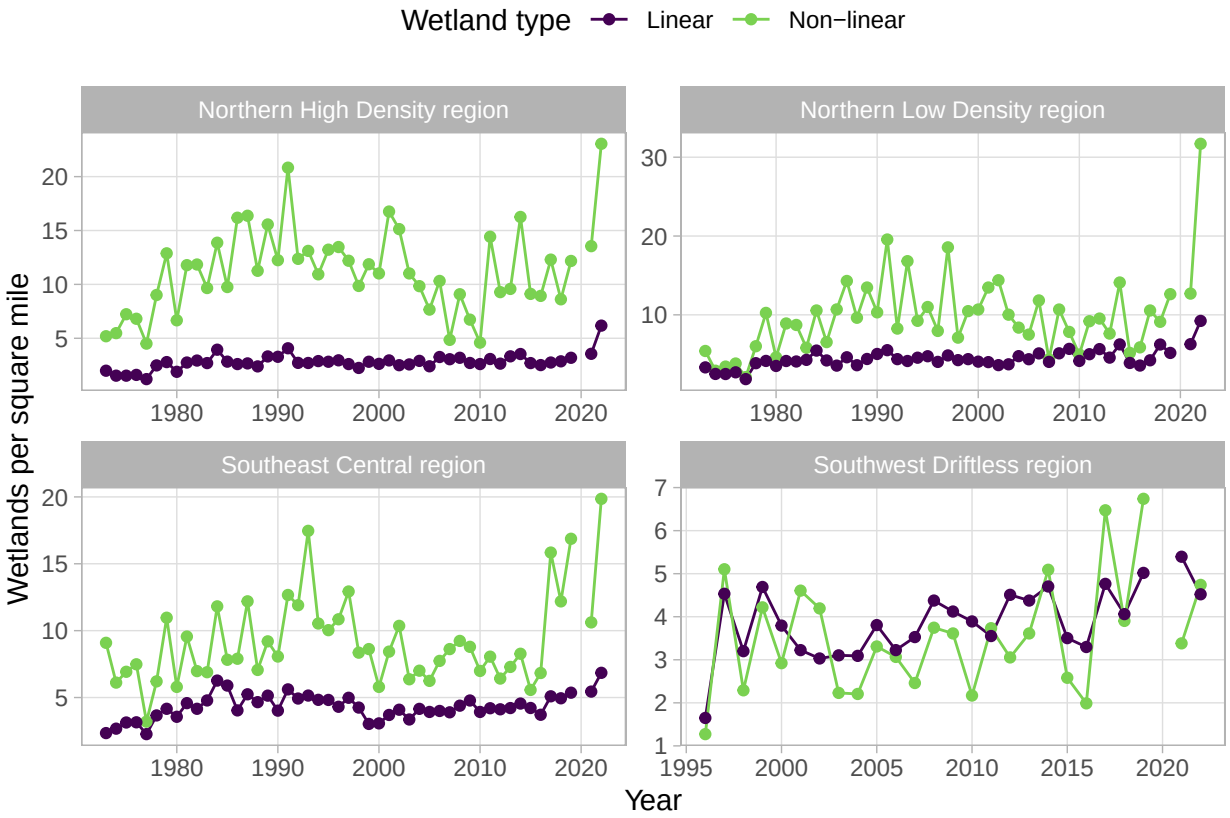

Figure 2: Annual variability in total linear and non-linear wetlands per square mile by survey region. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

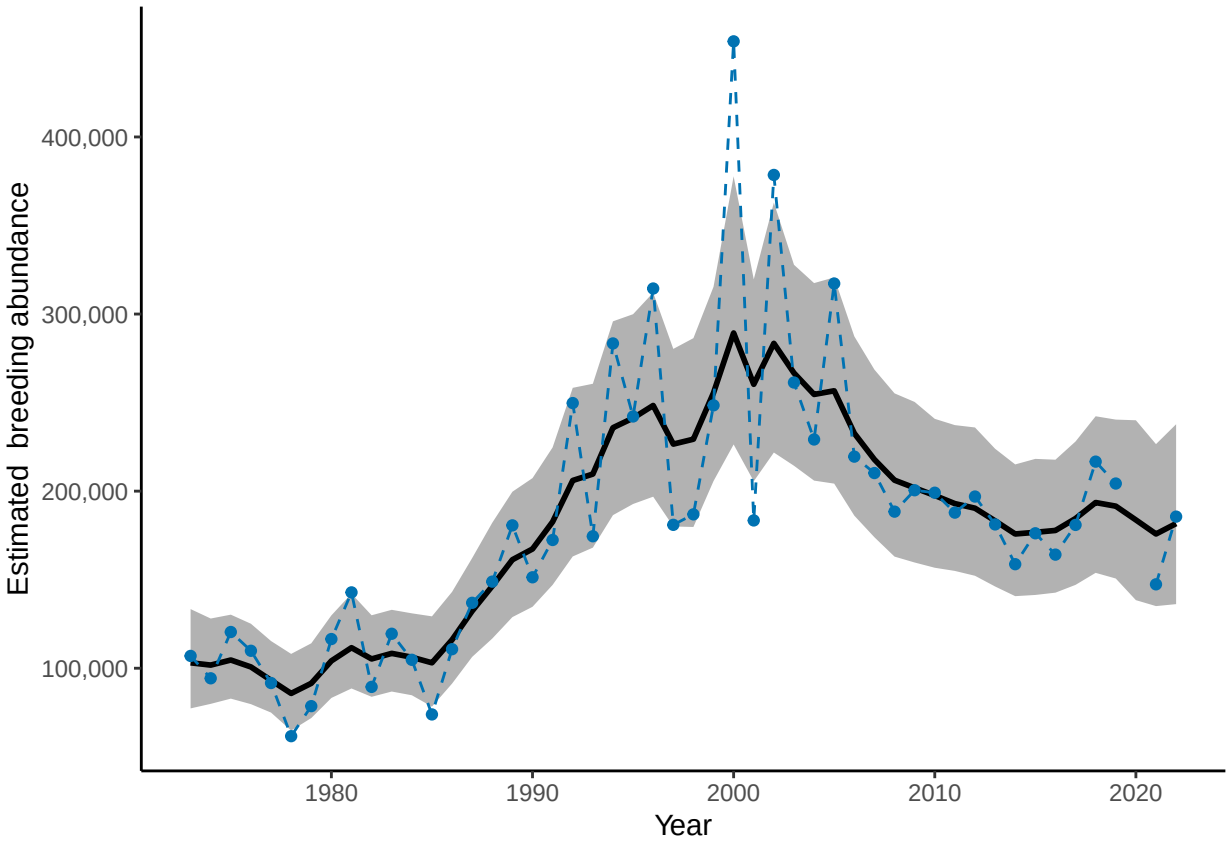

Figure 3: Annual statewide estimates of breeding mallard population size in Wisconsin, 1973–2022. Black line and gray shaded region are the mean and 95% credible interval estimates for the state-space population trend, and blue points and dashed line show the annual survey counts. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

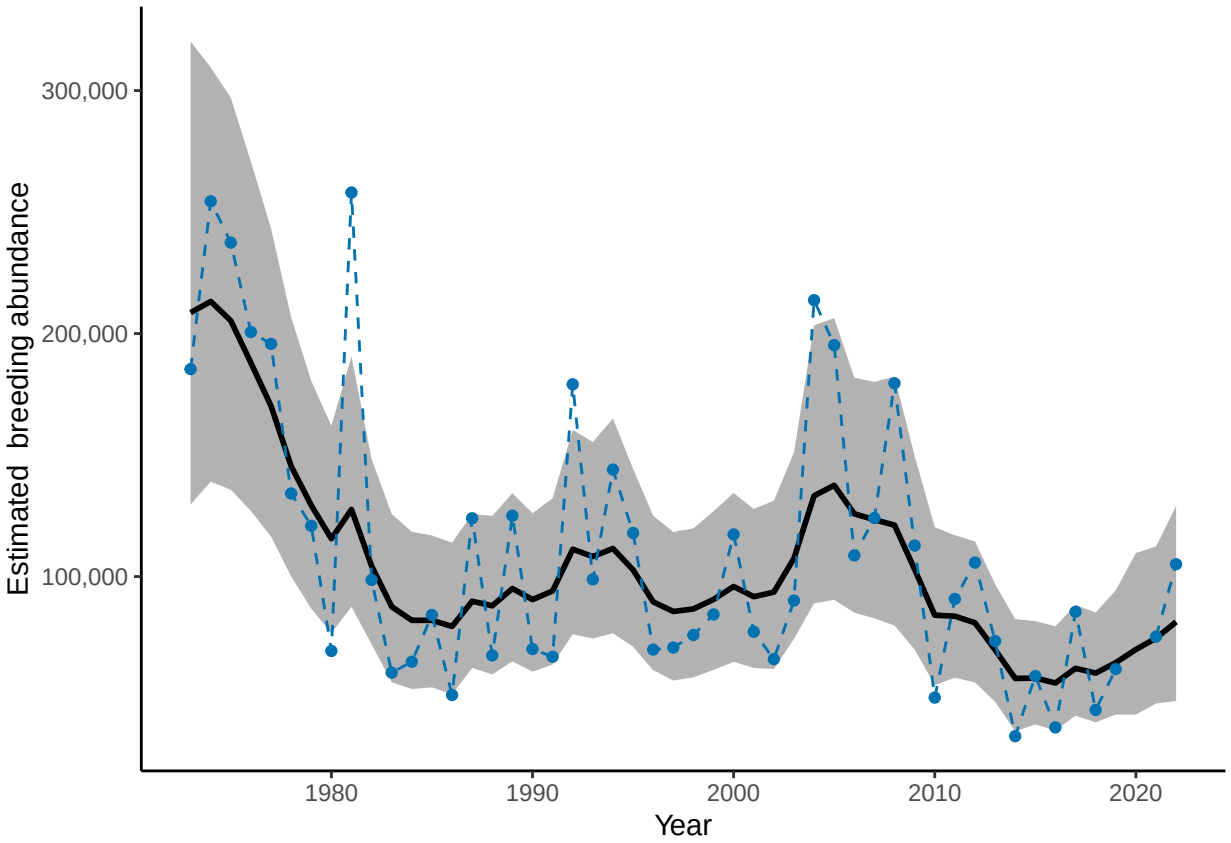

Figure 4: Annual statewide estimates of breeding blue-winged teal abundance in Wisconsin, 1973–2022. Black line and gray shaded region are the mean and 95% credible interval estimates for the state-space population trend, and blue points and dashed line show the annual survey counts. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

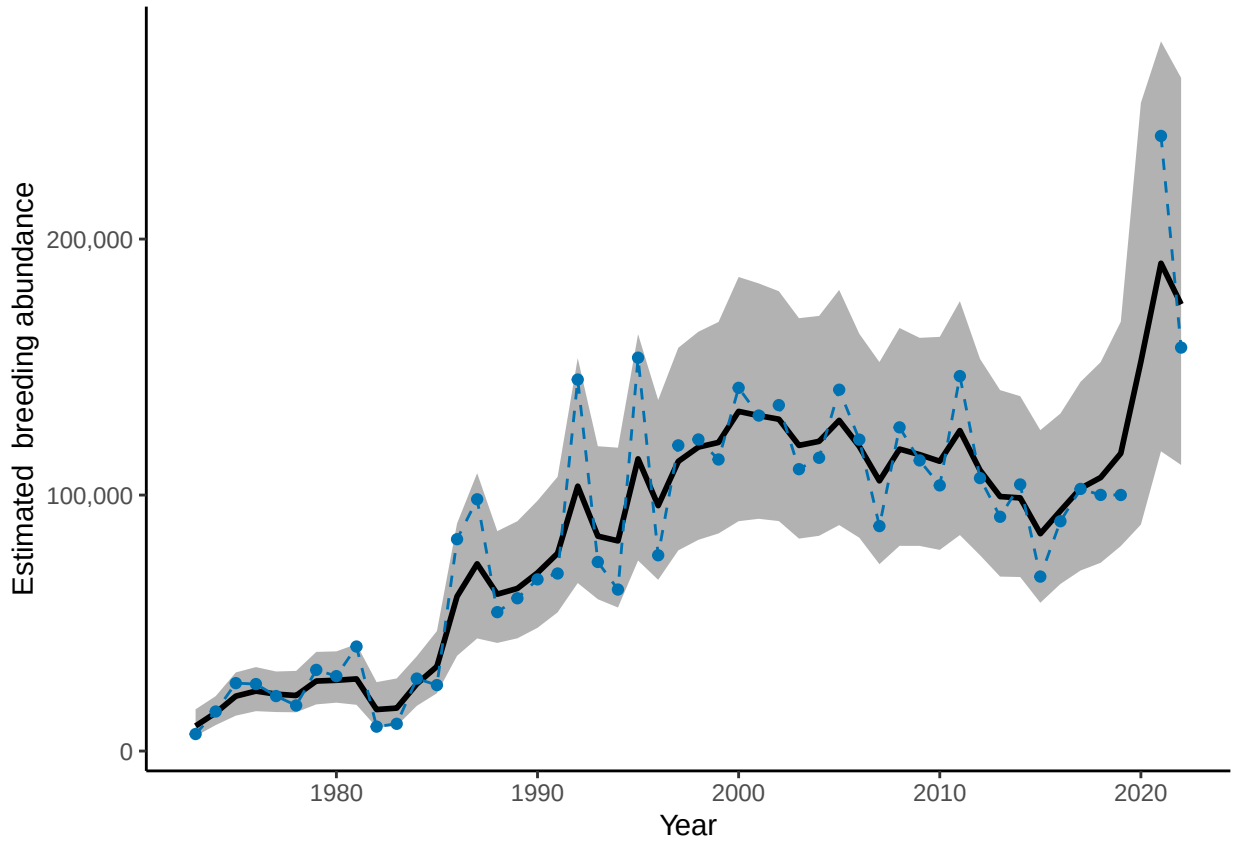

Figure 5: Annual statewide estimates of breeding wood duck abundance in Wisconsin, 1973–2022. Black line and gray shaded region are the mean and 95% credible interval estimates for the state-space population trend, and blue points and dashed line show the annual survey counts. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

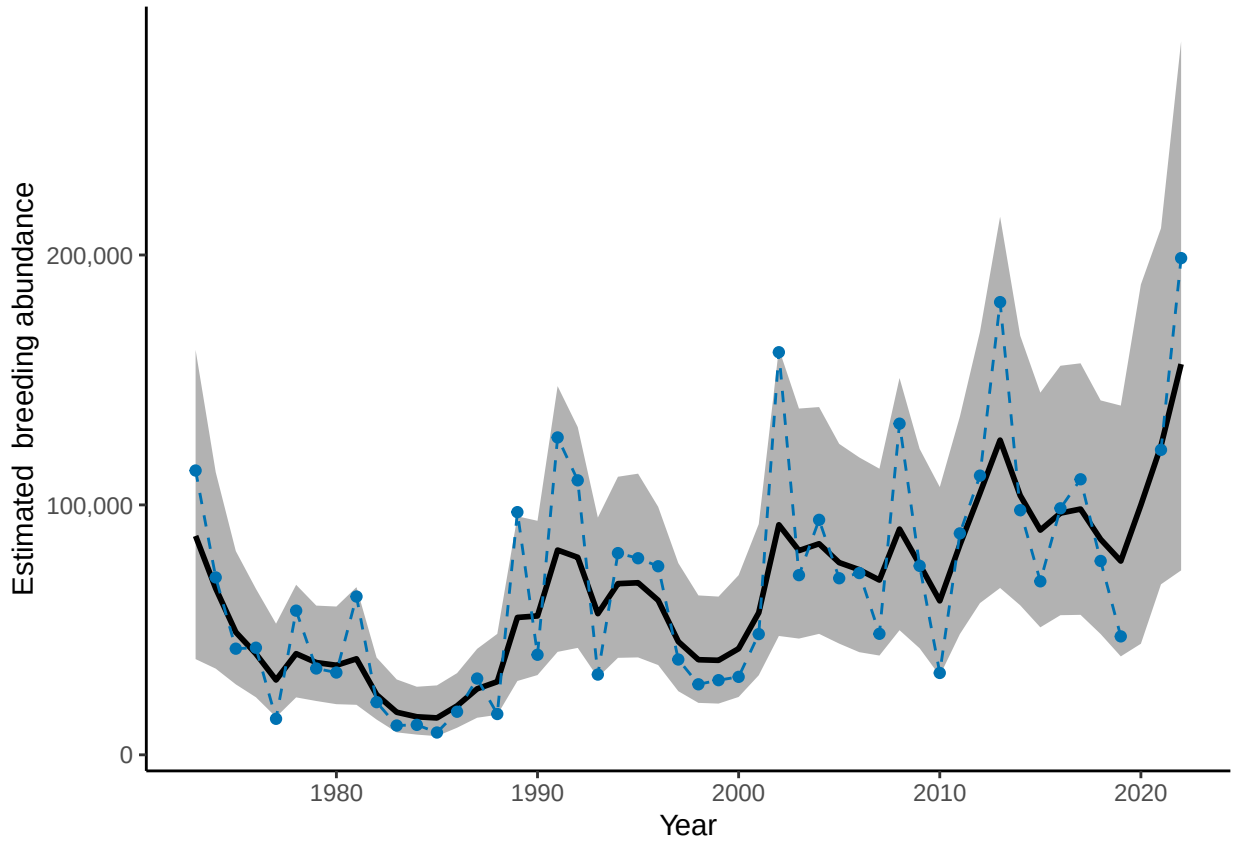

Figure 6: Annual statewide estimates of breeding 'other duck' abundance in Wisconsin, 1973–2022. Black line and gray shaded region are the mean and 95% credible interval estimates for the state-space population trend, and blue points and dashed line show the annual survey counts. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

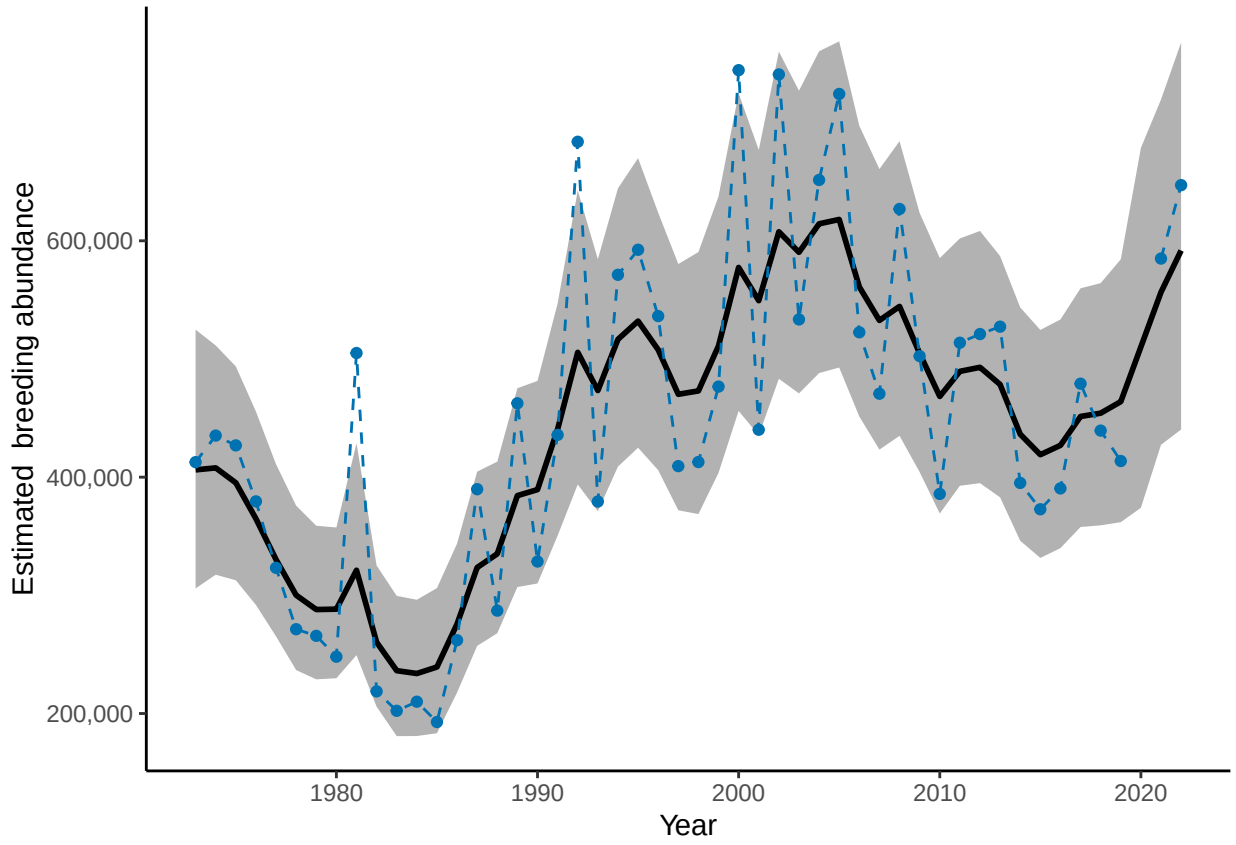

Figure 7: Annual statewide estimates of total breeding duck abundance in Wisconsin, 1973–2022. Black line and gray shaded region are the mean and 95% credible interval estimates for the state-space population trend, and blue points and dashed line show the annual survey counts. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

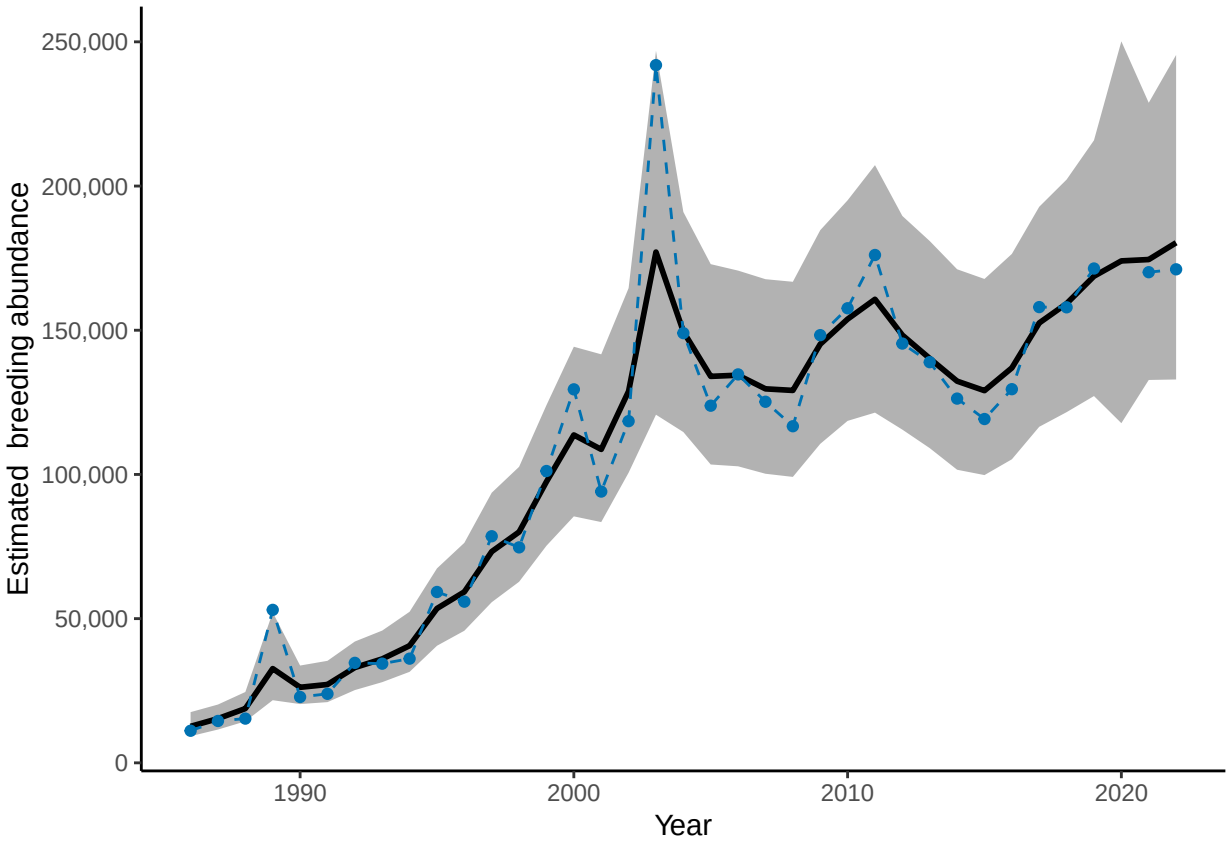

Figure 8: Annual statewide estimates of breeding Canada goose abundance in Wisconsin, 1986–2022. Black line and gray shaded region are the mean and 95% credible interval estimates for the state-space population trend, and blue points and dashed line show the annual survey counts. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

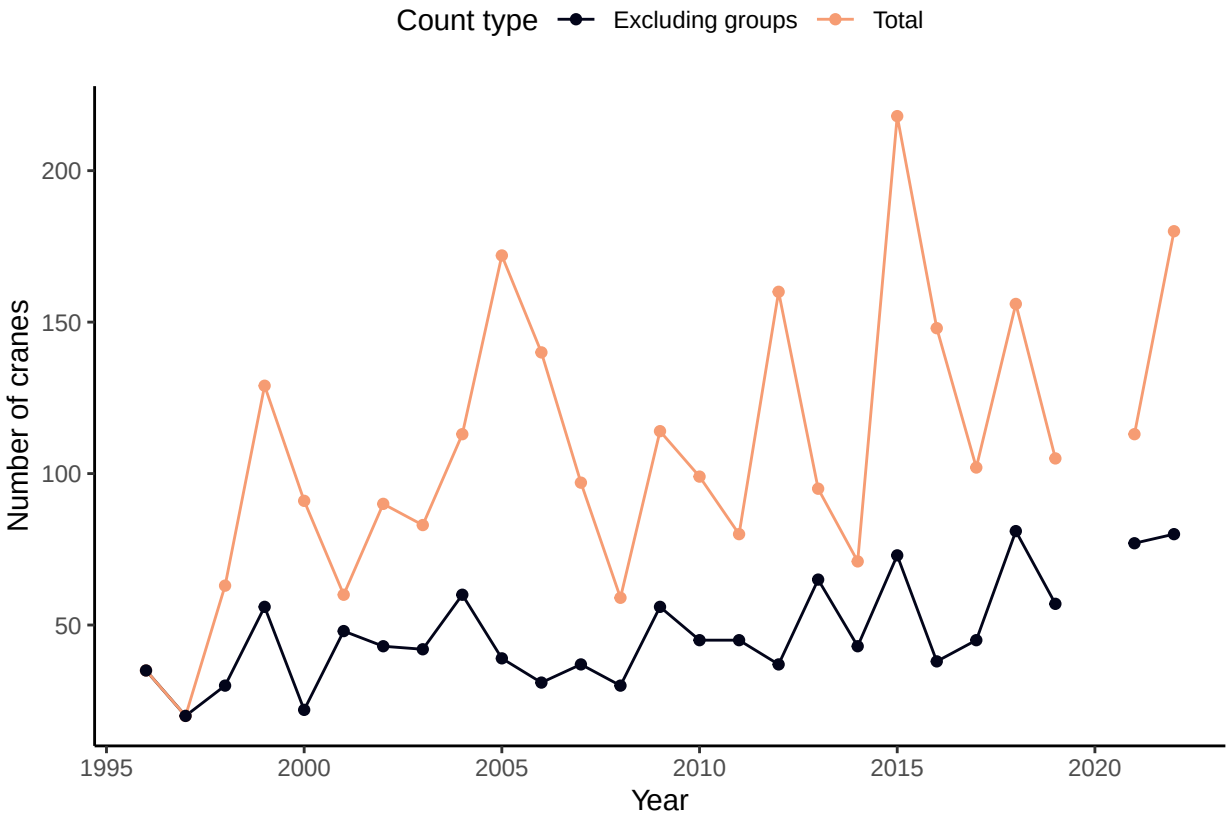

Figure 9: Annual counts of sandhill cranes (raw estimates) observed from the air during the Waterfowl Breeding Population Survey, 1996–2022. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.

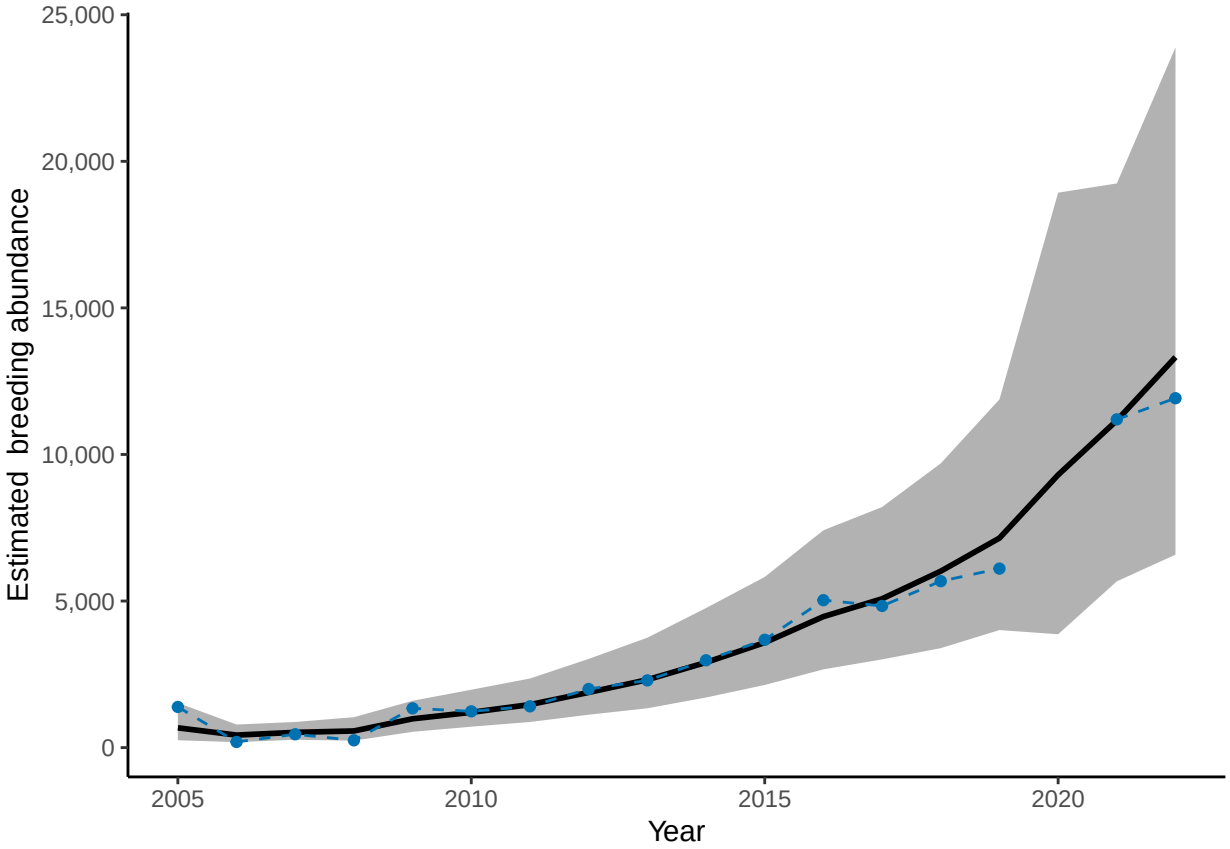

Figure 10: Annual statewide estimates of trumpeter swan abundance in Wisconsin, 2005–2022. Black line and gray shaded region are the mean and 95% credible interval estimates for the state-space population trend, and blue points and dashed line show the annual survey counts. Note that surveys were not conducted in 2020 due to the COVID-19 pandemic.