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National Wildlife Refuge System



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Midwinter Aerial Waterfowl Surveys on National Wildlife Refuges in the Southeast, 2025

Version 1.1 (PUBLIC RELEASE)



Cover Photograph: Ducks, Geese, and American coots at Bald Knob National Wildlife Refuge in January 2025 during an aerial survey flight. Credit. J. Marty.

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Overview

National Wildlife Refuges (NWR) in the Southeast (Region 4) have objectives to provide habitat resources for approximately 6.5 million waterfowl during the non-breeding season (Hagy et al. 2022b). Although many NWRs in the Southeast conduct some form of waterfowl monitoring (e.g., abundance, habitat, harvest, etc.), there has traditionally been no standard protocol or regionally coordinated effort to ensure statistically robust surveys for waterfowl to address local and regional information needs. For example, nearly three quarters of NWRs in the Lower Mississippi Valley ecoregion have an emphasis on waterfowl management and most conduct some form of waterfowl monitoring; however, there is currently limited survey coordination, use of written protocols, data sharing among NWRs, or analysis and reporting which drives future management decisions (Richardson et al 2014). Coordinated monitoring following best practices would enhance strategic resource allocation, facilitate adaptive resource management, and significantly increase the scientific basis of waterfowl management activities as required by Fish and Wildlife Service (FWS or Service) policy (Hagy et al. 2021).

Waterfowl abundances are used by the NWR system for public outreach, to assess performance relative to NWR purposes and objectives, and to assess the outcomes of management practices. Moreover, recent planning efforts within the NWR System have incentivized accurate estimates of total waterfowl population size and created a need for improved and coordinated waterfowl surveys among NWRs (Hagy et al. 2021, 2022a). The lack of a coordinated survey with a robust design and clear objectives limits usefulness of existing data and underscores the importance of implementing a coordinated waterfowl survey to address current information needs. Erosion of the existing Midwinter Waterfowl Survey due to criticisms on the lack of experimental design



Figure 1. Mallards, Northern Pintail, and American Wigeon in forested and emergent wetlands at Wapanocca National Wildlife Refuge in January 2025. Credit J. Marty.

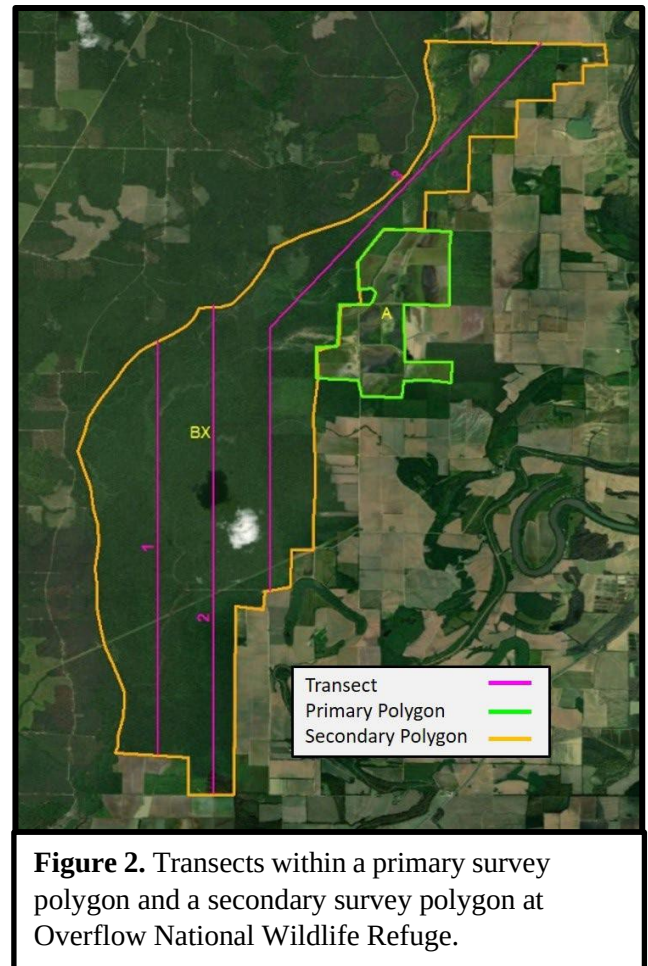
and implementation challenges provided an opportunity to test a model for replacement that combines sound experimental design with cost efficiency (Heusmann 1999, Sharp et al. 2002). Several southeastern state agencies (e.g., Mississippi Department of Wildlife, Fisheries, and Parks [MDWFP 2025]; Arkansas Game and Fish Commission [AGFC 2025], Louisiana Department of Wildlife and Fisheries [LDWF 2025]) have implemented large-scale probability-based waterfowl surveys (e.g., transect based), but inclusion of NWRs is sporadic and landscape-scale designs are inappropriate for estimating abundances on smaller, discrete areas, such as NWRs.

Several methods have been recommended to address science and administrative needs for waterfowl monitoring data using cost-efficient approaches and incorporating citizen science (Soulliere et al. 2013). Although ground surveys are currently common and can be a useful method for estimating waterfowl density and abundance on small, individual units, many NWRs have areas that are difficult to access and cannot overcome logistical difficulties posed by ground surveys to estimate total abundance. Additionally, use of ground counts through the Integrated Waterbird Monitoring and Management (IWMM) protocol are insufficient or impractical to generate unbiased estimates of total waterfowl abundance at most NWRs due to logistical challenges associated with the remote nature of many locations used by waterfowl within NWRs (Fig. 1; Rice and Hagy 2020). Alternatively, aerial surveys are logistically efficient, cost-effective, and scientifically valid for estimating waterfowl abundance on NWRs (Gilbert et al. 2021). For example, using a single point-in-time survey (i.e., midwinter waterfowl survey) and available migration curves (e.g., eBird, IWMM) to generate annual use days is an extremely cost-efficient and valuable technique for NWRs (Hagy 2020).

The goal of this project was to demonstrate the coordination of survey efforts across multiple NWRs supporting migrating and wintering waterfowl to address local and regional data needs and help quantify the conservation footprint of the NWR System for waterfowl in the Southeast. Specifically, our objective was to estimate waterfowl abundance by species on individual units of NWRs in the Southeast across many habitat resource types (e.g., emergent wetland, open water, forested, harvested agriculture, standing agriculture, mixed). Waterfowl population estimates are used by local and regional NWR staff to help allocate resources among NWRs, for public outreach, to assess performance relative to NWR purposes and objectives, and for essential administrative planning purposes.

Methods

Aerial Surveys



We estimated waterfowl abundance on 55 NWRs in Alabama, Arkansas, Florida, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee, during 1–30 January 2025. Surveys were conducted using a Cessna 182 (Pilots – J. Rayfield, G. Wilkerson; Observers – J. Marty, K. Schroyer, and N. Wirwa) in Alabama, Arkansas, Mississippi, and Tennessee; Quest Kodiak 100s (Pilots – J. Wortham, G. Wilkerson, S. Yates, S. Barlow; Observers - B. Fortier, C. Bleke, J. Marty, K. Schroyer, B. Van Druten) in Arkansas, Florida, Louisiana, North Carolina, and South Carolina. Wetlands and other areas (e.g., harvested agricultural fields) that were potentially occupied by waterfowl on NWR units were designated as primary (i.e., high density strata) or secondary (i.e., unknown or low-density strata) survey units based on size, logistical considerations, anticipated continuousness of waterfowl distribution, and anticipated abundance (Howard et al. 2024).

Primary survey units were generally small and discrete areas within sanctuaries where large groups of waterfowl congregated at high densities (e.g., groups of impoundments, agricultural fields with standing crops, small lakes and ponds, etc.; Fig. 2). For specific sites of interest and small areas where distribution of ducks is non-random (e.g., NWRs), transects and other randomized designs are typically inefficient, often inappropriate, and costly. However, census-style surveys used to conduct complete surveys of specific locations can be used to cost-effectively and accurately estimate waterfowl abundance in those areas (Gilbert et al. 2021). Within each primary survey unit, observers conducted a complete count using a census-style method to visually estimate total population size and species composition (Stafford et al. 2007, 2010).

Secondary survey strata units were typically large areas with unknown or low-density distribution of waterfowl (e.g., large lakes, bays, floodplain forests, rivers, etc.; Fig. 2). Within each secondary survey unit, observers counted waterfowl along transects that spanned each unit. Transects were spaced a minimum of 500 meters apart to maximize survey unit coverage and constrained so that observation areas did not overlap. Transects were randomly assigned to a location with respect to prior knowledge of waterfowl distribution and flooding conditions at the time of the survey. A transect location was assigned within 500–1000 meters of one side of a survey unit and



Figure 3. Observations of waterfowl or other waterbirds along transects at Pea Island and Lacassine NWRs.

subsequent transects were allocated at approximate equal intervals (randomly 500–1500 meters) throughout the rest of the survey unit. Transect locations were chosen to provide representative coverage across any known elevation gradients or habitat conditions within a systematic-random framework.

Observers recorded the number of waterfowl present by species or lowest practical taxon (i.e., dabbling ducks, diving ducks, geese) in each habitat resource type as possible (Fig. 3). Observations were recorded using a proprietary voice recording system developed for the Service and subsequently transcribed using program Scribe. We included unknown species in our estimate of dabbling ducks for summary purposes, as most encounters belonged to this guild. All surveys were conducted at approximately 200 feet (range 150–250 feet) above ground level (AGL) to minimize disturbance, minimize risk to aircrews, and allow suitable species identification. Observations were recorded within a 200-meter survey viewing area (approximately 30–230-meter lateral) from the aircraft in open cover types (e.g., open water, emergent vegetation, mudflats) and restricted to 100 meters in forested cover types based on best professional judgement. Some transects included only data from the primary observer seated in the front passenger seat of the aircraft, while some transects had a secondary observer available and provided concurrent data from the pilot-side, rear seat of the aircraft. All observers had experience conducting aerial bird surveys and practiced using USFWS flock size estimation training software (USFWS 2020).

Analysis

We estimated abundance within both primary and secondary survey units using a two-step visibility bias correction process to account for detection probability and count bias (Pearse et al. 2008). Visibility bias is the difference between the number of individual present in a survey area and the number of individuals counted in the same survey area. Detection probability is the probability that an observer will detect an individual or group of individuals given they are present in the survey area (Pearse et al. 2008b). Inaccurate counts or count bias arise from incorrectly estimating the number of individuals present or incorrectly identifying individuals to species given at least one individual is present and detected (Pearse et al. 2008b).

First, counts were multiplied by the reciprocal of a visibility estimate from the aircraft assigned by the primary observer (10–100%) to account for approximate detection probability (Pearse et al. 2008b; Fig. 4). These visual estimates represented the proportion of the transect or polygon survey area (i.e., water surface) that was viewable and not obstructed by canopy coverage, emergent vegetation, or other obstructions. Gilbert et al. (2021) determined that detection probability approximated 1.0 for census-style surveys of primarily open-water areas in the Illinois River Valley during autumn migration. Pearse et al. (2008b) found that detection probability varied by waterfowl group size and habitat resource type along transects conducted in the lower Mississippi Alluvial Valley. However, they determined that detection probability approached 1.0 when group size exceed 30 individuals in open cover types, which was almost always the case in primary polygons. Although Pearse et al. (2008b) showed that detection

probability was more dramatically affected by group size in forested wetlands, their surveys were conducted from ~500 feet AGL and those results likely differ from our surveys conducted from ~200 feet AGL due to increased detection probability at the lower altitude. Thus, we used a hybrid approach based on perceived visibility of the primary observer that resulted in correction within the range found by Pearse et al. (2008*a,b*). This approach assumes that if visibility (i.e., lack of physical obstructions) was not obstructed by emergent vegetation or tree canopy (visibility = 100%) then detection probability approximated 1.0 following Gilbert et al. (2021).

Secondly, detection-corrected estimates were adjusted for count bias using published correction factors (Table 1). Survey methodology and logistical issues did not allow visibility bias to be estimated using double observer or distance methods during the survey itself. If available, we used species-specific correction factors. If these produced unreasonable results or were unavailable, we substituted guild-specific correction factors from Gilbert et al. (2021), assuming that would be the conservative approach.

We estimated waterfowl abundance for secondary survey units by summing visibility-corrected estimates by transect, converting these abundances to densities using the survey area for each transect (Table 2), and extrapolating density estimates for each transect to the total area of the secondary polygon. We then weighted total abundance estimates for each secondary polygon by transect length by multiplying the transect length by the total waterfowl abundance, summing these products within each secondary survey unit, and dividing the total by the number of transects. Weighting estimates by transect length ensured that short transects did not have the same effect on estimates as longer transects that covered more area of the polygon. Prior to weighting, transect area surveyed was adjusted using visual estimates of proportional flooding.

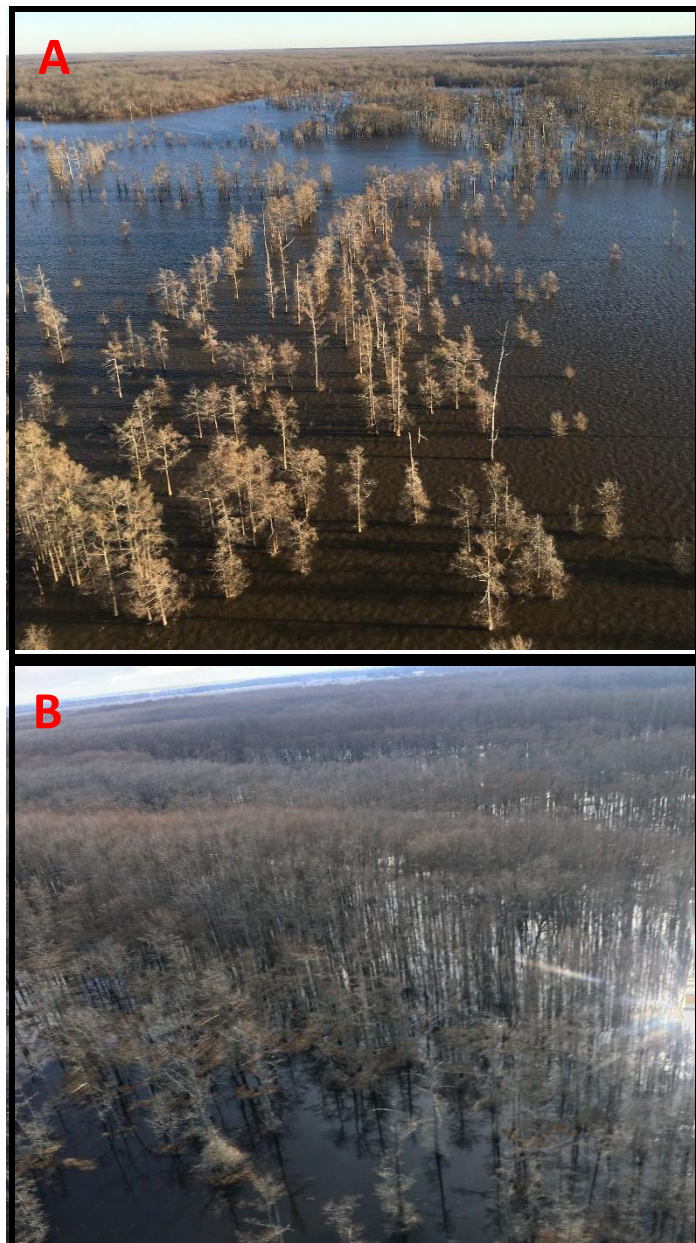


Figure 4. Forested wetlands at Matthews Brake (A; ~80% visibility) and Big Lake (B; ~50% visibility) National Wildlife Refuges during January 2020.

We estimated total use days from aerial surveys using migration curves from Hagy et al. (2022b) following the rationale of Soulliere et al. (2013). Hagy et al. (2022b) used eBird to build migration curves for all NWRs in the Southeast and then refined those curves using local NWR data and best professional opinion from local NWR staff. These “standard” curves represented average proportional abundance relative to peak migration of waterfowl by guild through the NWR. We adjusted abundance estimates by multiplying the reciprocal of the proportion of abundance relative to the peak from each curve anchored on 15 January, which was the approximate mid-point of the surveys (see Fig. 4 in Soulliere et al. 2013). For example, if a migration curve showed that the typical peak abundance at a NWR occurred in November and abundance was 70% of the peak in mid-January, the estimate was adjusted proportionally upward to account for this difference.

Variances were not calculated for primary or secondary polygon estimates because of the complexity of doing so at this time. Several sources of uncertainty existed at different steps in the estimation process, and variances were available for some of the model parameters but not all. More explicitly, both visibility bias components (i.e., detection probability and count bias) have associated variances, although the variance associated with detection probability used in our model was unknown and practically inestimable. Additionally, secondary polygons had a sufficient number of transects to estimate variances around estimates, but the transect weighting process would have affected how variances were applied to overall estimates, which was not a straightforward process. Similarly, use-day estimates resulting from the migration curve would also have required estimates of variance from multiple sources, including the migration curves themselves. Thus, estimating variances around final estimates would have required a complex simulation process that we have not completed at this time. In the future, we hope to include variance estimates, as they would be valuable to help refine the study design (e.g., optimal transect allocation).

Results

General

We used USFWS Migratory Bird Survey Branch (MBSB) aircraft to survey 2–8 NWR/day around the typical Midwinter Waterfowl Survey period in early January. Seven observers participated in the surveys on NWR units (*n*), including J. Marty (25), K. Schroyer (26), B. Van Druten (8), C. Bleke (11), B. Fortier (11), N. Wirwa (1). The proportion of raw observations included in the final estimates varied across observers (%) on NWR units, including J. Marty/K. Schroyer (54), B. Van Druten (27), C. Bleke (8), B. Fortier (8), N. Wirwa (3).

Survey polygons and transects were primarily categorized as mixed (42%), followed by perennial emergent (26%), forested wetlands (14%), open water (9%), seasonal emergent (7%), and other cover types (2%). Observer-estimated visibility for detection probability was least in forested cover types (53%), followed by mixed (79%), open emergent (93%), perennial emergent (93%), seasonal emergent (95%), unharvested crop (98%), open water (99%), harvested crop (100%) cover types. Proportional flooding was least in forested (46%) and mixed (53%) units, followed by unharvested crop fields (61%), open emergent (76%), perennial emergent (80%), seasonal emergent (81%), harvested crop (95%), and open water (98%) cover types.

Surveys included 261 polygons, with 175 primary and 86 secondary units. Primary polygons (census-style surveys) accounted for 47% of estimated waterfowl abundance and secondary polygons (transect-style surveys) accounted for 53% of waterfowl abundance estimates. However, this balance varied among taxa with secondary polygons accounting for 56% of dabbling duck, 67% of diving duck, 12% of geese, 86% of swan, and 11% of crane estimates.

Observers counted 2,260,106 waterfowl, including, 1,302,200 dabbling ducks, 615,647 diving ducks, 302,699 geese, 27,423 swans, 12,137 cranes. Observers also counted 75,755 American coot (*Fulica americana*) and 278 bald eagles (*Haliaeetus leucocephalus*).

Abundance

Approximately 2.3 million waterfowl were estimated on NWRs surveyed following visibility-bias correction and extrapolation (Table 3). Dabbling ducks (58%) comprised the majority of estimates, followed by diving ducks (27%), geese (13%), swans (1%), and cranes (1%). Mallards (34%), pintail (21%), teal (combined green-winged teal [*Anas carolinensis*] and blue-winged teal [*Spatula discors*]; 19%), gadwall (*Mareca strepera* [14%]), and American wigeon (*Mareca americana* [4%]), comprised most dabbling ducks.

Ring-necked ducks (*Aythya collaris*; 50%), redhead (*Aythya americana*; 19%), scaup (combined lesser scaup [*Aythya affinis*] and greater scaup [*A. marila*]; 16%), bufflehead (*Bucephala albeola*; 11%) and canvasback (*Aythya valisineria*; 2%) comprised the majority of diving ducks. Light geese (combined lesser snow [*Anser caerulescens*], greater snow [*A. caerulescens*], and Ross's geese [*A. rossii*]; 71%) and greater white-fronted geese (*Anser albifrons*; 24%) comprised the majority of geese. The greatest waterfowl estimates were from Bald Knob (457,520), Mattamuskeet (448,886), Delta (156,817), Lacassine (113,118), Panther Swamp (90,536), and Breton (79,392) NWRs. Collectively, abundance estimates on NWRs surveyed in 2025 were 34% below total waterfowl, 69% below dabbling duck, 28% below diving duck, 54% below goose, 45% below swan, and 84% below crane population objectives¹. Eight NWRs met or exceeded their NWR abundance objectives, including Breton, St. Marks, Pea Island, Delta, Bald Knob, Cameron Prairie, Mattamuskeet, and Merritt Island NWRs.

Peak abundance estimated from migration curves ranged from 0 to 1,220,962 waterfowl across all surveyed NWRs, with an average peak abundance of 68,184 waterfowl / NWR (Table 4). The migration curve model increased peak abundance by an average of 7% for dabbling ducks, 13% of diving ducks, 72% for geese, 4% for cranes, and 57% for swans across NWRs.

Comparison with State Surveys

The Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP 2025); Arkansas Game and Fish Commission (AGFC 2025); and Louisiana Department of Wildlife and Fisheries (LDWF 2025) conduct probability-based aerial waterfowl surveys in portions of Arkansas, Louisiana, and Mississippi during the traditional midwinter survey period. Estimates of total duck abundance on NWRs averaged 26.9% (range = 14–52%) of regional abundance in four survey regions (Fig. 9). Collectively, partners estimated 3.8 million ducks and geese in these regions during early January, with approximately 1 million occurring on NWRs during and following this survey period.

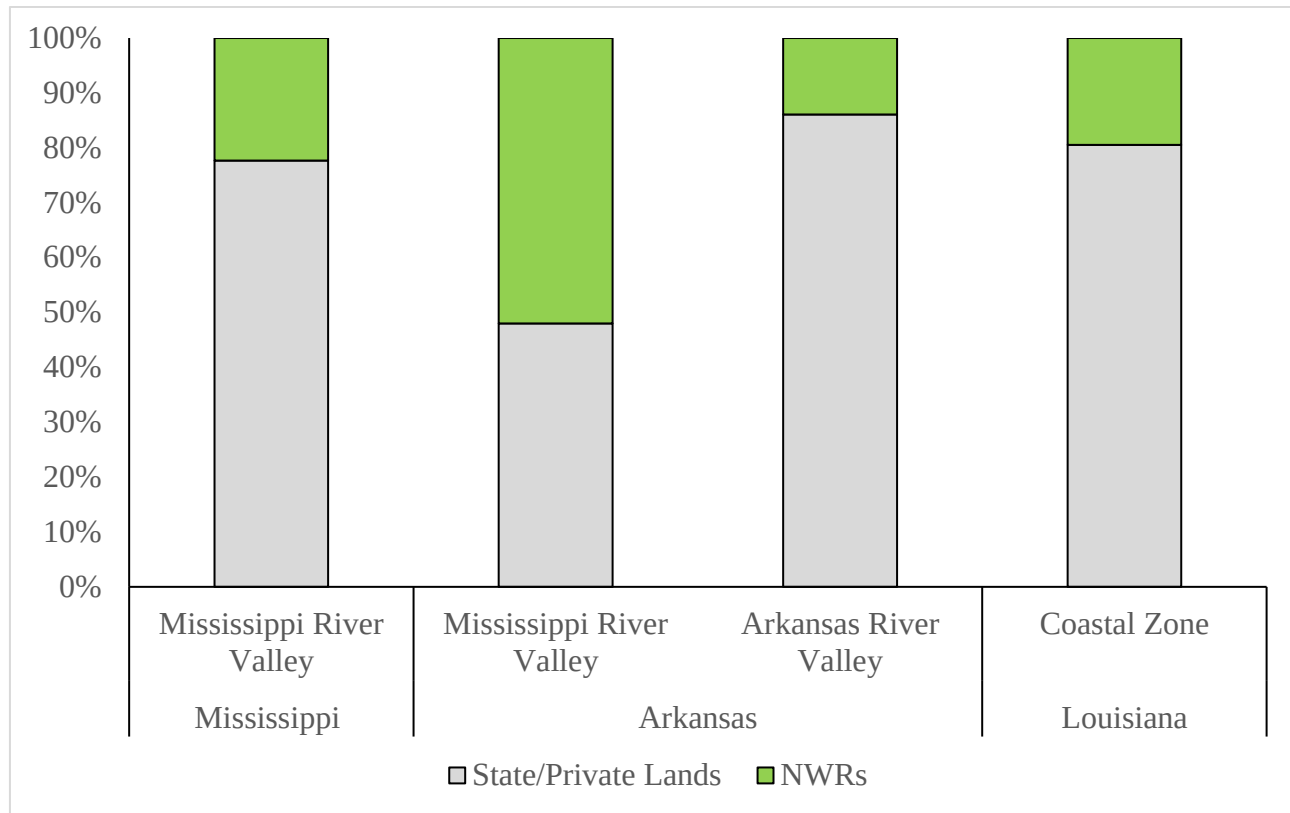


Figure 9. Proportion of total ducks observed on NWRs relative to those observed on state and private lands through state-coordinated aerial waterfowl surveys in regions of Arkansas, Louisiana, and Mississippi during early January 2025.

Use Days

Total estimated use days from aerial surveys across all NWRs were greatest for dabbling ducks (98.4 million), followed by geese (48.8 million), diving ducks (46.4 million), swans (3.4 million), and cranes (642,000; Table 5). Across taxa, predicted use equated to approximately 198 million waterfowl energy days. Waterfowl energy days are a generic unit of energy based on 300 kcal/day energy requirements, which is similar to the energetic needs of a mallard during winter. Collectively, use-day estimates on NWR surveyed in 2025 were 61% below total waterfowl, 237% below dabbling duck, 78% below diving duck, 49% above goose, 54% above swan, and 92% below crane energy objectives (Hagy et al. 2022).

Raw data, unit-level data, and spatial data can be found here:

<https://iris.fws.gov/APPS/ServCat/DownloadFile/272611>

Discussion

Aerial surveys were an efficient and effective survey method for estimating total waterfowl abundance on NWRs in the Southeast. These NWR-scale estimates are important for NWRs to communicate their importance to the public, assess their performance relative to objectives within an adaptive resource management framework, quantify contributions to the North American Waterfowl Management Plan, and advance waterfowl science and management (Hagy et al. 2021, 2022). Total waterfowl abundance across the region was 15% lower in 2025 than in 2024 (Hagy et al. 2024). In 2023-2024 much of North America was affected by droughts. Drought conditions throughout the summer and fall undoubtedly influenced food abundance and habitat availability. Waterfowl may have migrated earlier and/or further in 2024 than in 2025.

Surveys conducted during the first two weeks of January 2025 coincided with several strong cold fronts that froze lakes and ponds in the northern and central portions of the country. Dabbling ducks in the northern latitudes, may not have felt the same effects from the cold fronts as diving ducks, because they are able access a larger variety of food resources that may not have been made inaccessible by the freeze, or been covered with snow. Diving ducks likely migrated to the more southerly latitudes on the Atlantic and Gulf Coasts to find open water and access to food resources. For example, Mattamuskeet, Merritt, Breton, and Pea Island NWRs, all coastal refuges, contained >50,000 diving ducks during their respective survey periods.

Also, of note in 2025, the proportion of ducks counted on NWRs relative to partner-based counts in the Mississippi River Valley, Arkansas River Valley, and Louisiana Gulf Coast were down substantially from 2024 (Hagy et al. 2024). This was likely due to wetter conditions and a greater abundance water on the landscape from natural flooding and flooding of private impoundments during the survey period in 2025.

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Table 1. Correction factors (CF) used to account for count bias in aerial waterfowl surveys.

Taxon	CF	Source
Dabbling ducks	1.08	Gilbert et al. (2020)
Diving ducks	1.18	Gilbert et al. (2020)
Geese	1.09	Gilbert et al. (2020)
Swans	1.05	Gilbert et al. (2020)
Ducks	1.12	Gilbert et al. (2020)
Other waterbirds	1.20	Gilbert et al. (2020)
Mallard	1.42	Gilbert et al. (2020)
Gadwall	1.08	general dabbling duck from Gilbert et al. (2020)
Northern shoveler	1.08	general dabbling duck from Gilbert et al. (2020)
Teal (GWTE & BWTE)	1.08	general dabbling duck from Gilbert et al. (2020)
Northern pintail	1.08	general dabbling duck from Gilbert et al. (2020)
American wigeon	3.90	Gilbert et al. (2020)
American black duck	1.08	general dabbling duck from Gilbert et al. (2020)
Wood duck	1.48	general dabbling duck from Gilbert et al. (2020)
Mottled duck	1.08	general dabbling duck from Gilbert et al. (2020)
Ring-necked duck	1.08	general dabbling duck from Gilbert et al. (2020)
Scaup (LESC & GRSC)	2.83	Gilbert et al. (2020)
Canvasback	1.45	Gilbert et al. (2020)
Bufflehead	2.55	Gilbert et al. (2020)
Common goldeneye	1.38	Gilbert et al. (2020)
Ruddy duck	1.18	general diving duck from Gilbert et al. (2020)
Redhead	2.13	Gilbert et al. (2020)
Hooded merganser	1.49	Gilbert et al. (2020)
Merganser (COME & RBME)	1.49	hooded merganser from Gilbert et al. (2020)
Scoter (WWSC, SUSC, & BLSC)	1.18	general diving duck from Gilbert et al. (2020)
Snow goose (LSGO, GRSG, ROGO)	1.61	>8000 SNGO estimate from Boyd (2000)
Greater white-fronted goose	2.0	Hines et al. (2003) & Gilbert et al. (2020)
Canada goose	1.07	Gilbert et al. (2020)
Swan (TUSW, TRSW, MUSW)	1.05	Gilbert et al. (2020)
American coot	1.63	Gilbert et al. (2020)
Sandhill crane	1.07	Gilbert et al. (2020)
Whooping crane	1.07	Gilbert et al. (2020)
Bald eagle	1	No correction factor known

Table 2. Habitat resource type and transect width used during aerial waterfowl surveys.

Habitat Resource Type	Code	Explanation	Transect width (m)
Mix	MX	Mix of habitat resource types in close proximity so assigning birds to only 1 is impractical.	200
Open Water	OW	Large areas of generally deep, open water such as lakes, ponds, reservoirs, bay, lagoons, impounded river pools, etc. <30% emergent or floating leaf vegetation. Mudflats are included in OW.	200
Seasonal Emergent	SE	Managed moist-soil with primarily annual plants low-growing near water surface. Millet, buckwheat, and other small grain crops may fall in this category; includes Unharvested rice and other shorted emergent plants	200
Forested/scrub-shrub	FO	Forested and scrub-shrub wetlands with >30% woody vegetation	100
Perennial Emergent Marsh	PE	>30% emergent vegetation cover that is tall / persistent, such as <i>Typha</i> spp., <i>Phragmites</i> spp., <i>Spartina</i> spp., etc.	200
Open-Emergent	OE	Mixture of <30% emergent vegetation, floating-leaved vegetation, and open water; including aquatic bed	200
Harvested Cropland	HC	Harvested cropland with minimal emergent vegetation (<30%) that is >0.5 m	200
Unharvested Corn	UC	Unharvested corn / sorghum	100
Unharvested Other	UO	Unharvested other	200

Table 3. Abundance of waterfowl and cranes by guild and National Wildlife Refuge estimated during January 2025 through aerial surveys in the southeastern United States.

Complex/Area	NWR	Dabbling Ducks	Diving Ducks	Geese	Swans	Cranes	Total Waterfowl ^a	Total Waterbirds ^b
Alabama	Wheeler NWR	17,838	1,980	508	0	12,047	32,373	32,373
Central Arkansas	Bald Knob NWR	306,770	0	150,750	0	0	457,520	457,520
	Big Lake NWR	18,273	3,549	1,306	0	0	23,128	23,530
	Cache River NWR	64,701	32	1,514	0	0	66,247	66,264
	Holla Bend NWR	11,352	368	4,830	0	0	16,550	16,550
	Wapanocca NWR	13,044	2,160	10,561	0	0	25,765	30,166
	White River NWR	63,519	3,052	0	0	0	66,571	66,571
Central Louisiana	Catahoula NWR	885	16,571	0	0	0	17,455	17,455
	Grand Cote NWR	26,940	1,453	242	0	0	28,634	28,634
	Lake Ophelia NWR	10,969	1,202	0	0	0	12,170	12,170
Gulf Coast	Grand Bay NWR	15	1,196	0	0	0	1,211	1,211
	St. Marks NWR	286	22,435	0	0	0	22,721	22,721
North Louisiana	Black Bayou NWR	35	29	0	0	0	64	151
	D'Arbonne NWR	3,680	0	0	0	0	3,680	3,680
	Handy Brake NWR	353	54	0	0	0	407	407
	Red River NWR	1,889	263	3,015	0	2	5,169	5,169
	Tensas River NWR	3,074	55	0	0	0	3,129	3,129
	Upper Ouachita NWR	21,322	1,762	1,508	0	0	24,592	24,592
North Mississippi	Coldwater NWR	40,245	0	114	0	0	40,360	40,360
	Dahomey NWR	203	64	0	0	0	267	267
	Noxubee NWR	286	238	10	0	0	534	840
	Tallahatchie NWR	12,298	415	5	0	0	12,718	12,807
South Arkansas	Felsenthal NWR	709	104	0	0	0	813	813
	Overflow NWR	4,695	32	0	0	0	4,728	4,728
Bayou Sauvage Urban	Bayou Sauvage NWR	8,074	799	0	0	0	8,873	36,300
	Big Branch Marsh NWR	145	771	0	0	0	917	6,069
Southeast Louisiana	Breton NWR	0	79,392	0	0	0	79,392	79,392
	Delta NWR	95,615	42,209	18,993	0	0	156,817	181,967
	Mandalay NWR	5	0	0	0	0	5	1,130

Southwest Louisiana	Cameron Prairie NWR	37,467	5,266	9,172	0	0	51,905	55,048
	Lacassine NWR	56,671	47,500	8,948	0	0	113,118	117,136
	Sabine NWR	44,713	11,776	0	0	0	56,489	58,801
Theodore Roosevelt	Hillside NWR	0	0	0	0	0	0	0
	Holt Collier NWR	219	0	0	0	0	219	219
	Mathews Brake NWR	2,197	0	0	0	0	2,197	2,197
	Morgan Brake NWR	2,088	138	625	0	0	2,851	2,864
	Panther Swamp NWR	53,206	0	37,329	0	0	90,536	90,536
	St. Catherine Creek NWR	6,830	238	46	0	0	7,114	7,114
	Yazoo NWR	5,602	0	0	0	0	5,602	5,602
West Tennessee	Chickasaw NWR	9,942	82	4,220	0	0	14,244	14,244
	Hatchie NWR	10,554	2,074	755	0	0	13,382	13,382
	Lake Isom NWR	12,069	0	500	0	0	12,569	12,569
	Lower Hatchie NWR	32,218	0	30,565	0	0	62,783	62,783
	Reelfoot NWR	14,834	488	2,200	0	0	17,522	17,526
Eastern North Carolina	Mattamuskeet NWR	217,869	211,172	10,695	9,149	0	448,886	448,886
	Cedar Island NWR	265	0	0	0	0	265	265
	Pocosin Lakes NWR	13,972	7,184	3,796	17,411	0	42,362	42,362
	Swanquarter NWR	9,318	9,338	0	7	0	18,663	18,663
	Alligator River NWR	8,150	1,233	7	855	0	10,245	10,245
	Pea Island NWR	14,374	53,742	283	0	0	68,398	68,398
South Carolina	Ace Basin NWR	7,446	2,329	0	0	0	9,775	9,897
	Savannah NWR	605	1,569	0	0	0	2,174	2,174
	Santee NWR	1,105	1,777	202	0	88	3,172	3,172
	Cape Romain NWR	1,452	13,934	0	0	0	15,386	15,386
Florida	Merritt Island NWR	11,816	65,626	0	0	0	77,442	79,427

^aTotal Waterfowl Abundance includes dabbling ducks, diving ducks, geese, swans, cranes.

^bTotal Waterbird Abundance includes dabbling ducks, diving ducks, geese, swans, cranes, American coots.

Table 4. Peak abundance by waterfowl guild estimated from a single midwinter aerial survey in January 2025 and fixed migration curves on National Wildlife Refuge in the southeastern United States following Hagy et al. (2022b).

Complex/Area	NWR	Dabbling Ducks	Diving Ducks	Geese	Swans	Cranes	Total Waterfowl
Alabama	Wheeler NWR	17,838	2,152	565	0	12,549	33,104
Central Arkansas	Bald Knob NWR	383,462	0	837,500	0	0	1,220,962
	Big Lake NWR	19,862	4,176	2,374	0	0	26,411
	Cache River NWR	29,097	38	5,455	0	0	34,589
	Holla Bend NWR	12,339	433	8,782	0	0	21,553
	Wapanocca NWR	14,178	2,541	19,202	0	0	35,922
	White River NWR	69,042	3,591	0	0	0	72,633
Central Louisiana	Catahoula Lake NWR	903	23,672	0	0	0	24,575
	Grand Cote NWR	27,490	2,075	263	0	0	29,827
	Lake Ophelia NWR	11,192	1,717	0	0	0	12,909
Gulf Coast	Grand Bay NWR	16	1,708	0	0	0	1,724
	St. Marks NWR	304	22,435	0	0	0	22,739
North Louisiana	Black Bayou NWR	37	65	0	0	0	101
	D'Arbonne NWR	3,833	0	0	0	0	3,833
	Handy Brake NWR	368	120	0	0	0	488
	Red River NWR	1,928	583	3,277	0	4	5,792
	Tensas River NWR	3,202	122	0	0	0	3,325
	Upper Ouachita NWR	22,210	3,915	1,714	0	0	27,840
North Mississippi	Coldwater NWR	40,245	0	119	0	0	40,365
	Dahomey NWR	203	66	0	0	0	269
	Noxubee NWR	286	248	11	0	0	544
	Tallahatchie NWR	12,298	432	6	0	0	12,735
South Arkansas	Felsenthal NWR	738	231	0	0	0	969
	Overflow NWR	4,891	72	0	0	0	4,963
Southeast Louisiana	Bayou Sauvage NWR	8,498	1,142	0	0	0	9,640
	Big Branch Marsh NWR	153	1,102	0	0	0	1,255
	Breton NWR	0	113,417	0	0	0	113,417
	Delta NWR	108,653	44,903	45,222	0	0	198,778
	Mandalay NWR	5	0	0	0	0	5

Southwest Louisiana	Cameron Prairie NWR	39,439	7,522	15,287	0	0	62,248
	Lacassine NWR	59,653	67,857	14,913	0	0	142,423
	Sabine NWR	47,066	16,823	0	0	0	63,889
Theodore Roosevelt	Hillside NWR	0	0	0	0	0	0
	Holt Collier NWR	219	0	0	0	0	219
	Mathews Brake NWR	2,197	0	0	0	0	2,197
	Morgan Brake NWR	2,088	144	651	0	0	2,883
	Panther Swamp NWR	53,206	0	38,885	0	0	92,091
	St. Catherine Creek NWR	6,970	339	50	0	0	7,359
	Yazoo NWR	5,602	0	0	0	0	5,602
West Tennessee	Chickasaw NWR	10,051	97	4,442	0	0	14,590
	Hatchie NWR	11,228	2,765	770	0	0	14,762
	Lake Isom NWR	12,201	0	526	0	0	12,728
	Lower Hatchie NWR	33,914	0	33,223	0	0	67,136
	Reelfoot NWR	15,781	651	2,245	0	0	18,677
Eastern North Carolina	Mattamuskeet NWR	231,776	219,971	26,738	20,794	0	499,279
	Cedar Island NWR	270	0	0	0	0	270
	Pocosin Lakes NWR	14,864	7,483	9,489	39,571	0	71,407
	Swanquarter NWR	9,913	9,727	0	16	0	19,656
	Alligator River NWR	9,588	1,371	17	2,851	0	13,826
	Pea Island NWR	23,956	55,981	708	0	0	80,645
South Carolina	Ace Basin NWR	7,598	2,401	0	0	0	9,999
	Savannah NWR	618	1,617	0	0	0	2,235
	Santee NWR	1,127	1,832	206	0	88	3,252
	Cape Romain NWR	1,482	14,365	0	0	0	15,847
Florida	Merritt Island NWR	13,129	66,965	0	0	0	80,094

Table 5. Total use days by waterfowl guild for 1 October – 30 April and total waterfowl energy days estimated from a single midwinter aerial survey in January 2025 and fixed migration curves on National Wildlife Refuge in the southeastern United States following Hagy et al. (2022b).

Complex/Area	NWR	Dabbling Ducks	Diving Ducks	Geese	Swans	Cranes	Total WEDs
Alabama	Wheeler NWR	960,262	143,408	32,008	0	636,970	3,711,722
Central Arkansas	Bald Knob NWR	23,379,718	0	37,310,486	0	0	135,311,175
	Big Lake NWR	1,181,933	218,400	132,515	0	0	1,743,277
	Cache River NWR	1,731,493	1,994	304,489	0	0	2,646,457
	Holla Bend NWR	734,247	22,741	488,998	0	0	2,218,298
	Wapanocca NWR	843,716	132,905	1,069,241	0	0	4,151,118
	White River NWR	4,108,583	187,799	0	0	0	4,249,433
Central Louisiana	Catahoula Lake NWR	51,812	1,186,670	0	0	0	941,814
	Grand Cote NWR	1,577,470	104,025	11,894	0	0	1,691,171
	Lake Ophelia NWR	642,266	86,052	0	0	0	706,805
Gulf Coast	Grand Bay NWR	1,165	108,592	0	0	0	82,609
	St. Marks NWR	22,251	1,484,002	0	0	0	1,135,253
North Louisiana	Black Bayou NWR	2,122	3,536	0	0	0	4,774
	D'Arbonne NWR	222,103	0	0	0	0	222,103
	Handy Brake NWR	21,294	6,540	0	0	0	26,199
	Red River NWR	110,609	31,796	148,492	0	186	580,675
	Tensas River NWR	185,542	6,671	0	0	0	190,545
	Upper Ouachita NWR	1,286,958	213,388	75,614	0	0	1,673,842
North Mississippi	Coldwater NWR	3,009,445	0	6,126	0	0	3,027,824
	Dahomey NWR	15,182	4,356	0	0	0	18,449
	Noxubee NWR	21,362	16,284	546	0	0	35,213
	Tallahatchie NWR	919,597	28,402	288	0	0	941,761
South Arkansas	Felsenthal NWR	42,782	12,590	0	0	0	52,224
	Overflow NWR	296,100	3,939	0	0	0	299,054
Southeast Louisiana	Bayou Sauvage NWR	728,743	72,646	0	0	0	783,227
	Big Branch Marsh NWR	13,106	70,114	0	0	0	65,692
	Breton NWR	0	7,216,721	0	0	0	5,412,541
	Delta NWR	9,317,022	2,854,025	2,040,167	0	0	17,578,042
	Mandalay NWR	410	0	0	0	0	410

Southwest Louisiana	Cameron Prairie NWR	3,381,918	478,128	689,658	0	0	5,809,487
	Lacassine NWR	5,111,090	4,308,236	672,800	0	0	10,360,668
	Sabine NWR	4,035,934	1,069,249	0	0	0	4,837,871
Theodore Roosevelt	Hillside NWR	0	0	0	0	0	0
	Holt Collier NWR	16,400	0	0	0	0	16,400
	Mathews Brake NWR	164,309	0	0	0	0	164,309
	Morgan Brake NWR	156,116	9,471	33,502	0	0	263,727
	Panther Swamp NWR	3,978,629	0	2,001,001	0	0	9,981,633
	St. Catherine Creek NWR	399,955	17,015	2,250	0	0	419,467
	Yazoo NWR	418,897	0	0	0	0	418,897
West Tennessee	Chickasaw NWR	692,951	6,368	264,305	0	0	1,490,642
	Hatchie NWR	774,085	182,515	45,812	0	0	1,048,407
	Lake Isom NWR	841,205	0	31,316	0	0	935,152
	Lower Hatchie NWR	2,338,150	0	1,976,758	0	0	8,268,424
	Reelfoot NWR	1,088,013	42,921	133,571	0	0	1,520,919
Eastern North Carolina	Mattamuskeet NWR	17,547,156	14,423,822	922,695	1,120,771	0	36,736,961
	Cedar Island NWR	20,477	0	0	0	0	20,477
	Pocosin Lakes NWR	1,125,295	490,664	327,453	2,132,874	0	13,140,022
	Swanquarter NWR	750,487	637,811	0	861	0	1,233,152
	Alligator River NWR	711,876	107,615	583	153,649	0	1,562,583
	Pea Island NWR	1,595,886	3,670,745	24,436	0	0	4,422,251
South Carolina	Ace Basin NWR	490,217	157,298	0	0	0	608,191
	Savannah NWR	39,858	105,855	0	0	0	119,250
	Santee NWR	72,732	119,881	11,914	0	4,808	217,616
	Cape Romain NWR	95,609	941,180	0	0	0	801,494
Florida	Merritt Island NWR	1,092,737	5,456,317	0	0	0	5,184,974

¹ A waterfowl energy day is equivalent to the approximate energy needs of one mallard-sized duck for one day (300 kcal) and can be adjusted by multiplication factors according to body mass for other taxa (diving ducks = 0.7 WED, geese = 3 WED, swans = 5 WEDs, cranes = 4 WEDs).

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