Status and movements of reintroduced Trumpeter Swans *Cygnus buccinator*, and the status and control measures for non-native Mute Swans *Cygnus olor*, in Ohio, USA

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Abstract

A programme to reintroduce the native Trumpeter Swan *Cygnus buccinator* to Ohio commenced in 1996, after the species had been extirpated from the state for nearly three hundred years. Reintroduction releases continued through to 2003, when the population reached the management goals of the state's wildlife agency, the Ohio Department of Natural Resources – Division of Wildlife. Trumpeter Swan population growth was initially slow but began to increase more rapidly, likely because of management actions such as the continued protection and restoration of wetlands, control of invasive plant and animal species, and continued state legal protection of the swans. From 2003 to the 2023 breeding season, the number of breeding Trumpeter Swan pairs continued to grow at an average annual rate of 15.5% (s.d. ± 26.3%), and successful breeding pairs averaged 2.22 ± 0.40 cygnets per year. In recent years, large flocks of non-breeding Trumpeter Swans (50–200 individuals, which may include some failed breeders) have been seen in summer at sites across the state. Monitoring and management of swans in Ohio has also included counts of and control measures for non-native Mute Swans *Cygnus olor* since 2006 with the latter causing a decline in Mute Swan numbers in recent years, which may have contributed to improved Trumpeter Swan breeding success. Whether Trumpeter Swans breeding in Ohio migrate during the non-breeding season, however, remained unknown. In 2020 and 2021, twenty adult Trumpeter Swans therefore were captured and tagged with GPS/GSM transmitters fitted to neck collars, to determine whether they were migratory or sedentary. The tracking data showed that most dispersed locally (remaining < 40 km from their capture site) between July 2020 and July 2022, but three undertook long-distance movements. One hypothesis to explain these short

movement patterns is that, because swans in Ohio are at the southern periphery of their current breeding distribution and experience mild winter conditions, they do not need to migrate to have open water and food available throughout the winter. Overall, the Trumpeter Swan reintroduction programme in Ohio has been successful but, as the population is primarily non-migratory, it continues to remain a year-round management responsibility of the Ohio Department of Natural Resources – Division of Wildlife.

Key words: breeding population, GPS, management, movement patterns, Mute Swan, Trumpeter Swan.

Native Trumpeter Swans *Cygnus buccinator* were extirpated from the state of Ohio, USA by at least the early 1700s (Sherman 2007), and the Interior Population (IP) of Trumpeter Swans, breeding in the midwestern USA and Canada, within the Mississippi Flyway, was extinct by the early 1900s (Banko 1960). Following successful Trumpeter Swan reintroductions in other states and provinces within the IP's range (Shea *et al.* 2002), a Trumpeter Swan reintroduction programme was initiated in Ohio by the Ohio Department of Natural Resources – Division of Wildlife (ODNR-DOW) in 1996. Trumpeter Swans were released in four phases: 1) adult Trumpeter Swans (older than 2 years), obtained from private propagators across the USA and Canada, were released from 1996–1997, 2) Trumpeter Swans captive-reared by zoos from eggs obtained from wild populations in Alaska were released during 1997–2000, 3) parent-reared swans obtained from private propagators were released from 2001–2003, and 4) swans translocated from Kellogg Bird Sanctuary in Michigan, USA were released also in 1997 and 2003 (Tori 1997; Sherman 2007). Approximately half of the released birds were sourced from the Alaska population, approximately 10 percent from the Kellogg Bird Sanctuary, and the remainder from private propagators (ODNR-DOW, unpubl. data). Between 1996 and 2003, a total of 154 swans were released at 11 wildlife conservation areas in seven counties throughout the state of Ohio (Sherman 2007). The released swans began breeding as early as 1997, and by the end of 2003 117 cygnets had fledged (ODNR-DOW, unpubl. data). Since 2003, the Trumpeter Swan population has been monitored annually by the ODNR-DOW.

Continued management for the swans has included the maintenance, protection and restoration of their wetland habitats. Trumpeter Swans have also been legally protected through their inclusion on Ohio's endangered species list, which limits the take and possession of wildlife under threat of extinction (Ohio Revised Code (ORC) 1531.25). Trumpeter Swans were delisted in the spring of 2024, as a result of the continued growth of the population. Finally, management for Trumpeter Swans has included control of non-native species, both invasive wetland plant species, such as Common Reed *Phragmites australis* and Purple Loosestrife *Lythrum salicaria*, and the non-native Mute Swan *Cygnus olor*.

An increase in the numbers of Mute Swans was considered to be a major obstacle to the recovery of the Trumpeter Swan in Ohio and nearby states from the late 2000s through to the early 2010s. Mute Swans were introduced from Europe to North America in the late 1800s, and to Ohio in 1911 (Lever 1987; Wood *et al.* 2024), although breeding in the wild in Ohio was not documented until the late 1980s (Peterjohn & Rice 1991). In Ohio and the eastern USA, Mute Swans compete with Trumpeter Swans for limited wetland habitat. For instance, in both its native and introduced range, Mute Swans are noted for consuming submerged aquatic vegetation that might otherwise be available to other wildlife, particularly when present in high densities (*e.g.* O'Hare *et al.* 2007; Tatu *et al.* 2007). In Ohio, Mute Swans initiate breeding approximately 3 weeks earlier than Trumpeter Swans, and once established, often chase Trumpeter Swans away and prevent their establishment of breeding territories (D. Sherman, pers. obs). The United States Migratory Bird Treaty Reform Act of 2004 removed protections of non-native bird species such as the Mute Swan in the early 21st century (USFWS 2020), which permitted increased control of the species. The Mississippi Flyway Council, a group of 13 states in the USA and three provinces in Canada that is responsible for managing migratory bird resources within the Mississippi Flyway, consequently adopted a goal of reducing the Mississippi Flyway population to 4,000 or fewer Mute Swans by 2030 and preventing the establishment of any new breeding populations. Mute Swan numbers were also expanding in other Great Lakes states and provinces, and the Great Lakes Mute Swan Task Force was formed to address these concerns and develop region-wide management objectives (ODNR-DOW 2013). Under consultation with the Mississippi Flyway Council and the Great Lakes Mute Swan Task Force, Ohio developed the "Ohio Swan Management Plan", which outlined recovery goals for the Trumpeter Swans as well as goals for reducing numbers of Mute Swans in the state. The plan set the following goals for achievement by 2020: 1) expansion of the Trumpeter Swan range to 15 Ohio counties and 40 breeding pairs within the state, 2) eradication of Mute Swans from all Ohio public lands, and 3) zero population growth of Mute Swans on Ohio private lands (ODNR-DOW 2013). Within that plan, reduction in Ohio's Mute Swan population was deemed necessary to allow for continued growth of Ohio's Trumpeter Swan population, as well as to protect other native Ohio wildlife and ecosystems.

Although the Ohio Swan Management Plan did not explicitly state goals for a migrating Trumpeter Swan population, a primary goal within the management plan developed for the IP Trumpeter Swans was "to restore a self-sustaining migratory population of Trumpeter Swans in the Mississippi and Central Flyways" (Mississippi and Central Flyway Councils 1998). As the Trumpeter Swan populations increased in size and fewer swans in the IP were marked, largely due to the phasing out of active releases of swans by state agencies, it became difficult to assess the migratory status and thus the extent to which swans in Ohio and throughout the IP might

be affected by management elsewhere. In 2019 the Minnesota Cooperative Fish and Wildlife Research Unit therefore initiated a movement study for IP Trumpeter Swans, to provide better insight into the swans' dispersal and the extent of any long-distance migration (Wolfson 2024). Whilst the study initially focused on the swans in Minnesota, where most of the IP breeds, other states and provinces with both breeding and wintering Trumpeter Swans (including Ohio) joined this initiative, by tagging and tracking swans in their areas.

Methods

Study area

The state of Ohio, USA, has a population of *c.* 11.8 million people and covers a land area of 105,796 km^2 (U.S. Census Bureau 2024). Ohio contains a diverse mix of habitats and is bordered by Lake Erie, one of the Great Lakes, in the north, and the Ohio River in the south. Northern and western parts of the state are characterised by their flat, glacial plains, and a fragmented landscape which is rich in agriculture with scattered woodlots, grasslands and wetlands. The southeastern part of the state is unglaciated, and dominated by hills and contiguous, mature forests. In Ohio, wildfowl are most abundant in the wetlands of the glaciated plain, particularly in the Lake Erie coastal marshes of northwest Ohio, but also use dammed inland reservoirs and human-made lakes and ponds scattered throughout the state. Overall, wetland habitat covers approximately 1.8% of the state (USGS 1996).

Trumpeter Swan monitoring

Trumpeter Swans were censused annually, during aerial surveys made by helicopter across major public and private wetland areas in Ohio, over a 2- to 3-day period in early to mid-July. The helicopter was flown at heights of between 90–150 m across wetland areas, and confidence in detecting all swans in the wetland was therefore very high. The 11 wetland complexes where the original Trumpeter Swan releases took place were surveyed each year. In Ohio, wetland habitat is limited, so these wetland complexes represent core breeding areas and roughly 80–90% of suitable breeding habitat for swans. As Trumpeter Swans were discovered at additional sites during the aerial surveys, or were reported by the public or ODNR staff at adjacent or other smaller wetland areas (*e.g.* county metroparks, other state and federal land, and some private land), new areas identified as having swans were included in the annual surveys and monitored in subsequent years.

Reports from the general public posted on eBird and any other ODNR staff sightings of territorial and nesting pairs of Trumpeter Swans seen in June and July, verified by photos or repeat sightings, were also included for areas not surveyed from the air because their location was away from core breeding areas, or within restricted flight areas due to the proximity of large commercial airports, and/or because of flight time constraints. These observations were included in calculating the number of breeding pairs, but only if cygnets were observed were those data included on determining the number of cygnets

produced per successful pair. These additional sightings make up a small percentage of the overall count, for example, only 3% of observations in 2022.

Mute Swan management

Control of Mute Swans was conducted opportunistically, following the American Veterinary Medical Association's (AVMA) guidelines for euthanasia (*e.g.* AMVA 2020). Control activities are conducted primarily by the ODNR-DOW or by the United States Department of Agriculture-Animal Plant Health and Inspection Service (USDA-APHIS) – Wildlife Services, which receive funding for Mute Swan control in the Lake Erie watershed in northern Ohio through the "Great Lakes Restoration Initiative" (GLRI), a federal initiative to protect and restore the Great Lakes ecosystem through actions such as invasive species control (GLRI 2019). In some areas of Ohio, public resistance to these measures has limited Mute Swan control to the addling of eggs to prevent reproduction.

Movement study

Twenty adult Trumpeter Swans were captured on public and private lands, with permission from the respective state, federal, and private landowners, in northwest, northeast and central Ohio, USA in July–August 2020 (n = 12) and July–August 2021 (n = 8) (Table 1). The swans were moulting (and therefore flightless) at the time, so 2–3 persons were able to catch them by hand or using a shepherd's crook from a small motorboat on the waterbodies used by the birds. Both breeding and non-breeding adults were captured; breeding adults were those captured in a pair or as an adult with cygnets. Non-breeding adults were those captured in flocks without an obvious partner or cygnet. Once captured, the birds were weighed, measured, sexed by examining the cloaca, banded with a USGS metal leg ring, bled for additional studies (lead levels and DNA analysis, see Wolfson 2024), fitted with a 55g Ornitela GPS/GSM collar (Model OrniTrack-N62 3G) and then released at the capture site.

Table 1. Sex and breeding status of Trumpeter Swans captured in Ohio, USA, in 2020 and 2021 for the movement study.

Location/Sex	Breeding adult	Non-breeding adult
Northwest Ohio		
Male	2	0
Female	4	2
Northeast Ohio		
Male	0	1
Female	2	3
Central Ohio		
Male	1	1
Female	4	0
Total		
Male	**3**	**2**
Female	**10**	**5**

The Ornitela transmitters were programmed to collect GPS locations at 15 min intervals throughout each 24 h period. Locations were uploaded daily via the cellular network to the Movebank database (Kays *et al.* 2022). Swan days were calculated from the day the collar was put

on the swan to the day that the tag stopped working (n = 10), or the bird perished (n = 7); three swans had collars which were still providing location data at the end of the study period. Net-squared displacement (NSD), a quantitative metric commonly used to describe telemetry data, was used to summarise the movements of the GPS-tagged swans (Wolfson *et al.* 2022). NSD was estimated for each swan as the distance between its capture location (*i.e.* breeding territory) and each telemetry location throughout the year. NSD was back-transformed to displacement for easier inference. Displacements were summarised by regions: northeast, northwest and central Ohio, and by season: breeding (March–July), autumn (August–November) and winter (December–February).

Results

Between 2003 and 2023, there was an average annual increase (mean ± s.d.) of 15.5 ± 26.3% in the number of Trumpeter Swan breeding pairs (Fig. 1A) and an 18.5 ± 45.2% average annual increase in cygnet production (Fig. 1A). The long-term average of cygnet production between 2003 and 2023 has been 2.22 ± 0.40 cygnets/successful pair. Groups of non-breeders (adult and sub-adult birds in small flocks) began to appear more frequently in 2014, and have since been monitored more closely, and a high of 341 non-breeding swans were observed in 2022 (Fig. 1B). Several flocks of non-breeders (50–200 swans per flock) now persist at some of the large wetlands throughout the summer. In 2023, the total state population of Trumpeter Swans reached a record count of 896 individuals, and breeding pairs were found in 26 out of 88 total counties (*c.* 30%) in the state (Fig. 2).

A total of 866 Mute Swans were lethally removed in Ohio between 2006–2022, with a major removal of 208 birds in 2014 (Fig. 3A) when a large aggregation in northwestern Ohio was occupying the coastal marshes and river mouths. Between 2004–2013, during the early years of Mute Swan control efforts, the Trumpeter Swan population increased at an average annual rate of 12.8 ± 33.0%, but between 2014–2023 (after the large removal) the population increased at a rate of 19.7 ± 19.6%. A non-parametric Wilcoxon ranked sums test, however, did not support a statistically significant difference in the annual growth rate recorded for the two time periods (W = 60, P = 0.47). The number of Mute Swans in the state has declined gradually since 2014, particularly in comparison to Trumpeter Swan numbers, as illustrated by the Christmas Bird Count Data (Fig. 3B).

GPS-tagged Trumpeter Swans (n = 20) were tracked for a total of 8,532 days from July 2020–April 2023. The number of days tracked per swan ranged from 56–1,000 (almost 3 years). Fifteen birds were tracked for more than 365 days (1 year), and only three were tracked for more than 730 days (2 years).

Eighty-five percent (n = 17) of the tagged birds remained within Ohio during the time that they were alive, or their GPS transmitters were active (Fig. 4A). The total number of daily movements for these birds was 7,595. The median displacement distance of these swans with localised movements in Ohio was 1.79 km (mean ± s.e. =

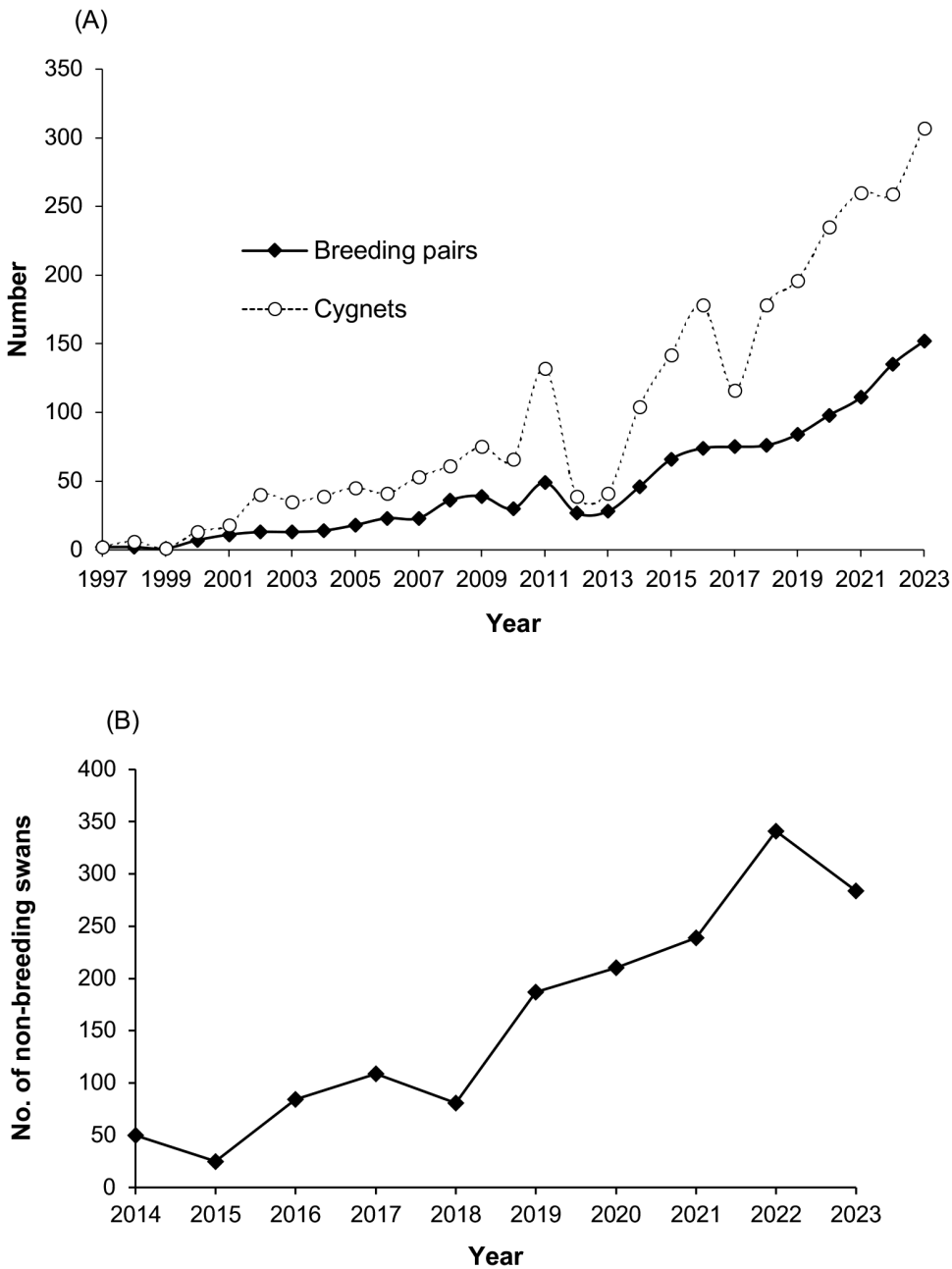

Figure 1. (A) Number of Trumpeter Swan breeding pairs and cygnets in Ohio, USA, 1996–2023, and (B) number of non-breeding Trumpeter Swans in Ohio, USA, 2014–2023.

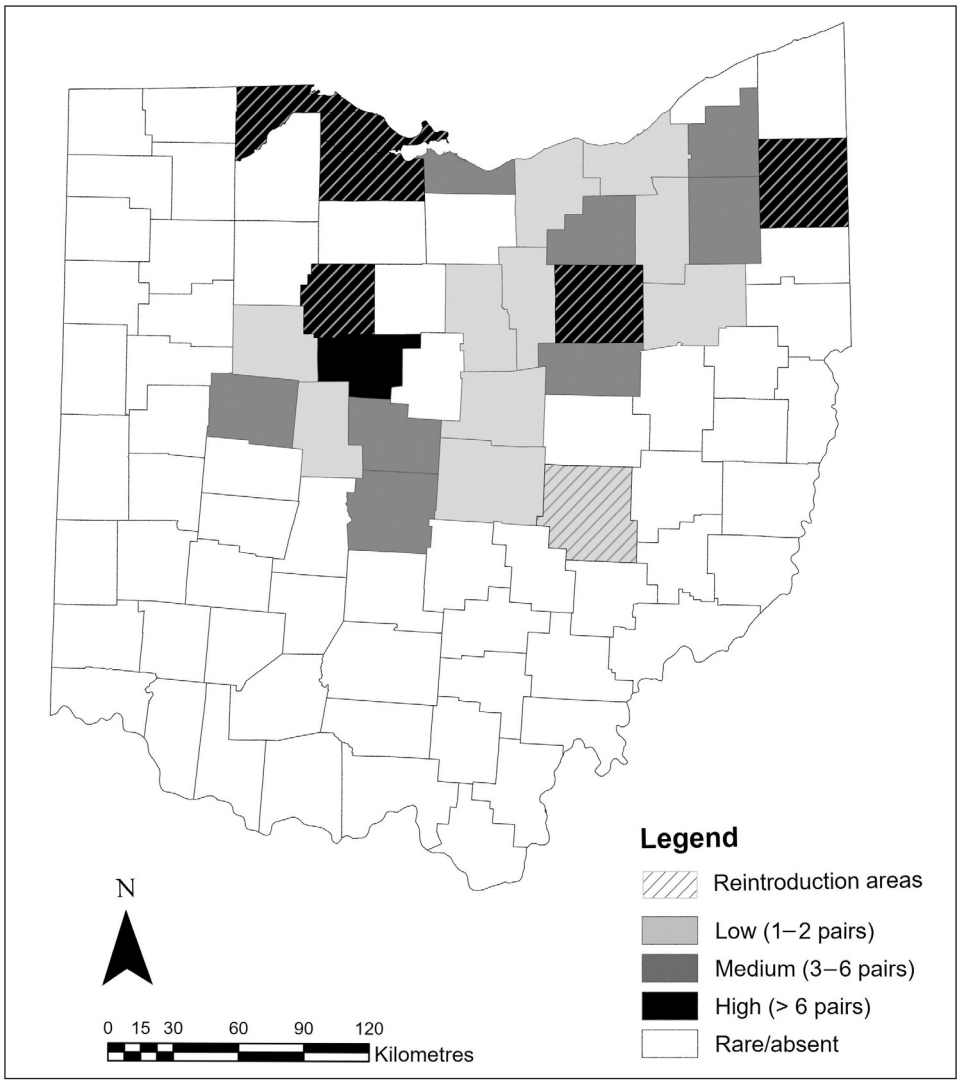

Figure 2. Counties with reintroduced Trumpeter Swans from 1996–2003 (yellow hatching), and breeding Trumpeter Swans within the state of Ohio, USA in 2023. Densities of breeding pairs are indicated by shading: light grey = 1–2 breeding pairs; medium grey = 3–6 breeding pairs; black = more than 6 pairs; white = no breeding.

5.23 ± 0.10 km; range = 0.01–62.65 km). Displacement distances varied little across the three major regions where swans were captured (Table 2). There was also little difference across seasons, with only a slight increase in winter (Table 2).

Three of the GPS-tagged Trumpeter Swans (all females) left the state (Fig. 4B).

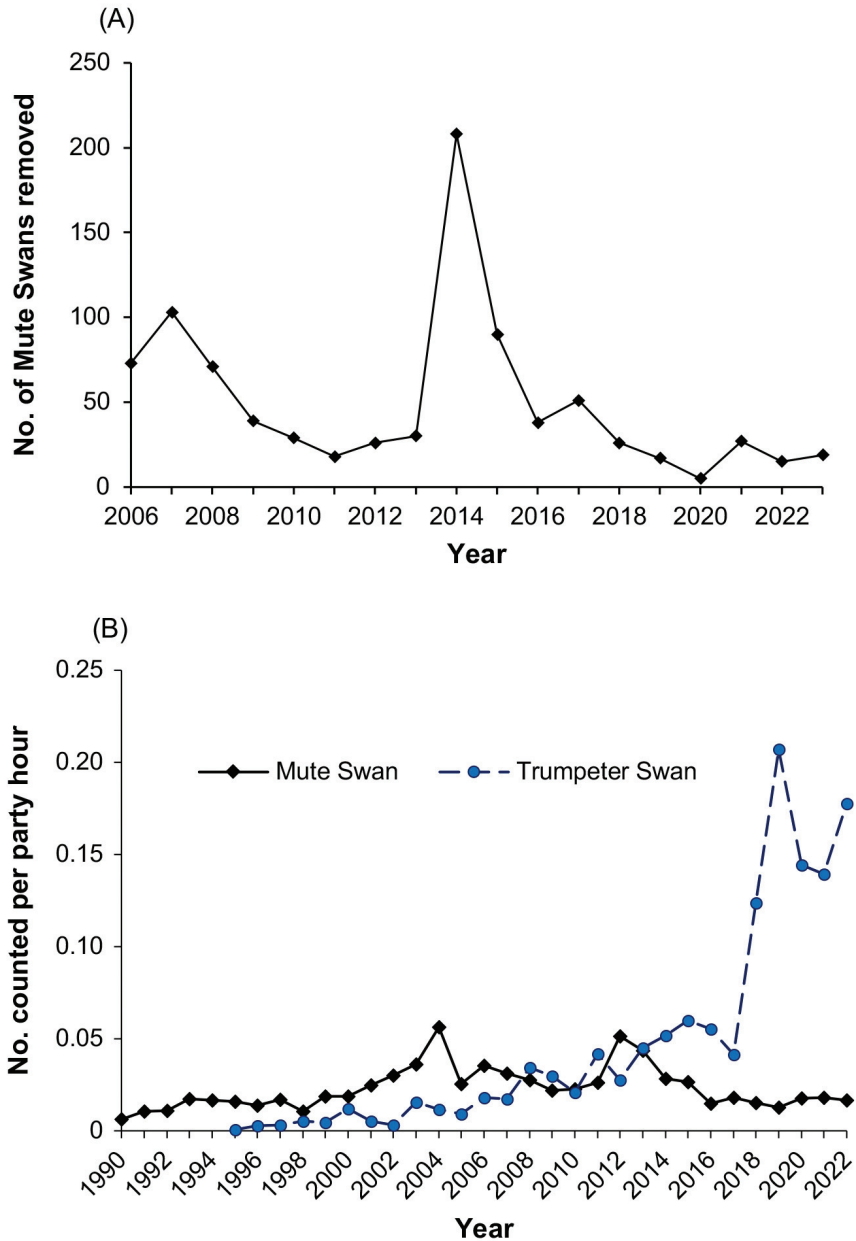

Figure 3. Ohio Mute Swans: (A) the number of Mute Swans removed as part of management actions to stimulate Trumpeter Swan population growth (2006–2023), and (B) the number of native Trumpeter Swans (blue line) in relation to number of non-native Mute Swans (black line) counted by party hour during the Christmas Bird Count in Ohio, 1990–2022 (National Audubon Society 2022).

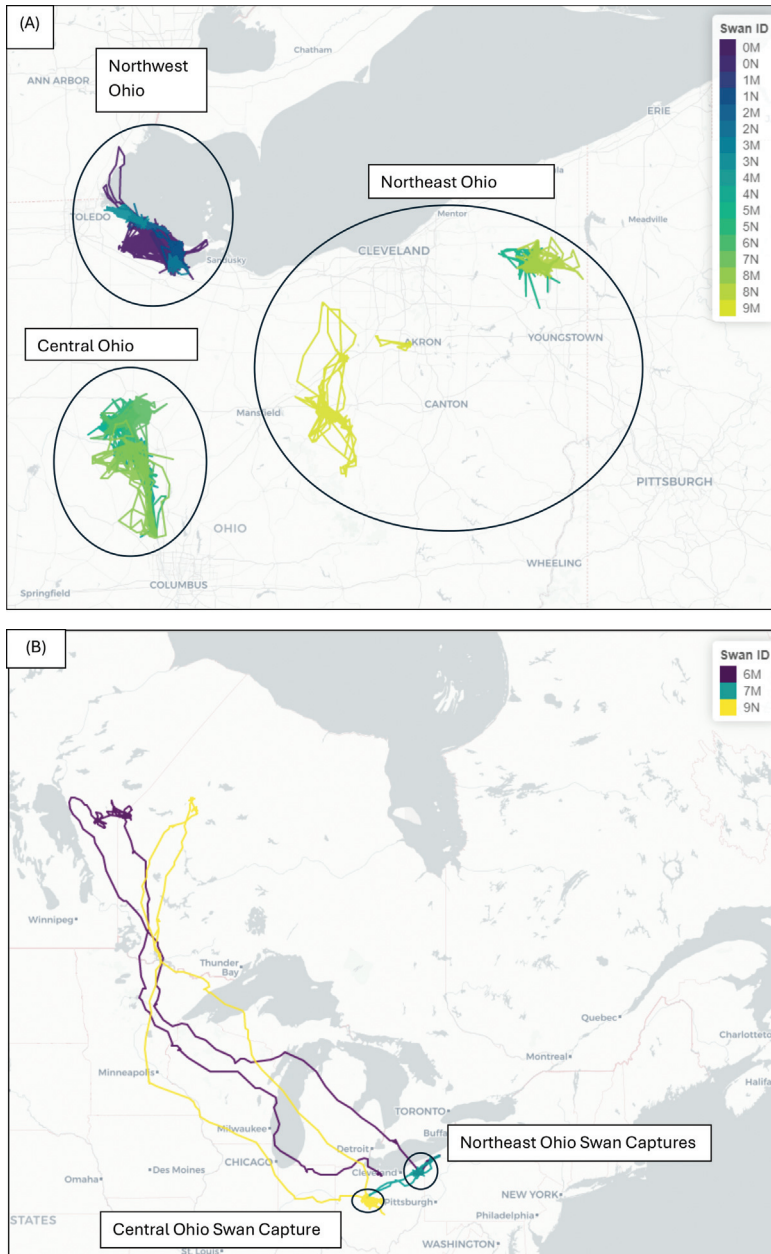

Figure 4. Trumpeter Swan movements in Ohio, USA, July 2020–April 2023 for: (A) GPS-tagged swans with local movements (n = 17), and (B) GPS-tagged swans with long-distance movements (n = 3). The circles indicate the geographic origin of captured swans.

Table 2. Summary of the local movements (*i.e.* distance recorded from the catch site) recorded for GPS-tagged Trumpeter Swans that remained in Ohio, USA (n = 17) during July 2020–April 2023. Swan days were calculated from the day the collar was put on the swan to the day that the tag stopped working (n = 9) or the bird perished (n = 6). Two swans had collars still providing data at the end of the study period. Three swans that moved out of the state were not included in this table.

	No. of swans	Mean ± s.e. (km)	Range (km)
Region			
Central	5	4.41 ± 0.14	0.01–62.65
Northeast	4	7.85 ± 0.31	0.01–59.55
Northwest	8	5.45 ± 0.11	0.06–43.85
Season			
Breeding (Mar–July)	15	4.89 ± 0.15	0.01–43.85
Autumn (Aug–Nov)	17	4.44 ± 0.11	0.01–47.27
Winter (Dec–Feb)	15	7.66 ± 0.21	0.02–62.65

One swan (7M), caught as a non-breeding bird in 2021 in northeastern Ohio (Trumbull County), moved to northwest Pennsylvania in spring of 2022 but died in October 2022 of unknown causes. She dispersed a maximum of 187 km. The other two swans, also captured in 2021, both dispersed by > 1,500 km into northwestern Ontario (9N) and eastern Manitoba, Canada (6M), respectively in the spring of 2022, but returned to Ohio in the late autumn of 2022. The Ontario bird returned and wintered primarily in Delaware County in central Ohio, where she had been captured as a breeding female (with cygnets) in the summer of 2021. In July of 2023, she was observed with four cygnets in the marsh where she had originally been captured. The Manitoba swan returned to Erie County in the autumn of 2022, *c.* 150 km west of the site where she had been caught, as a non-breeder, in Trumbull County. She remained in Erie County until her tag became inactive in April of 2023.

Discussion

Like other states and provinces which have reintroduced Trumpeter Swans within the historical breeding range of the IP (see Handrigan *et al.* 2016; Groves 2017), Trumpeter Swans have made an impressive recovery in Ohio. Since Mute Swan control began in Ohio the population trajectories of both Trumpeter and Mute Swans suggest that implementation of the Ohio Swan Management Plan, and the resulting control

of Mute Swans in the state, may have been an important factor in the Trumpeter Swan's recovery. Moreover, the restoration and protection of wetlands in the region continues be important for maintaining and increasing available habitat. Further, data from the movement study suggest that Ohio's Trumpeter Swan population is non-migratory.

Ohio's Trumpeter Swan population formally reached the goals of the Ohio Swan Management Plan (ODNR-DOW 2013) in 2019 (ODNR-DOW, unpubl. data), which includes expansion of the breeding population into 15 counties, and 40 pairs breeding in the state for three consecutive years; hence, it was delisted from the state's list of threatened and endangered species in 2024. Ohio's swans still form only a small proportion of the overall IP (accounting for < 1% of the population census during the 2015 survey; Groves 2017). While Mute Swans are increasingly uncommon in Ohio, efforts to remove them from public land will need to continue given the scope for influx from much larger populations to the north, including the state of Michigan where Mute Swan numbers were estimated at 8,133 birds in 2017 (Arsnoe & Duffiney 2018) and from the Canadian province of Ontario, where > 3,000 were recorded in 2012 and the species is protected by federal law (Environment and Climate Change Canada 2017). Fortunately, the growth trajectory of Ohio's Trumpeter Swans remains above the average population growth rate of 6.6% reported for all Trumpeter Swan populations from 1968–2015 (Groves 2017), whilst Ohio's cygnet production per pair (2.22 ± 0.4) is similar to that reported across their breeding range (Mitchell & Eichholz 2020), suggesting that their conservation status is currently reasonably secure.

Restoration and protection of Ohio's wetlands have been an important part of Trumpeter Swan recovery in the state. Laws protecting Ohio's wetlands became effective in the late 1990s, and wetland restoration efforts have been active for many decades. For example, over 16,000 ha of Ohio wetlands had been protected and/or restored through funds raised through the sale of Ohio's Wetland Habitat stamp between 1982 and 2016 (ODNR 2016). An additional state effort to restore wetlands, called H2Ohio and initiated in 2019, has the goal to "create, enhance or restore" more than 3,000 ha of wetlands (ODNR 2021).

Although at least some Trumpeter Swans from most of the other states/provinces migrated during the IP movement ecology study (Wolfson *et al.* 2024), the Ohio Trumpeter Swans did not. A few Ohio swans demonstrated shorter southward inside-state movements during prolonged below-freezing temperatures, and a few swans dispersed long distances north to out-of-state areas. Migratory movements were also found to be unusual when a larger number of Ohio Trumpeter Swans were fitted with neck collars but without transmitters from 2003–2008 (*e.g.* Sherman 2007). For example, only 5.9% (seven of 118) of wild-hatched, marked individuals were resighted at southern locations outside of Ohio during this period (Table 3). Thus, given the swans' relatively sedentary nature, management of Ohio's Trumpeter Swan population is a year-round responsibility for the ODNR-DOW, Ohio's state wildlife agency.

Table 3. Locations of Trumpeter Swans wild-hatched in Ohio, USA which migrated south out of the state, 2003–2009.

Individual collar code	Original location and year collared	Re-sighting year(s)	Winter location(s)
2A8	Muddy Creek (2005)	2005	Pesotum, Illinois
6A3	Killdeer Plains (2005)	2006, 2008	Tunica, Mississippi; Lafayette, Indiana
7A2	Big Island (2005)	2007	Kinmundy & Alton, Illinois
0A4	Shenango (2004)	2005, 2006, 2009	Warrenton & Airlie, Virginia
18M	Shenango (2002)	2009	Airlie, Virginia
1C4	Shenango (2008)	2009	Boyd Co, Kentucky
1C6	Shenango (2008)	2009	Boyd Co, Kentucky

Despite the lack of long-distance migration, some short-distance movements south within Ohio were observed during the harsher weather of the non-breeding season. Interestingly, marked swans that moved further from capture sites during non-breeding periods often made use of quarry lakes and small farm or residential ponds near agricultural areas as they sought open-water and reliable foraging areas. In regions where large wetland complexes may be a limiting factor, such human-created habitats provide important stop-over and roosting sites for the swans.

The dispersals of three Trumpeter Swans, one northeast to Pennsylvania in the USA and two northwest to Ontario and Manitoba in Canada, were interesting given the otherwise general lack of migratory and long-distance movements of the Ohio swans. All birds were female, and two were caught as non-breeders. The long-distance dispersals of over 1,500 km of two swans to Canada, and the return of those birds in autumn was remarkable and unexpected. The non-breeding female departed in April of 2022, and the breeding female departed in late May of 2022, which was later than when Trumpeter Swans in other parts of the country typically migrate north. Similar long-distance movements northwards during the breeding period have also been made by swans from other states/provinces during the full IP movement study (Wolfson 2024; Wolfson *et al.* 2024). Other instances of non-wintering dispersal in Trumpeter Swans include moult-migration (Harms & Dinsmore 2022). In other swan species, differences between the sexes in the birds' long-distance dispersal and migratory patterns have been recorded in some studies (*e.g.* Coleman & Minton 1979; Rees 1987) but not in others (*e.g.* Ely *et al.* 2014). In our study, more females were captured than males, which may have introduced a sex-bias in our observations. Indeed, more

research is needed to understand sex differences in the dispersal and migration of individual Trumpeter Swans, particularly in the IP, and the factors associated with long-distance movements which are unusual in this population.

In conclusion, the Trumpeter Swan reintroduction in Ohio has been successful. Ongoing control of invasive Mute Swans in Ohio is likely to be needed to protect both Trumpeter Swans and other native wildlife and ecosystems into the future. As the results of the movement study indicate, Ohio will also continue to need to provide both suitable breeding and non-breeding habitat for the Trumpeter Swans to thrive. Finally, monitoring and research will continue to be an important part of understanding how the reintroduced Trumpeter Swans continue to be assimilated into Ohio's wildlife communities and ecosystems.

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