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Migratory patterns of mallards in eastern North America as revealed from band-recovery data

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Abstract

Mallard (*Anas platyrhynchos*) distributions have changed in North America over the last century because of altered habitat and the direct augmentation of eastern populations with captive-bred game-farm mallards in the early twentieth century. Geographical overlap between wild and game-farm individuals has resulted in interbreeding, with North American mallard populations now ranging from largely wild to more feral and feral x wild hybrids. How changing genetic integrity of North America's mallards translates behaviorally remains unknown. We analyzed band-recovery data from 1949–2019 to estimate emigration rates and geographic distributions of mallards to understand whether the admixed genetic heritage of mallards in North America's Mississippi and Atlantic flyways resulted in variable autumn distributions. We included American black ducks (*Anas rubripes*) as a flyway migratory comparative, and analyzed datasets partitioned by flyway and major international space (i.e., Canada vs. United States). We present results that correspond to the hypothesis that western mallard populations of the 1950s expanded eastward and were the precursor populations of mallards in the Canadian provinces of the Atlantic Flyway, while mallards of the Atlantic Flyway in the United States showed substantially differing patterns. Specifically, we estimate that since 1990, approximately 23% of banded mallards on the United States side of the Atlantic Flyway are annually recovered in the Mississippi Flyway as compared to about 5% of those banded in Canadian provinces of the Atlantic Flyway. Given that mallards from the United States side of the Atlantic Flyway are considered a feral

× wild hybrid swarm, annual westward emigration of 23% of these mallards is concordant with increasing prevalence of game-farm mallard molecular variation detected in the Great Lakes and mid-continent mallard populations. Our results provide insight into potential means for the movement of game-farm molecular variation from the Atlantic into the Mississippi Flyway, and suggest that the effect of these mallards on the genetic integrity and future adaptive capacity of mallard populations in the Mississippi Flyway requires attention and consideration in future management decisions.

KEYWORDS

Anas, banding records, conservation, corridors, geographic distribution, historical ecology, migration, migratory habitat

In North America, mallards (*Anas platyrhynchos*) are geographically managed as western, mid-continent, and eastern populations within the Pacific, Central and Mississippi, and Atlantic flyways, respectively (Sæther et al. 2008, Mattsson et al. 2012). Among these, there is growing concern over the eastern mallard population associated with the Great Lakes Regions and Atlantic Flyway more generally, which has been declining since the 1990s (U.S. Fish and Wildlife Service [USFWS] 2013, 2017). In addition to changing habitat, the origins of their respective ancestral stocks may be an important cause for their decline (Lavretsky et al. 2020). Specifically, mallards were ancestrally present within the western and mid-continent regions, and only recently established east of the Mississippi River (i.e., after 1900; Johnsgard 1967, Snell 1986, Merendino and Ankney 1994). Starting in the 1950s, mallard abundance increased 600-fold east of the Mississippi River, which is attributed to colonization by mallards into previously forested landscapes in eastern Canada and the United States that were converted to open agricultural and residential cover types (Johnsgard 1967, Heusmann 1974). Concurrent with substantial removal of forest cover, game managers, sportsmen, and others directly released approximately 500,000 captive-bred game-farm mallards per year along the Atlantic coast from the early 1920s to the 1960s, with ≥210,000 game-farm mallards still being released annually (Heusmann 1974; Soutiere 1986; Hepp et al. 1988; USFWS 2013, 2017). The presence, and subsequent interbreeding, of these 2 distinct stocks (i.e., wild, game farm) was recently confirmed through molecular analysis of landscape-level contemporary and historical mallard samples (Lavretsky et al. 2019, 2020) where the extent of introgressive hybridization between game-farm and wild mallards fundamentally changed the genetic composition of eastern mallards with 8% being described as wild North American mallards and the remaining 92% being described as feral (i.e., game-farm mallards that are found in the wild) or feral x wild mallard hybrids (Lavretsky et al. 2019). Thus, the eastern mallard is a product of the eastern expansion of the mid-continent population and releases of game-farm mallards.

This complex genetic history at least partially explains currently declining North American mallard populations in the east, but we also posit that these genetic combinations likely influence migratory behavior and even landscape use (i.e., urban vs. rural habitats). Lavretsky et al. (2019) also described a westward decline in the proportion of feral and feral × wild hybrid mallards composing more western populations; about 40% of mallards in the Mississippi Flyway and 3% of more western mallard populations are identified as feral and feral × wild hybrids. Whether game-farm molecular variation is due to local releases in each of the flyways or westward movement of feral and feral × wild hybrids out of the Atlantic Flyway remains unknown. Nevertheless, variance in game-farm mallard genetic contributions across North America's mallard populations is not surprising given that approximately 85% of all released game-farm mallards are within the Atlantic Flyway (USFWS 2013, 2017). Thus, it is possible that westward movement of mallards in the Atlantic Flyway can be a way that game-farm genetic variation moves westward.

The American black duck (*Anas rubripes*; black duck) represents the ecological counterpart to mallards in eastern North America (Brodsky and Weatherhead 1984). In short, black ducks generally demonstrate similar migratory aptitudes as mallards in each of the areas (Bellrose and Crompton 1970, Ankney et al. 1987, Krementz et al. 1992, Merendino and Ankney 1994, Schummer et al. 2010), including near identical queuing to weather severity and under future climatic conditions (Notaro et al. 2014, Schummer et al. 2017). Thus, black ducks provide an ideal comparative to determine whether any migratory oddities are truly specific to mallards.

Our objectives were to estimate mallard and black duck emigration rates from the Mississippi and Atlantic flyways and to determine their band recovery locations through time to examine patterns of movement. Lavretsky et al. (2014) reported significant differences in flyway fidelity between black ducks in the Mississippi and Atlantic flyways, which supported previous work suggesting ducks in the Mississippi Flyway have a greater propensity to move between flyways than those hatched in the Atlantic Flyway (Zimpfer and Conroy 2006). If the eastward expansion of mallards in the early 1950s and 1960s is observed in the mallard banding dataset, then we expected datasets to include mallards that move between their more western origin and newly colonized eastern regions, which would be represented by high and similar emigration rates and variance in those rates during expansion years, and by changing distributions. Additionally, given the complex history leading to the establishment of eastern mallard populations (i.e., immigrants from the Mississippi Flyway, release of game-farm mallards in the Atlantic Flyway), we expected mallards in the Atlantic Flyway to potentially show different temporal changes in emigration and recovery distribution patterns when compared to their respective black duck group. Conversely, similar year-to-year rates and distributions regardless of region would support stability in migratory tendencies.

STUDY AREA

Our study area ranged from 25–63°N latitude and 52–98°E longitude, and encompassed the 2 eastern-most migratory bird flyways in North America: the Mississippi Flyway and the Atlantic Flyway (https://www.fws.gov/media/migratorybirdprogramadministrativeflywaysstateandprovincemapjpg, accessed 20 Jun 2022). Continentally, the flyways represent ecologically significant regions (Lincoln 1935) and generally follow geopolitical boundaries in the United States and Canada. As such, they provide a valuable spatial scale for guiding management and research across large areas. The area includes ecologically distinct regions such as tundra, Hudson Bay plains, taiga, Atlantic coast, northern forests, and eastern temperate forests (Omernik and Griffith 2014). Waterfowl generally nest north of 40°N latitude during summer months and migrate to areas south of 40°N latitude for the winter (Dalby et al. 2014). Climatic conditions are variable throughout because of the timeframe of the study and large extent of the study area. For example, the average December temperature ranges from −18°C in northern latitudes to 15°C at southern latitudes, and have increased by approximately 1–3°C over the course of the study (1949–2019).

METHODS

We obtained band release and encounter records from 1949–2019 from GameBirds software provided by Patuxent Wildlife Research Center (U.S. Geological Survey, Patuxent, MD, USA). We restricted records to direct recoveries (recoveries occurring within the same band year) of normal, wild individuals banded from June through August that had single sightings (i.e., shot, found dead) during September through February, which represents the range of legal sport hunting seasons in North America (Bellrose and Crompton 1970). Next, we partitioned direct band recoveries by banding flyway (i.e., Mississippi or Atlantic) and by major international boundaries, producing 4 regional sub-samples for mallards and black ducks: Canadian Mississippi Flyway, United States Mississippi Flyway, Canadian

Atlantic Flyway, and United States Atlantic Flyway. Moreover, we used boxplots to visually assess median longitude and associated variation among regional sub-samples to ensure that major shifts in banding locations did not occur during the study period.

To account for differential harvest vulnerability between Mississippi and Atlantic Flyway band recoveries, we first modeled flyway (l) and species (s) and specific recovery probabilities (f) for each year (t) from m-arrays (π) drawn from a binomial distribution (Brownie et al. 1985):

$$\pi_{l,s,t} \sim \text{Binomial}(releases_{l,s,t}, f_{l,s,t}).$$

We used autoregressive random effects on recovery parameters to smooth posterior parameter estimates by logit transforming parameters as random autoregressive processes (Link and Barker 2010, Schaub and Kéry 2021). We modeled species- and flyway-specific recovery probabilities in the first year as parameters with vague priors:

$$f_{l,s,t=1} \sim \text{Beta}(1, 1).$$

After the first year, we modeled band recovery probabilities as normal distributions with a mean of the logit transformed recovery probability from the previous year and the associated variance (σ^2), which we modeled using vague priors on standard deviations:

$$logit\,(f_{l,s,t}) \sim \text{Normal}\left(logit\,(\hat{f}_{f,s,t-1}), \sigma^2_{l,s,t}\right),$$

$$\sigma_{l,s,t} \sim \text{Uniform}(0, 5).$$

We evaluated changes in migratory tendencies by deriving the proportional emigration rates across years for each group (1949–2019). We scaled the raw recovery data (R) to account for differential vulnerability between the Mississippi and Atlantic flyways by dividing recoveries (r) for each combination of country (c), flyway (l), species (s), and year (t), by their associated band recovery probability ($\hat{f}$):

$$\hat{R}_{c,l,s,t} = \frac{r_{c,l,s,t}}{\hat{f}_{l,s,t}}.$$

We then calculated emigration rates (γ) as the number of corrected band recoveries that occurred outside a banding region ($o = 1$) divided by the sum of band recoveries that occurred outside the banding region and those that occurred in the banding region ($o = 0$):

$$\gamma_{c,l,s,t} = \frac{\hat{R}_{c,l,s,t,o=1}}{\hat{R}_{c,l,s,t,o=1} + \hat{R}_{c,l,s,t,o=0}}.$$

We fit models using JAGS (Plummer 2003) in R version 4.1.2 (R Core Team 2020) and the jagsUI package (Kellner 2016). We ran 3 chains of 50,000 iterations, discarded the first 10,000 interactions as burn-in, and saved every fifth iteration. We assessed convergence by visual inspection of trace plots and Gelman-Rubin test statistics ($\hat{R}$; Brooks and Gelman 1998).

To evaluate emigrational trends through time, we used a moving average (a common method of time-series analysis; Box et al. 1976, Montgomery et al. 2015) with a sliding window of 5 years. We used trends in these rates (i.e., large changes in rates) to bin data for geographic distribution reconstruction, which we used to visualize directionality and prevalence of bands across the landscape. To do so, we calculated kernel density estimates (KDE) from all recovery positions for a given banding region using a search band radius of 1.65

(optimized in Lavretsky et al. 2014), and overlaying the 95% and 50% KDE contours on North American maps using ArcGIS 10.7.1 (Esri, Redlands, CA, USA).

RESULTS

First, we confirmed that there were no major shifts in banding locations during our study period that could explain shifting migratory patterns (Figure S1, available in Supporting Information). Band recovery probabilities varied between species and flyway, and on average were greatest for black ducks in the Atlantic ($f = 0.114$, 95% CI = 0.101–0.128) and Mississippi ($f = 0.076$ 95% CI = 0.061–0.093) flyways, and lowest for mallards in the Mississippi ($f = 0.061$, 95% CI = 0.056–0.065) and Atlantic ($f = 0.062$, 95% CI = 0.055–0.071) flyways. Emigration rates varied across the time-series of 3 mallard groups (Canadian Mississippi, United States Atlantic Flyway, and Canadian Atlantic Flyway) and 1 black duck (Canadian Mississippi Flyway) group (Table 1; Figure 1;

TABLE 1 Total band recoveries, band recoveries in emigrant flyway, and mean emigration rates calculated by species (mallard, black duck), source population (Canada, United States), and flyway (Mississippi, Atlantic). We calculated mean emigration rates and 95% confidence intervals (95% CI) from recovery data from 1949–2019 that were corrected for differential vulnerability between flyways. Additional results are provided for time intervals and the respective populations in which we observed substantial fluctuations in emigration rates.

Sampling group	Band recoveries	Bands recovered from non-banded flyway	Corrected emigration rate means (95% CI)
Mississippi Flyway			
Canada mallard	26,328	5,502	0.16 (0.14–0.18)
<1970	3,336	696	0.17 (0.14–0.19)
1970–1985	6,970	1,691	0.19 (0.17–0.21)
>1985	16,022	3,115	0.14 (0.13–0.15)
USA mallard	34,268	2,096	0.04 (0.04–0.05)
Canada black duck	2,764	630	0.29 (0.25–0.34)
<1970	1,398	314	0.29 (0.25–0.33)
1970–1985			0.29 (0.25–0.33)
>1985	1,126	248	0.30 (0.25–0.36)
USA black duck	733	36	0.04 (0.03–0.05)
Atlantic Flyway			
Canada mallard	11,395	1,787	0.11 (0.10–0.12)
<1990	2,371	739	0.15 (0.14–0.17)
≥1990	9,024	1,048	0.06 (0.06–0.07)
USA mallard	16,573	3,562	0.19 (0.17–0.21)
<1990	6,442	1,216	0.16 (0.13–0.19)
≥1990	10,131	2,346	0.23 (0.21–0.25)
Canada black duck	12,305	514	0.02 (0.02–0.03)
USA black duck	6,326	414	0.04 (0.03–0.05)

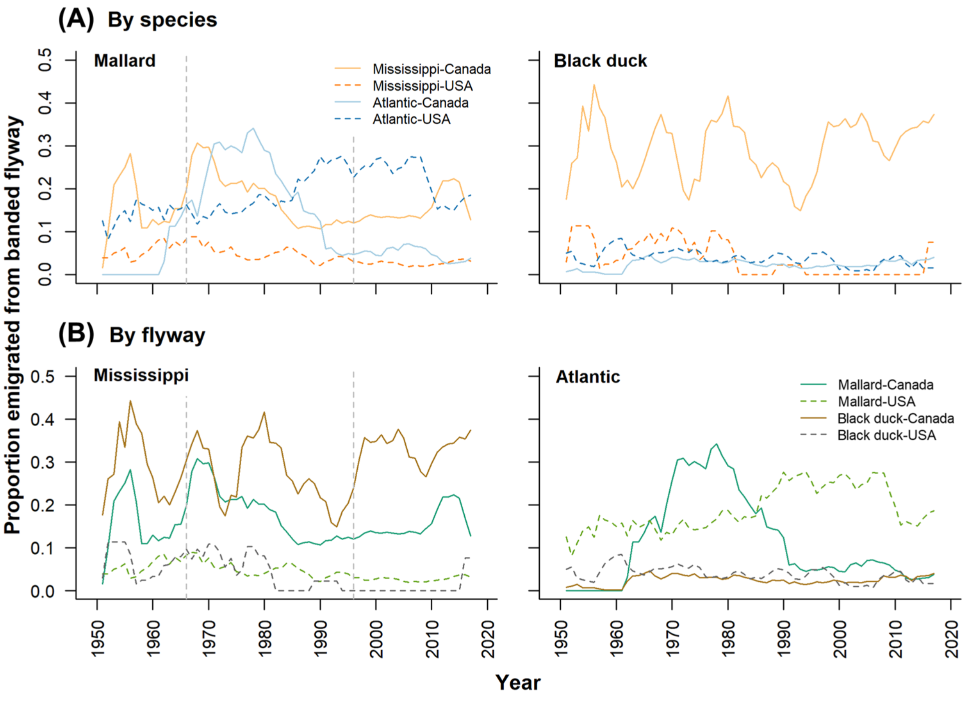

FIGURE 1 Emigration rates (measured as annual proportion of band recoveries obtained in the non-banded flyway) by A) species or B) flyway based on a 5-year sliding window calculated from 1949–2019 direct band recoveries of mallards and American black ducks in North America. Represented groups are mallards and black ducks in Canada and the United States (USA) that were banded in the Mississippi or Atlantic flyway but recovered outside their respective flyways.

Figure S2, available in Supporting Information). Conversely, for mallards and black ducks in the Mississippi Flyway in the United States, and black ducks in the Atlantic Flyway, there was a constant 5–6% recovery rate of bands in the non-banding flyway across time (Table 1). Though we calculated KDEs from all possible recoveries for each analyzed group (Figure S3, available in Supporting Information), we further partitioned mallards in the Canadian Mississippi Flyway and black ducks into 3 time-series (i.e., pre-1970, 1970–1985, post-1985; Figure 2), and mallards in the Atlantic Flyway into 2 time-series (i.e., pre-1990, post-1990; Figure 3); these time cut-offs followed changes in emigration rates identified for each of these groups (Figure 1).

Mallards and black ducks from the United States Mississippi Flyway were identical in time-series emigration rates (~4%; Table 1; Figure 1B) and overall KDE distributions (Figure S3). In general, these mallards and black ducks tend to be distributed from the Great Lakes region to the upper portion of the Mississippi Alluvial Valley (MAV). As with their United States counterparts, mallards and black ducks in the Canadian Mississippi Flyway were also very similar in time-series emigration rates (Figure 1B) but differed substantially in their overall (Figure S3) and partitioned (Figure 2) KDE distributions. Unlike their respective United States conspecifics, mallards and black ducks in the Canadian Mississippi Flyway showed cyclical-like emigration rates across time (Figure 1B). While overall distributions for mallards in the Canadian Mississippi Flyway were similar in pattern to mallards in the United States, their distributions extend throughout the MAV and included the Prairie Pothole regions of the Central Flyway. These distributions were consistent across the 3 time sets, suggesting that emigration out of the Mississippi Flyway includes individuals moving into the Central and Atlantic Flyways (Figure 2). Conversely, black ducks in Canada were the most unique in distributions for the 4 analyzed Mississippi Flyway groups, with distributions including the eastern Great Lakes region, northern parts of the

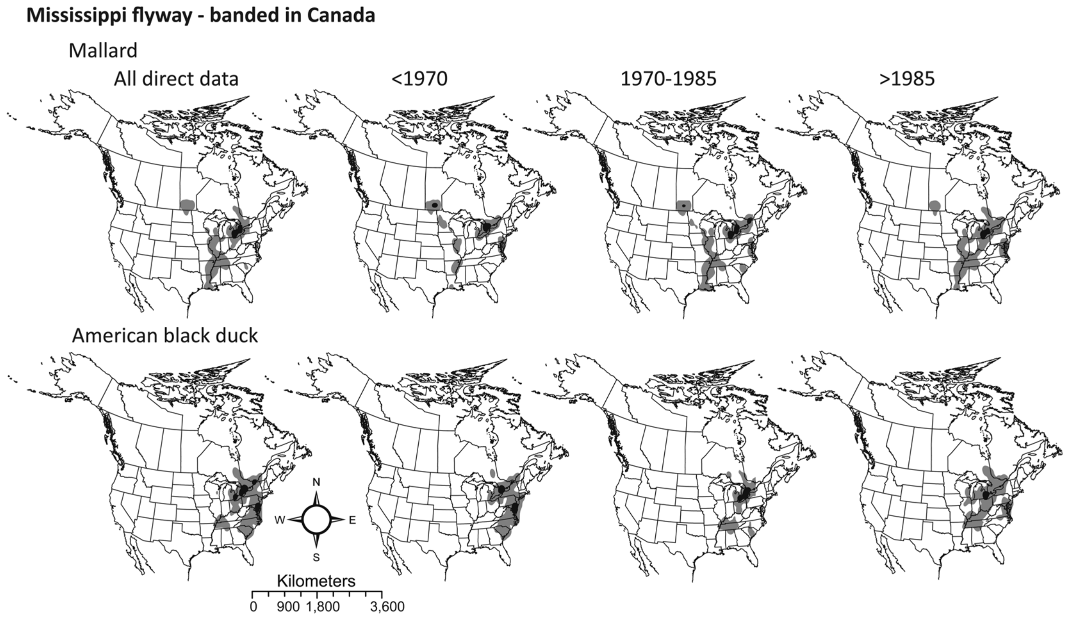

FIGURE 2 The 95% (grey) and 50% (black) kernel density estimate distributions calculated from 1949–2019 direct band recoveries of mallards and black ducks banded in the Canadian Mississippi Flyway. Maps represent kernel density estimates reconstructed from all possible direct band recoveries (left), followed by 3 dataset partitions based on time intervals with fluctuations in emigration rates: before-1970, 1970–1985, and post-1985.

MAV and large parts of the Atlantic Flyway (Figure 2). When partitioning black ducks from the Canadian Mississippi Flyway into 3 time-series, years of greater emigration rates (<1970; Figure 1) corresponded with increased KDE overlap in the Atlantic Flyway (Figure 2). Thus, unlike mallards in Canada, black ducks in the Canadian Mississippi Flyway largely emigrate into the Atlantic Flyway.

While the Mississippi Flyway showed that mallard migratory landscape use varied across time but in conjunction with their black duck counterparts, mallards in the Atlantic Flyway showed greater variance in emigration rates (Figure 1B) and substantial changes in their distributions (Figure S3). For black ducks in the Atlantic Flyway, there was no change in emigration rate (2–4%; Table 1; Figure 1) and overall similar distributions as reported in Lavretsky et al. (2014; Figure S3). Next, despite relatively higher emigration rates pre-1990 (Figure 1B), distributional reconstructions demarcated that the majority of these eastern mallard bands were recovered, and thus stayed at the border of Quebec and Ontario, Canada and the bordering states in the United States (Figure 3). We detected distributional changes when analyzing post-1990 band recoveries, with distributions of mallards from Canada generally overlapping black ducks in the Atlantic Flyway (Figure 3; Figure S3). Next, despite a mean emigration rate for mallards from the United States Atlantic Flyway to the Mississippi Flyway of approximately 19% (Table 1), there was a general positive trend until early 1990s when their emigration rates generally showed stable or declining trends (Figure 1); though the average remained at approximately 23% (Table 1). Mallards in the United States Atlantic Flyway show overall distributions that substantially extend into the Mississippi Flyway, and the increasing emigration trends until the early 1990s are visually evident in their pre-1990 partitioned dataset where 95% KDEs clearly overlap the Great Lakes area and further into the northern part of the MAV (Figure 3). Conversely, whereas mallards post-1990s from the United States Atlantic Flyway show 95% KDE distributions still overlapping the eastern part of the Great Lakes Region, they no longer overlap the MAV.

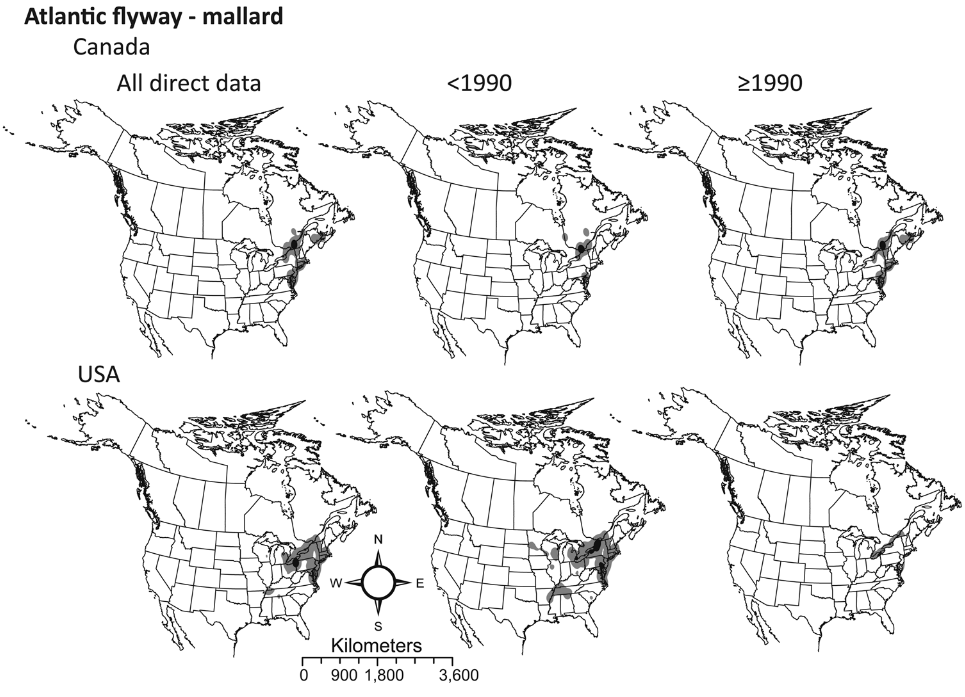

FIGURE 3 The 95% (grey) and 50% (black) kernel density estimate distributions calculated from 1949–2019 direct band recoveries of mallards banded in Canada or the United States Atlantic Flyway. Maps represent kernel density estimates reconstructed from all possible direct band recoveries (left), followed by 2 dataset partitions based on time intervals with fluctuations in emigration rates: pre-1990 versus post-1990.

DISCUSSION

Comparative analysis of direct band-recovery data for mallards and black ducks collected from 1949–2019 in the Mississippi and Atlantic flyways shed light on differences between flyways and species, and supports our hypothesis that mallards in the Atlantic Flyway of North America would show distinct migratory patterns because of their relatively recent origins and complex genetic history. Similarities in emigration rates (Figure 1) and landscape distributions (Figures 2 and 3, S3) among mallard and black duck band-recovery data were best explained by an individual's geographic starting position and not by species in the Mississippi Flyway. Ducks banded in the United States had greater flyway fidelity because mallards and black ducks banded in Canada were 3- to 5-times more likely to emigrate from their banding region. Whereas distributions of black ducks from Canada identify the Atlantic Flyway as the primary area of emigration, distributions of mallards from Canada include regions in the Central and Atlantic flyways (Figures 2, S3). Thus, while the propensity to emigrate in any single year for mallards and black ducks from Canadian Mississippi Flyway appears similarly influenced, where they go differs.

In the Atlantic Flyway, we observed changes in time-series and density plot differences among mallards as compared to black ducks that showed low (or no) variability in their geographic distributions through time in the Atlantic Flyway (Figures 1, 2, and 3; Zimpfer and Conroy 2006, Lavretsky et al. 2014, Robinson et al. 2016). We posit that differences in the natural histories of black ducks and mallards likely explain these distinctions. Whereas black ducks are endemic to eastern North America, mallards are relatively recent colonizers of the region (Hanson et al. 1949, Heusmann 1974, Soutiere 1986, Hepp et al. 1988). In particular, the sources (i.e., wild vs. game farm) of the now genetically admixed populations of eastern mallard populations (Lavretsky et al. 2019) likely contribute to the considerable variation in geographic distributions and emigration rates across these mallards. Alternatively, it is possible that large-scale restoration and habitat enhancements in the Mississippi Flyway (e.g., MAV; Hagy et al. 2017) and climate change (Meehan et al. 2021) may also result in changing emigration patterns; however, under such a scenario we would also expect to see similar responses of all mallards from the Atlantic Flyway and some response by black ducks.

Our results support the early hypothesis that eastward-expanding western mallard populations of the 1950s (Heusmann 1974, Soutiere 1986, Hepp et al. 1988) were the likely precursor populations of mallards in the Canadian Atlantic Flyway, and that the unique migratory patterns of mallards in the United States Atlantic Flyway corresponds with their genetically admixed ancestry. First, emigration rates of mallards from the Canadian Atlantic Flyway were greatest until the 1980s, and mimic emigration rates of mallards from the Mississippi Flyway until approximately 1995 (Figure 1A). Diverging paths between these 2 also resulted in distributions during and following the precipitous decline in emigration rates identified for mallards from the Canadian Atlantic Flyway to be geographically similar to those detected for black ducks in the Atlantic Flyway (Figure S3). Thus, these results suggest that mallards from the Canadian Atlantic Flyway became largely restricted to the Atlantic Flyway only since the mid-1990s. We postulate that this time series captures the westward mallard expansion and subsequent establishment of mallards in the Atlantic Flyway of Canada in northern latitudes. Together, these results are consistent with the prediction of mallards in the West being the ancestor of current mallards in the Canadian Atlantic Flyway in which the first arrivals maintained an affinity to their ancestral wintering region prior to these birds apparently adapting to (or learning) more optimum migratory strategies of the Atlantic Flyway within 40–50 years of the initial colonization event. As of 2020, 64% of mallards harvested in the Atlantic Flyway are of Canadian origin as revealed by stable isotopes (Kucia et al. 2023).

Mallards in the United States Atlantic Flyway are the only group among mallards and black ducks to show significant contemporary movement into the Mississippi Flyway (Figures 1 and 3). Without an established breeding wild counterpart before 1950–1960, mallards in the Atlantic Flyway largely consisted of feral game-farm mallards that were released starting in the 1920s (Heusmann 1974, Soutiere 1986, Hepp et al. 1988, Lavretsky et al. 2020). In short, mallards from the United States Atlantic Flyway were increasingly detected in the Mississippi Flyway up to approximately 1995 (Figure 1), and 95% KDE distributions for the pre-1990 dataset even included the wintering region of the MAV (Figure 3). Since the mid-1990s, the recovery of mallards from the United States Atlantic Flyway in the Mississippi Flyway has been steadily declining (Figure 1); however, 15% of 2019 banded birds emigrated from the flyway and 50% and 95% KDEs encompassed the eastern Great Lakes region (Figure 3). Thus, the historical and contemporary effects of mallards from the United States Atlantic Flyway on Mississippi Flyway wintering populations are evident and important to consider given their known genetic origins. Given that mallards from the United States Atlantic Flyway have been reported to have generally greater proportions of game-farm ancestry (Lavretsky et al. 2019, 2020), our analyses provide a potential pathway of how game-farm molecular ancestry is being distributed westward across North America. Geographically, the Mississippi Flyway has the next greatest proportion of mallards identified to carry game-farm mallard ancestry (~40%), with the proportion substantially declining farther west (Lavretsky et al. 2019, 2020). Among these regions, the continued contribution of mallards in the United States Atlantic Flyway into the Great Lakes region needs to be carefully studied to determine the annual rate of mallard exchange occurring between these flyways, and how many of these carry game-farm mallard ancestry. In fact, a recent analysis of mallards wintering around Lake Erie's shores in northwestern Ohio, USA, reported that 75% of 299 samples were of game-farm or game-farm x wild mallard hybrid ancestry (Schummer et al. 2023). These updated proportions are higher than previous estimates, suggesting an increasing interchange of mallards between flyways, the release of game-farm mallards more locally, or both. Considering KDE distributions of mallards from United States Mississippi and Atlantic flyways have 50% KDEs surrounding the western area of Lake Ontario (Figures 2 and 3, S3), this area is ideal to study the mallard interchange between flyways (Schummer et al. 2023).

CONSERVATION IMPLICATIONS

The effect of mallards from the Atlantic Flyway on the genetic integrity of Mississippi Flyway populations requires careful consideration. We provide evidence that mallards from the Atlantic Flyway are moving westward in substantial numbers where they may further cause genetic admixture of North America's wild mallard populations. Towards this end, we identify the Great Lakes region as an important area of interchange with mallards from the Atlantic Flyway. Future studies could focus efforts on understanding how game-farm mallards may be affecting the genetic integrity and demography of mallards in the Mississippi Flyway, and more western mid-continent populations. We suggest that genetic ancestry be examined to determine if interbreeding between game-farm and wild mallards influences behavioral differences among wild populations of mallards to assist with their management.

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CONFLICT OF INTEREST STATEMENT
The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available in from the GameBirds software provided by the Patuxent Wildlife Research Center (U.S. Geological Survey, Patuxent, MD, USA).

ETHICS STATEMENT
We did not have direct handling or use of animal materials in this study. All band-recovery data were obtained from the GameBirds software provided by Patuxent Wildlife Research Center (U.S. Geological Survey, Patuxent, MD, USA).

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SUPPORTING INFORMATION

Additional supporting material may be found in the online version of this article at the publisher's website.

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