MIGRATION ROUTES AND CHRONOLOGY OF AMERICAN BLACK DUCKS

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Migration influences the ecology, evolution, and conservation of migratory animals (Webster et al. 2002), yet migration routes and timing between breeding and wintering areas is virtually unknown for American black ducks *Anas rubripes*. We used satellite telemetry to identify migration routes and stopovers, estimate migration chronology, and describe variation among black ducks marked between 2007–2009 in Delaware, New Jersey, New York, Ohio, and Virginia. A total of 31 transmitters provided at least one full data set during spring migrations. Black ducks departed wintering areas March 18–June 7 ($\bar{x}$ = April 17), averaged 3.35 stopovers (SE = 0.3 stopovers; range = 1–5 stopovers) and 6.44 d at stopovers (SE = 0.8 d; range = 0.54–12.2 d), migrated 1,126 km (SE = 89.5 km; range = 270–1,396 km), and arrived at inferred nesting areas April 16–June 28 ($\bar{x}$ = May 9). South Atlantic Flyway black ducks migrated almost twice as far and took nearly twice as many stopovers as Mississippi and North Atlantic Flyway black ducks; South and North Atlantic Flyway black ducks arrived at inferred nesting areas approximately 2 and 4 weeks after those from the Mississippi Flyway, respectively. Black ducks south of the 40th parallel migrated more than 50% farther, took nearly twice as many stopovers, and arrived at inferred

nesting areas 2 weeks after those to the north. Black ducks east of the 76th meridian migrated nearly 25% farther and arrived at inferred nesting areas 3 weeks after those to the west. Nine black ducks spent all or portions of spring migration along the Atlantic Coast, and 10 used the Hudson and St. Lawrence River valleys. Stopovers included Long Island Sound, NY, Narragansett Bay, RI, Lake Champlain, VT, Merrymeeting Bay, ME, and the Gulf of St. Lawrence, Canada. All 11 black ducks wintering in Ohio stopped at Lake St. Clair, Saginaw Bay, St. Mary's River, or the Georgian Bay. A total of 13 transmitters provided at least partial data during autumn migrations. Black ducks departed inferred nesting or molting areas October 5–December 1 ($\bar{x}$ = October 24), averaged 2.0 stopovers (SE = 0.3 stopovers; range = 1–4 stopovers) and spent 12.6 d at stopovers (SE = 3.5 d; range = 0.25–41 d), migrated 993 km (SE = 202.9 km; range = 277–1,485 km), and arrived at wintering areas November 18–December 18 ($\bar{x}$ = December 1). Our study confirms the importance of known stopovers and emphasizes the continued need for conservation and management of wetland habitats along established migration corridors. Furthermore, migration chronology and stopover duration of stay from our study should be incorporated into energetic carrying capacity models to better inform and direct habitat goals for black ducks in northeastern North America.

Chapter 1

INTRODUCTION

Populations of American black ducks *Anas rubripes* (hereafter black ducks) have declined significantly over the last 50 years. Midwinter waterfowl survey counts range from over 750,000 in 1955 to less than 300,000 in 1983 and 1984 (USFWS 2012). The 1986 North American Waterfowl Management Plan (NAWMP) population goal for black ducks was set at the 1970s level of 385,000 wintering birds; NAWMP also called for the formation of Joint Ventures (JV), including the Black Duck JV, to help institute the standard by 2000 (NAWMP 1986). Despite increased attention, the 2000 midwinter waterfowl survey count was 260,372 black ducks with as few as 246,334 wintering black ducks counted in 2012 (USFWS 2012). Their population remains more than 30% below the NAWMP goal (Figure 1).

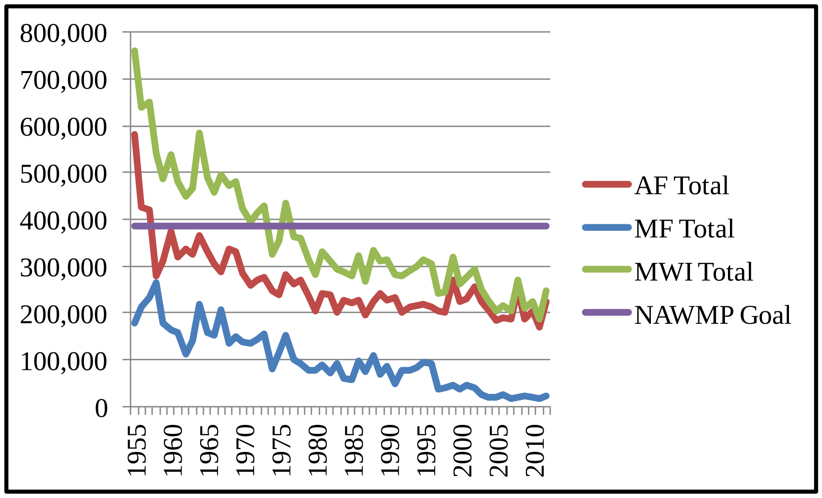

Figure 1 Number of American black ducks counted during the midwinter waterfowl survey, 1955–2012. Source: USFWS 2012.

Several explanations for the black duck decline have been proposed, principle among them overharvest, competition and hybridization with mallards *Anas platyrhynchos*, habitat loss, and disease. Attempts to identify the primary factor have been inconclusive (Conroy et al. 2002). Previous studies have uncovered information regarding black duck breeding (Reed 1975; Seymour 1991; Merendino and Ankney 1994; McAuley et al. 2004; Maisonneuve et al. 2006), post-breeding (Parker 1991; Bowman and Brown 1992; Longcore et al. 2000), and wintering periods (Morton et al. 1989; Plattner et al. 2010; Cramer et al. 2012), but none have addressed their migration ecology. Migration influences the ecology, evolution, and conservation of migratory animals (Webster et al. 2002), yet migration routes and timing between breeding and wintering areas is virtually unknown for black ducks.

Information regarding chronology, length and duration of migration, and routes and stopovers of black ducks is a priority information need identified by the Black Duck (2008) and Upper Mississippi River and Great Lakes Region (UMRGLRJV; Soulliere et al. 2007) JVs. It is required for developing black duck population objectives, from which habitat objectives are estimated through the use of bioenergetics models. Additionally, knowledge of primary black duck breeding, staging, and wintering locations can help waterfowl managers direct conservation efforts in key areas.

Current information regarding the migration routes of black ducks has been derived primarily from band returns, which are generally limited to autumn and winter (Addy 1953). Spring migration routes of black ducks have never been examined, and spring migration routes do not necessarily retrace autumn routes in other waterfowl species (Bellrose 1968; Wege and Raveling 1983; Ely et al. 1997). Band returns also have provided limited insight into departure and arrival dates of black ducks during autumn migration. Coulter (1955), Bellrose (1980), and Longcore et al. (2000) offered generalizations on the timing of seasonal movements, identifying months during which migration either occurs or peaks, and Chaulk and Turner (2007) provided a similar description of arrival during spring migration by week. None are explicit, however. The same paucity of information exists for time spent on migratory stopovers (Arzel et al. 2006).

We used satellite telemetry to identify migration routes and stopovers, estimate migration chronology, and describe variation among black ducks from different regions, latitudes, and longitudes. Our study was the first attempt to examine connectivity across biomes during their annual life cycle and will supplement current research aimed at acquiring the necessary data to model habitat requirements of black ducks across their entire range.

Chapter 2

STUDY AREA

Our study area included all black duck satellite telemetry locations from winter, staging, and inferred nesting areas (Figure 2), which encompassed most of eastern North America. Black ducks are endemic to eastern North America, with a breeding range from Ontario to Newfoundland and south through the Great Lakes and mid-Atlantic coast of the U.S., and a winter range from the Great Lakes and St. Lawrence River south through the Mississippi and Atlantic Flyways (Bellrose 1980). Bellrose (1980) suggested that the single most important migration corridor for black ducks extended along the Atlantic Coast from Virginia to Atlantic Canada. Other important migration corridors in the Atlantic Flyway extended from the New England Coast to eastern Quebec and from the Chesapeake Bay to western Quebec and eastern Ontario (Bellrose 1980). In the Mississippi Flyway, the majority of black ducks used the marshes of western Lake Erie during migration into Ontario (Bellrose 1980).

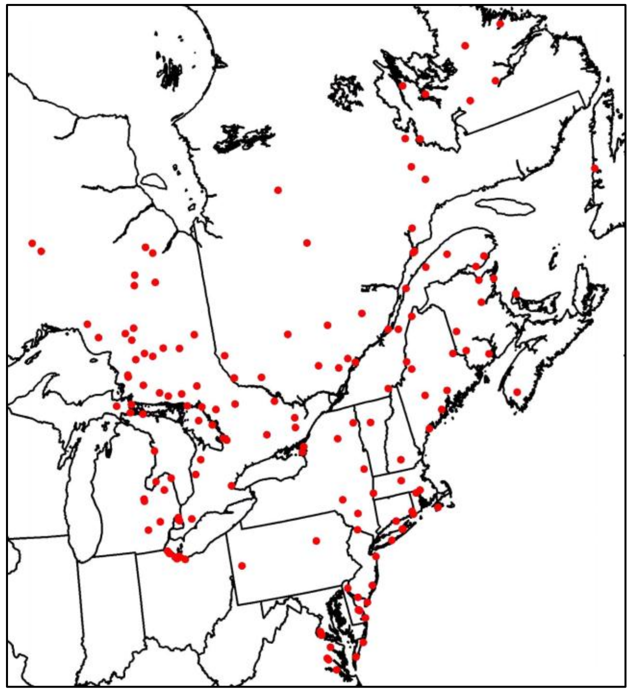

Figure 2 Geographic extent of adult female American black ducks PTT-tagged in New Jersey, Ohio, Virginia, Delaware, and New York, USA during winters 2007–2008 and 2008–2009.

We trapped black ducks during winters 2007–2008 and 2008–2009 in and around multiple sites in northern Ohio (Castalia, Mud Creek Bay, and Ottawa National Wildlife Refuge [NWR]), Virginia (Brownsville Farm, Caledon Natural Area, Chincoteague NWR, and Eastern Shore NWR), and New Jersey (Cape May NWR and Edwin B. Forsythe NWR); during winter 2008–2009, we added trap sites in Delaware (Prime Hook NWR) and Long Island, New York (Hubbard County Park) (Figure 3). We selected these locations because we were able to gain access to capture birds and also because they represented areas with the greatest densities of wintering black ducks. In 2008, over 90% of black ducks wintered in the Atlantic Flyway, with New

Jersey (136,520) holding more than half (USFWS 2012). Maryland (22,952), Maine (19,099), Massachusetts (18,491), Virginia (15,355), and New York (15,060) also were important for wintering black ducks in the Atlantic Flyway (USFWS 2012). In the Mississippi Flyway, most black ducks over-wintered in either Tennessee (6,300) or Ohio (5,644) in 2008 (USFWS 2012).

Figure 3 Approximate trapping locations for adult female American black ducks PTT-tagged in New Jersey, Ohio, Virginia, Delaware, and New York, USA during winters 2007–2008 and 2008–2009.

During winters 2007–2008 and 2008–2009, mean temperatures in the northeast region of the United States were -2.5°C and -3.2°C, or 0.6°C and 0.1°C above the 100-year average, respectively (NOAA 2013). Mean precipitation during winter 2007–2008 was 44.5 cm, or 13.1 cm above the 100-year average, and ranked 1st in the northeast region for the same period during the preceding century (NOAA 2013). Mean precipitation during winter 2008–2009 was 32.3 cm, or 0.9 cm above the 100-year average (NOAA 2013). In the central region of the United States, which included Ohio and Tennessee, mean temperatures were 1.6°C during winters 2007–2008 and 2008–2009, nearly identical to the 100-year average (NOAA 2013). Mean precipitation during winter 2007–2008 was 46.1 cm, or 13.8 cm above the 100-year average, and ranked 3rd in the central region for the same period during the preceding century (NOAA 2013). Mean precipitation during winter 2008–2009 was 34.4 cm, or 2.1 cm above the 100-year average (NOAA 2013).

Chapter 3

METHODS

Study Design

We followed protocols described by Gaunt et al. (2010) during the capture and handling of black ducks. We captured black ducks using cloverleaf (swim-in) traps, walk-in traps, and rocket nets baited with corn. We used bill, cloacal, and feather (Ashley et al. 2006) characteristics to identify and retain after second year females because of their role in population dynamics and previous experience with migration (Miller et al. 2005*a*). Additionally, we weighed after second year females and selected only those that were ≥1000 g. Females with lower body mass are more likely to be adversely affected by satellite transmitters because of mass or aerodynamic impacts that result in aberrant behavior or mortality (Miller et al. 2005a).

We affixed to each selected female a standard USGS leg band and solar-powered, satellite Model 100 Platform Transmitting Terminal (PTT; Microwave Telemetry, Columbia, MD). Each PTT weighed 22 g, measured 62 mm x 22 mm x 21 mm, and had a 178 mm-long nylon-coated flexible-stranded stainless steel antenna that protruded posteriorly at a 45° angle. We attached all PTTs mid-dorsally between the wings by a 0.38 cm-wide harness made of Natural Tubular Teflon® tape (Bally Ribbon Mills, Bally, PA). Each harness set was 13 g and included breast and belly loops connected by a strap along the edge of the keel, similar to designs used by Malecki et al. (2001), Petrie and Wilcox (2003), and Miller et al. (2005a,b). Each PTT and harness together totaled 3% of average body mass at capture ($\bar{x}$ = 1,134 g, SE = 13.6 g), which satisfied the 3% guideline established by Gaunt et al. (2010) and U.S. Geological Survey Bird Banding Laboratory (http://www.pwrc.usgs.gov/bbl/MANUAL/aarequs.cfm). We held marked females to afford them time to acclimate to the harness and then released them diurnally at the capture site within 24 h following capture. Because we attached PTTs prior to spring departure, marked females had time to adjust to the transmitter (Cox and Afton 1998) and potentially find new mates if necessary (Miller et al. 2005a).

We programmed PTTs to acquire six GPS fixes daily, which we staggered to provide consistent 24 h coverage of bird movement throughout the year. The only exceptions were PTTs deployed during winter 2008–2009, which we programmed to acquire four fixes daily from November–February. We instituted the change due to radio performance issues encountered during the same period among transmitters deployed the previous winter. We primarily used GPS fixes because of their accuracy (±15 m). However, because PTTs do not transmit continuously, we used Argos (Argos, Inc., Landover, MD) fixes to supplement incomplete or missing data. Argos estimates positional locations from the Doppler shift in transmission frequency and groups them into seven Location Classes (LCs) based on accuracy (Argos 2011). Although the reliability of Argos fixes is vastly improved (Britten et al. 1999; Hays et al. 2001), we used only LCs 3, 2, and 1. Argos (2011) lists their accuracy as <150, 150–350, and 350–1000 m, respectively. Hays et al. (2001) determined the least accuracy in LC 0 (>1000m), so we omitted fixes in this LC. Likewise, we omitted LCs A, B, and Z because no measure of accuracy is provided (Argos 2011). Location data from GPS and Argos fixes were uploaded every 3rd day to the Argos satellite tracking system (CLS America, Inc., Largo, MD). We tracked marked black ducks until they died or we lost contact with the PTT. We considered a female dead when it remained at the same location for more than two consecutive duty cycles simultaneously with on-board activity and temperature sensors having indicated no movement of the PTT and an irregular drop in temperature during that period, respectively (Krementz et al. 2011).

Data Analyses

We characterized terminal positions (i.e., inferred nesting and wintering areas) as movement ≤0.5 degrees latitude or longitude (Afton 2008) for ≥30 days at known areas during those respective periods (Miller et al. 2005b; Krementz et al. 2011). We defined each migratory move as a flight >0.5 degrees latitude or longitude and each stopover as a clustered location (>1 fix) varying ≤0.5 degrees (Afton 2008). We also defined arrival as the first fix at a clustered location and departure as the last fix at the same location (Miller et al. 2005a; Haukos et al. 2006). When data gaps >1 day but <10 days existed, and an individual bird made a migratory move during that time, we redefined departure as the median date and time between the last known fix at the previous clustered location and the first known fix at the next clustered location; we maintained arrival date as the latter. We did not calculate departure from the previous clustered location, arrival at the next, or length of stay at either if the data gap was ≥10 days (Miller et al. 2005a; Haukos et al. 2006). We followed the same criteria to estimate the minimum number of stopovers, length of stay at stopovers, and total straight-line distance between stopovers and terminal positions.

For comparison, we grouped black ducks by region (i.e., Mississippi Flyway–OH; North Atlantic Flyway–NJ and NY; South Atlantic Flyway–DE and VA) similar to evaluations by Rogers and Patterson (1984), Rusch et al. (1989), Petrie (1998), and Zimpfer and Conroy (2006). We also established a latitudinal boundary at the 40th parallel and a longitudinal boundary at the 76th meridian to create north–south (i.e., North–OH and NY; South–NJ, DE, and VA) and east–west (i.e., East–Eastern Shore VA, DE, NJ, and NY; West–OH and western VA) groups, respectively. We selected the 40th parallel because it afforded even data distribution and the 76th meridian because it effectively cleaved the Chesapeake Bay. According to Addy (1953), most black ducks harvested on the western shore of the Chesapeake Bay come from the northwest, whereas black ducks wintering on the Delmarva Peninsula (i.e., DE, MD Eastern Shore, and Eastern Shore of VA) come from the eastern breeding range.

We investigated the difference between date and time of departure from one terminal position and date and time of arrival at the opposite terminal position among regions and between latitudes and longitudes (Miller et al. 2005*a*; Haukos et al. 2006; Malecki et al. 2006). We also investigated the difference between minimum number of stopovers, duration of stay at stopovers (days), distance of each migratory move (km), total distance traveled (km), and rate of movement (km/h) between groups. Our intent was to determine if black ducks from any particular area were consistently included in groups disadvantaged during any facet of migration, and offer insight into potential consequences and conservation. We conducted our analyses using Analysis of Variance and Student's *t* test in JMP 9.0.1 (SAS Institute, Inc., Cary, NC). We blocked on year in JMP. We also established an a priori alpha of ≤ 0.10 to determine statistical significance similar to Krementz et al. (2012) and because it is appropriate for observational studies and useful for management purposes (Tacha et al. 1982).

Finally, we used simple linear regression in JMP to evaluate the relationship between several migratory variables (i.e., main effects) and their responses irrespective of group for the purpose of determining if any one variable affected another, which might ultimately impact life history and survival. Specifically, we analyzed all data together to determine the effect: 1) departure date had on the number of and length of stay on stopovers, and the total distance of migration, 2) total distance of migration had on the number of and length of stay at stopovers, 3) distance and duration of a migratory move had on the duration of stay at the next stopover, and 4) duration of stay at a stopover had on the distance and duration of the following migratory move.

Chapter 4

RESULTS

We affixed PTTs to 29 black ducks during winter 2007–2008 (NJ, *n* = 10; OH, *n* = 9; VA, *n* = 10) and another 39 black ducks during winter 2008–2009 (NJ, *n* = 10; OH, *n* = 11; VA, *n* = 10; DE, *n* = 5; NY, *n* = 3). Of the 29 PTTs deployed in winter 2007–2008, 12 provided a full data set during spring migration 2008 (NJ, *n* = 1; OH, *n* = 6; VA, *n* = 5). Two of the 2008 PTTs continued transmitting during winter 2008–2009 and provided another full data set during spring migration 2009. Additionally, 17 of the 39 PTTs deployed during winter 2008–2009 provided a full data set during spring migration 2009 (NJ, *n* = 1; OH, *n* = 5; VA, *n* = 4; DE, *n* = 5; NY, *n* = 2). Still another PTT provided partial data during spring migration 2009, which we included in our analyses where appropriate.

Black ducks departed wintering areas March 18–June 7 ($\bar{x}$ = April 17) and averaged 3.35 stopovers (SE = 0.3 stopovers; range 1–5 stopovers) and 6.44 d at stopovers (SE = 0.8 d; range 0.54–12.2 d) during spring migrations 2008 and 2009 combined (Table 1). Departure date and duration of stay on stopovers did not vary by region, latitude, or longitude (Tables 2–4). However, South Atlantic Flyway black ducks took nearly twice as many stopovers as Mississippi and North Atlantic Flyway black ducks (Table 2), as did black ducks south of the 40th parallel (Table 3). During spring migrations both years, black ducks migrated 1,126.1 km (SE = 89.5 km; range 270–1,396 km) before they arrived at inferred nesting areas April 16–June 28 ($\bar{x}$ = May 9). The average distance of each migratory move did not vary by region, latitude, or longitude (Tables 2–4), although black ducks south of the 40^{th} parallel migrated almost 10 km/h faster during each migratory move than northern black ducks (Table 3). In total, South Atlantic Flyway black ducks migrated almost twice as far as those from the Mississippi and North Atlantic Flyways (Table 2), black ducks south of the 40^{th} parallel migrated more than 50% farther than those to the north (Table 3), and black ducks east of the 76^{th} meridian migrated nearly 25% farther than those to the west (Table 4). Likewise, black ducks from the South and North Atlantic Flyways arrived at inferred nesting areas approximately 2 and 4 weeks after those from the Mississippi Flyway, respectively (Table 2). Black ducks south of the 40^{th} parallel arrived at inferred nesting areas 2 weeks after those to the north (Table 3), and black ducks east of the 76^{th} meridian arrived at inferred nesting areas 3 weeks after those to the west (Table 4).

Table 1 Range of departure dates from wintering areas (mean), arrival dates on inferred nesting areas (mean), # of stopovers (mean ± SE), duration of stay (days; mean ± SE), and total distance traveled (km; mean ± SE) of adult female American black ducks PTT-tagged in New Jersey, Ohio, Virginia, Delaware, and New York, USA during spring migrations 2008 and 2009.

Year	Trap Site	*n*	Departure date	Arrival date	# of stopovers	Duration of stay	Total distance
2008	NJ	1	6 May	8 May	1.00 ±	0.54	795.4 ±
	OH	6	22 Mar–22 Apr (7 Apr)	8 Apr–14 May (24 Apr)	2.67 ± 0.6	6.40 ± 3.4	802.8 ± 83.6
	VA	5	26 Mar–25 May (13 Apr)	21 Apr–10 July (21 May)	5.00 ± 0.6	6.40 ± 1.5	1702.2 ± 217.4
	All	12	26 Mar–25 May (17 Apr)	8 Apr–10 July (6 May)	3.50 ± 0.6	6.28 ± 1.2	1176.9 ± 163.3
2009	NJ	1	7 June	28 June	2.00 ±	10.1 ± 3.2	270.4 ±
	OH	7	1 Apr–7 May (19 Apr)	16 Apr–19 May (5 May)	2.14 ± 0.6	6.14 ± 1.6	810.3 ± 120.6
	VA	4	21 Mar–22 Apr (10 Apr)	23 Apr–15 May (7 May)	4.00 ± 0.4	6.20 ± 1.9	1395.6 ± 168.7
	DE	5	31 Mar–13 May (21 Apr)	25 Apr–30 May (12 May)	4.20 ± 0.8	4.66 ± 1.3	1363.3 ± 203.8
	NY	2	18 Mar–8 Apr (28 Mar)	4 May–1 June (18 May)	4.00 ± 2.0	12.2 ± 5.4	1222.5 ± 216.2
	All	19	18 Mar–7 June (18 Apr)	16 Apr–28 June (11 May)	3.26 ± 0.4	6.55 ± 1.0	1094.0 ± 106.5
Both	All	31	18 Mar–7 June (17 Apr)	16 Apr–28 June (9 May)	3.35 ± 0.3	6.44 ± 0.8	1126.1 ± 89.5

Table 2 Migratory variables (mean ± SE) of adult female American black ducks by region during spring 2008 and 2009. Levels not connected by the same letter within a row are significantly different.

	Region								
	Mississippi		North Atlantic		South Atlantic				
	n	$\bar{x}$ ± SE	*n*	$\bar{x}$ ± SE	*n*	$\bar{x}$ ± SE	*df*	*F*	*P*
Departure date[1]	14	14 Apr ± 3.6	4	25 Apr ± 17.6	14	16 Apr ± 5.0	2, 28	0.39	0.68
Departure time[2]	14	1921 ± 1.6	4	1600 ± 7.9	14	1750 ± 1.8	2, 28	0.88	0.42
Arrival date	14	30 Apr ± 3.4 B	4	26 May ± 12.6 A	14	14 May ± 5.3 A	2, 28	3.74	0.04
Arrival time	14	1457 ± 4.0	4	1225 ± 6.1	14	1371 ± 4.1	2, 28	0.10	0.90
# of stopovers	13	2.38 ± 0.4 B	4	2.75 ± 1.1 B	14	4.43 ± 0.4 A	2, 27	6.23	<0.01
Duration of stay[3]	33	6.26 ± 1.2	11	10.75 ± 4.0	62	5.77 ± 0.9	2, 102	1.92	0.15

[1] SE in days
[2] Military time ± hours
[3] Days

Table 2, cont.

Total distance[4]	13	806.8 ± 72.5 B	4	877.7 ± 242.7 B	14	1493.6 ± 116.2 A	2, 27	12.4	<0.01
Distance (leg)	48	237.8 ± 27.5	15	234.1 ± 43.6	76	275.1 ± 20.0	2, 135	0.78	0.46
Rate of movement[5]	48	32.7 ± 3.5	15	31.8 ± 3.8	76	41.4 ± 3.3	2, 135	2.08	0.13

[4] Km
[5] Km/h

Table 3 Migratory variables (mean ± SE) of adult female American black ducks by latitude during spring 2008 and 2009. Levels not connected by the same letter within a row are significantly different.

	Latitude						
	North		South				
	n	$\bar{x}$ ± SE	*n*	$\bar{x}$ ± SE	*df*	*F*	*P*
Departure date[1]	16	12 Apr ± 3.6	16	21 Apr ± 5.5	1, 29	1.75	0.20
Departure time[2]	16	1806.3 ± 2.3	16	1806.3 ± 1.7	1, 29	0.00	1.00
Arrival date	16	2 May ± 3.5 B	16	17 May ± 5.4 A	1, 29	4.60	0.04
Arrival time	16	1444.8 ± 3.8	16	1337.5 ± 3.6	1, 29	0.11	0.74
# of stopovers	15	2.6 ± 0.4 B	16	4.1 ± 0.4 A	1, 28	5.85	0.02
Duration of stay[3]	41	7.41 ± 1.4	65	5.82 ± 0.9	1, 103	1.02	0.32

[1] SE in days
[2] Military hours ± hours
[3] Days

Table 3, cont.

Total distance[4]	15	862.3 ± 76.0 B	16	1373.5 ± 132.5 A	1, 28	10.7	<0.01
Distance (leg)	58	239.0 ± 24.5	81	271.3 ± 19.3	1, 136	1.09	0.30
Rate of movement[5]	58	31.7 ± 3.0 B	81	41.5 ± 3.1 A	1, 136	4.99	0.03

[4] Km
[5] Km/h

Table 4 Migratory variables (mean ± SE) of adult female American black ducks by longitude during spring 2008 and 2009. Levels not connected by the same letter within a row are significantly different.

	Longitude						
	East		West				
	n	$\bar{x}$ ± SE	*n*	$\bar{x}$ ± SE	*df*	*F*	*P*
Departure date[1]	11	23 Apr ± 7.9	21	3 Apr ± 2.8	1, 29	1.77	0.19
Departure time[2]	11	1718.2 ± 3.0	21	1852.4 ± 1.5	1, 29	0.01	0.94
Arrival date	11	23 May ± 7.2 A	21	2 May ± 2.6 B	1, 29	7.76	0.01
Arrival time	11	1409.1 ± 4.6	21	1381.0 ± 3.1	1, 29	2.31	0.14
# of stopovers	11	4.0 ± 0.6	20	3.0 ± 0.4	1, 28	0.01	0.94
Duration of stay[3]	44	7.16 ± 1.4	62	5.93 ± 0.9	1, 103	0.43	0.51

[1] SE in days
[2] Military time ± hours
[3] Days

Table 4, cont.

Total distance[4]	11	1284.4 ± 165.0 A	20	1039.1 ± 102.9 B	1, 28	3.68	0.07
Distance (leg)	55	256.9 ± 22.5	84	258.4 ± 20.5	1, 136	<0.01	0.96
Rate of movement[5]	55	39.7 ± 4.0	84	35.9 ± 2.6	1, 136	0.98	0.32

[4] Km
[5] Km/h

Black ducks followed a variety of routes during spring migrations both years (Figure 4). Nine black ducks spent all or portions of migration along the Atlantic Coast, and 10 used the Hudson and St. Lawrence River valleys. Stopovers included Long Island Sound, NY, Narragansett Bay, RI, Lake Champlain, VT, Merrymeeting Bay, ME, and the Gulf of St. Lawrence, Canada. During spring 2008, the routes of two females wintering on opposite sides of the Chesapeake Bay converged along the St. Lawrence River in Quebec and mirrored one another to Labrador. All 11 black ducks wintering in Ohio stopped at Lake St. Clair, Saginaw Bay, St. Mary's River, and the Georgian Bay, or some combination thereof. The two black ducks that completed spring migrations in consecutive years returned to the same respective wetlands on inferred nesting areas despite different trajectories (Figure 5). Black ducks settled into inferred nesting areas in Newfoundland (n = 1), Labrador (n = 4), New Brunswick (n = 2), Quebec (n = 7), Nova Scotia (n = 1), Vermont (n = 1), and Ontario (n = 16) (Figure 4).

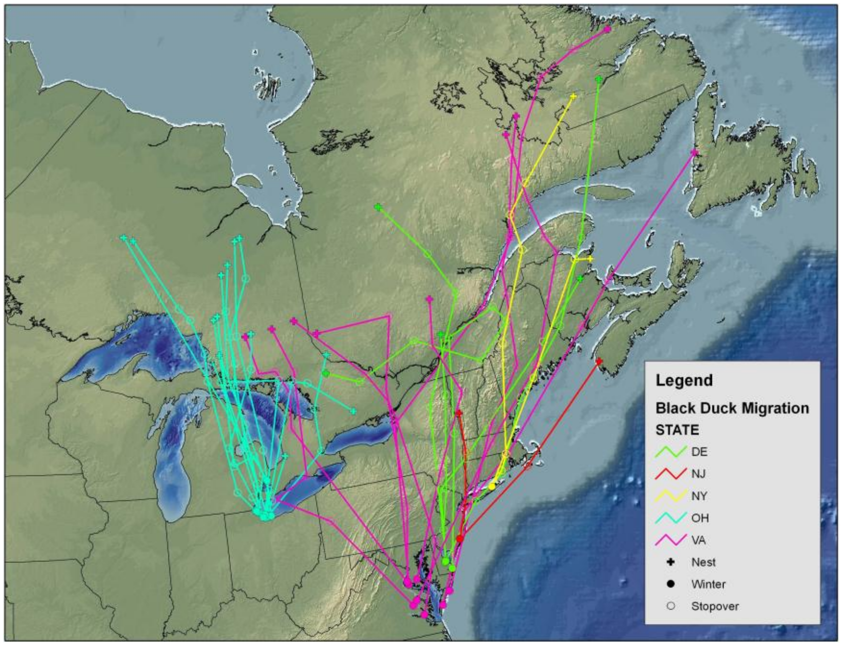

Figure 4 Spring migration routes of adult female American black ducks PTT-tagged in New Jersey, Ohio, Virginia, Delaware, and New York, USA during winters 2007–2008 and 2008–2009.

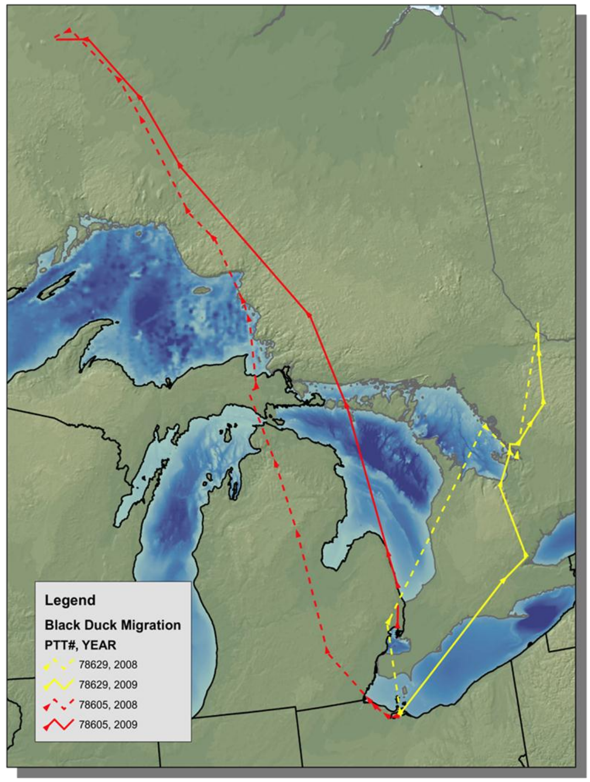

Figure 5 Spring migration routes and inferred nesting locations of 2 adult female American black ducks PTT-tagged in Ohio during winter 2007–2008.

Among all black ducks (Table 5), departure date explained 18% and number of stopovers explained 44% of the variation in duration of stay on stopovers, respectively. Total distance of migration explained 61% and 33% of the variation in number of and duration of stay on stopovers, respectively. Duration of a migratory leg explained 3% of the variation in length of stay on the next stopover.

Table 5 Relationships between migratory variables of adult female American black ducks in eastern North America during spring 2008 and 2009.

Independent Variable	Dependent Variable	*df*	*F*	*P*	R^2	β
Departure date	# of stopovers	1, 29	2.21	0.15	0.07	-0.03
Departure date	Duration of stay on stopovers (hrs)	1, 29	6.15	0.02	0.18	-8.50
Departure date	Distance of migration (total; km)	1, 29	1.30	0.26	0.04	-5.44
# of stopovers	Duration of stay on stopovers (hrs)	1, 29	23.2	<0.01	0.44	142.7
Distance of migration (total; km)	# of stopovers	1, 29	45.6	<0.01	0.61	0.003
Distance of migration (total; km)	Duration of stay on stopovers (hrs)	1, 29	14.4	<0.01	0.33	0.45
Distance of migration (leg; km)	Duration of stay on next stopover (hrs)	1, 104	0.02	0.90	<0.01	-0.01
Duration of migration (leg; hrs)	Duration of stay on next stopover (hrs)	1, 104	2.87	0.09	0.03	5.06
Duration of stay on stopover (hrs)	Distance of next migration (leg; km)	1, 104	0.63	0.43	<0.01	0.06
Duration of stay on stopovers (hrs)	Duration of next migration (leg; hrs)	1, 104	0.04	0.84	<0.01	-0.001

A total of 13 PTTs (Ohio, n = 6; Virginia, n = 3; Delaware, n = 2; New York, n = 2) provided at least partial data during autumn migrations in either 2008 or 2009. Of those, four ceased transmitting, four were lost due to hunter harvest, and five provided a full data set (Ohio, n = 2; Delaware, n = 2; New York, n = 1). Black ducks departed inferred nesting or molting areas October 5–December 1 ($\bar{x}$ = 24 October), averaged 2.0 stopovers (SE = 0.3 stopovers; range 1–4 stopovers) and 12.6 days at stopovers (SE = 3.5 d; range 0.25–41 d), migrated 993 km (SE = 202.9 km; range 277–1,485 km), and arrived at wintering areas November 18–December 18 ($\bar{x}$ = December 1) (Table 6). Only eight black ducks returned to wintering areas, of which four returned to the same location they were captured the previous winter (Prime Hook NWR, n = 2; Ottawa NWR, n = 1; Castalia, OH, n = 1). With few exceptions, black ducks that completed either full or partial autumn migrations followed different routes than their respective spring trajectories.

Table 6 Range of departure dates from inferred nesting areas (mean), arrival dates at wintering areas (mean), # of stopovers (mean ± SE), duration of stay on stopovers (d; mean ± SE), and total distance traveled (km; mean ± SE) of adult female American black ducks PTT-tagged in New Jersey, Ohio, Virginia, Delaware, and New York, USA during autumn migrations 2008 and 2009.

Inferred nesting area	*n*	Departure date	Arrival date	# of stopovers	Duration of stay	Total distance
Ontario	7	5 Oct – 3 Nov (24 Oct)	30 Nov – 11 Dec (5 Dec)	2.0 ± 0.0	13.1 ± 5.3	663.0 ± 386.0
Quebec	3	14 Oct – 4 Nov (26 Oct)	20 Nov – 18 Dec (4 Dec)	3.0 ± 1.0	9.24 ± 4.8	1200.9 ± 283.9
Labrador	2	5 Oct	18 Nov	1.0 ±	27.1 ± 14.0	1237.9 ±
New Brunswick	1	1 Dec			0.5 ±	

Chapter 5

DISCUSSION

Black ducks in this study used well-known spring migration routes (Addy 1953; Bellrose 1980) and stopovers (Bookhout et al. 1989; Jorde et al. 1989; Belanger and Lehoux 1994). Specifically, Atlantic Flyway black ducks followed the Atlantic Coast and the Hudson and St. Lawrence River Valleys, and stopped at Long Island Sound, NY, Narragansett Bay, RI, Lake Champlain, VT, Merrymeeting Bay, ME, and the Gulf of St. Lawrence, Canada. In the Mississippi Flyway, black duck migration centered on the Great Lakes, notably Saginaw Bay, MI, Georgian Bay, ON, and the international Lake St. Clair and St. Mary's River, similar to descriptions by Bellrose (1980) and Jorde et al. (1989).

Our PTT-derived data corroborate band recoveries used to detect strong associations between black ducks wintering in the Mississippi and South Atlantic Flyways to breeding areas in western Quebec and Ontario (Zimpfer and Conroy 2006), despite changes in land use and other environmental variables unfavorable to black ducks in the latter (Rogers and Patterson 1984). All 14 Ohio black ducks stayed in the Mississippi Flyway during spring migrations. Ohio black ducks were joined by four more from the South Atlantic Flyway: two birds from western Virginia migrated directly into the Great Lakes region before advancing into Ontario, and one bird each from Delaware and western Virginia settled in Ontario after spending most of their migrations in the Atlantic Flyway. Contrary to Addy (1953), western Virginia black ducks displayed no apparent aversion to crossing the Chesapeake Bay; three of seven crossed it at the onset of spring migrations and progressed into the eastern breeding range. Excepting the single Delaware bird that settled in Ontario, all six black ducks wintering on the Delmarva Peninsula proceeded into the eastern breeding range, however.

Waterfowl migration may span several months each year, though migration chronology varies by species (Arzel et al. 2006), season (Wege and Raveling 1983; Petrie and Wilcox 2003), year (Wege and Raveling 1983; Murphy-Klassen et al. 2005), origin (Haukos et al. 2006), and destination (Miller et al. 2005a). Among black ducks, spring migration is gradual, beginning in February and continuing through April (Bellrose 1980; Arzel et al. 2006). We failed to detect a difference in the onset of migration, as black ducks from different regions, latitudes, and longitudes departed wintering areas at approximately the same time irrespective of year. Our data suggests the severe weather experienced during winter 2007–2008 had no discernible effect on departure date among black ducks when compared to the milder winter 2008–2009.

South Atlantic black ducks migrated farther, took more stopovers, spent a greater amount of time on stopovers, and despite travelling faster, still arrived later at inferred nesting areas. Their behavior is consistent with the increased energetic demand of longer migrations (Arzel et al. 2006; Newton 2006) and has the potential to adversely affect reproductive success (Heitmeyer and Fredrickson 1981; Kaminski and

Gluesing 1987; Raveling and Heitmeyer 1989; Devries et al. 2008). Hens in better body condition upon reaching the breeding grounds have a greater propensity to breed (Alisauskas and Ankney 1992), earlier onset of egg-laying (Dubovsky and Kaminski 1994), increased clutch size (Krapu 1981), and are better able re-nest if a nest is destroyed (Arnold et al. 2002). Given that departure date was a non-factor in all group-wise comparisons, the tardiness in arriving at inferred nesting areas among South Atlantic Flyway black ducks was likely a result of the positive relationship between total distance of migration and both number of and duration of stay on stopovers. Regardless, Rohwer (1992) summarized an enormous volume of work when he asserted that nesting chronology affects clutch size, recruitment, and survival, and black ducks from their southern wintering and western breeding ranges have experienced disproportionate declines (Rogers and Patterson 1984; Petrie 1998; Zimpfer and Conroy 2006). While we do not have any direct evidence linking delayed arrival at inferred nesting areas with population declines among South Atlantic Flyway black ducks, the potential for causality warrants further consideration.

When developing its habitat goals, the UMRGLRJV assumed black ducks settle in the region 45 d during spring migration, 90 d over winter, and 15 d during autumn migration, for a total estimate of 150 d (Soulliere et al. 2007). In this study, Ohio black ducks spent only 7.22 d (SE = 2.0 d; range 0.08–23.2 d) in the JV region during spring migration, but multi-year data from two Ohio birds indicated they stay approximately 144 d over winter. Although fall data was limited, if we define duration of stay in the JV region as half the total duration of stay on fall stopovers among black ducks that departed inferred nesting or molting areas in Ontario (Table 6), we derive a total estimate of 164 d spent in the JV region.

The UMRGLRJV established its black duck population goal as a product of the NAWMP goal and the proportion of black ducks harvested in the JV region. The JV population goal was multiplied by estimated duration of stay to arrive at duck use days, which were then related to the daily energetic requirement of black ducks, total energy required to achieve the JV population goal, and total energy available on the landscape to arrive at the amount of habitat required to meet the JV population goal. Soulliere et al. (2007) asserted black ducks almost exclusively use healthy, coastal marshes and other large marsh and open water complexes >10 ha during all life cycle stages in the JV region. Therefore, it is possible the UMRGLRJV underestimated the annual habitat requirements for black ducks in the region by 5,036 ha, or nearly 10%, during the 2 years of our study.

Transmitter weight, limited sample size (i.e., $n < 30$), and attachment methodologies have the potential to bias results in satellite tracking studies of migratory animals (Webster et al. 2002; Miller et al. 2005a; Lindbergh and Walker 2007; Barron et al. 2010). We affixed PTTs to 68 black ducks at wintering areas that accounted for 67% of all black ducks counted during the 2008 midwinter waterfowl survey (USFWS 2012). In the future, samples from New England, the southern Mississippi Flyway, or elsewhere black ducks are concentrated during winter are advised. Although our geographic distribution of marked black ducks did not equally represent all wintering areas, we attempted to distribute our effort between latitudes and longitudes as best as possible given cost and logistical considerations. We therefore restrict inference to our sample of marked black ducks during the 2 years we tracked them. However, we also compare our findings to available observational and banding data on black duck migration chronology, suggest how they might inform conservation and management of black ducks and their habitats, and provide suggestions for future research to increase the temporal and spatial scope of knowledge regarding black duck ecology.

To develop habitat conservation goals based on energetic carrying capacity models, planners must estimate duration of stay at stopovers by migrating waterfowl. Our data suggests the UMRGLRJV overestimated the habitat needs of black ducks in the region during spring 2008 and 2009, and may have underestimated the total habitat required during all seasons during the 2 years of our study. We suggest the UMRGLRJV and others consider using satellite telemetry data with waterfowl counts (Petrie et al. 2011) and food availability sampling (Brasher et al. 2007, Straub et al. 2012) when refining habitat goals used in waterfowl management strategies. Additionally, black ducks in our study used previously described migration corridors and stopovers, supporting the need for their continued conservation and management. Because black ducks acquire resources at stopovers during spring migration, an increased emphasis should be placed on protection and active management of key wetland types along known routes with the aim of increasing the likelihood of reproduction and survival while simultaneously helping achieve the NAWMP population goal for black ducks.

REFERENCES

Addy CE. 1953. Fall migration of the black duck. United States Department of the Interior, Fish and Wildlife Service. Special Scientific Report: Wildlife No. 19.

Afton AD. 2008. Chronology and rates of migratory movements, migration corridors, and habitats used throughout the annual life cycle by female lesser scaup radio-marked on Pool 19 of the Mississippi River. Progress Report submitted to the Upper Mississippi River and Great Lakes Region Joint Venture, 10 November 2008. Available: http://www.ppjv.org/PPJV_presntations/Pool%2019%20 Progress%20Report%2011-10-2008.pdf (March 2009).

Alisauskas RT, Ankney CD. 1992. The cost of egg laying and its relationship to nutrient reserves in waterfowl. Pages 30–61 in Batt BDJ, Afton AD, Anderson MG, Ankney CD, Johnson DH, Kadlec JA, Krapu GL, editors. Ecology and management of breeding waterfowl. Minneapolis, Minnesota: University of Minnesota Press.

Argos. 2011. Argos user's manual. Service Argos, Inc., Landover, Maryland. Available: http://www.argos-system.org/files/pmedia/public/r363_9_argos_ manual_en.pdf. (March 2009).

Arnold TW, Howerter DW, Devries JH, Joynt BL, Emery RB, Anderson MG. 2002. Continuous laying and clutch-size limitation in mallards. Auk 119:261–266.

Arzel C, Elmberg J, Guillemain M. 2006. Ecology of spring-migrating Anatidae: a review. Journal of Ornithology 147:167–184.

Ashley EP, North NR, Petrie SA, Bailey RC. 2006. Age determination of American black ducks in winter and spring. Wildlife Society Bulletin 34:1401–1410.

Barron DG, Brawn JD, Weatherhead PJ. 2010. Meta-analysis of transmitter effects on avian behavior and ecology. Methods in Ecology and Evolution 1:180–187.

Belanger L, Lehoux D. 1994. Use of a tidal saltmarsh and coastal impoundments by sympatric breeding and staging American black ducks, *Anas rubripes*, and mallards, *A. platyrynchos*. Canadian Field Naturalist 108:311–317.

Bellrose FC. 1968. Waterfowl migration corridors east of the Rocky Mountains in the United States. Illinois Natural History Survey Biological Notes 61.

Bellrose FC. 1980. Ducks, Geese, and Swans of North America. 3rd edition. Mechanicsburg, Pennsylvania: Stackpole.

[BDJV] Black Duck Joint Venture. 2008. Black Duck Joint Venture Strategic Plan 2008–2013. U.S. Fish and Wildlife Service, Hadley, Massachusetts. Available: http://www.blackduckjv.org/docs/BDJV%20Strategic%20Plan%20 2008_2013.pdf (December 2012).

Bookhout TA, Bednarick KE, Kroll RW. 1989. The Great Lakes marshes. Pages 131–156 in Smith LM, Pederson RL, Kaminski RM, editors. Habitat management for migrating and wintering waterfowl in North America. Lubbock, Texas: Texas Tech University Press.

Bowman TD, Brown PW. 1992. Site fidelity of male black ducks to a molting area in Labrador. Journal of Field Ornithology 63:32–34.

Brasher MG, Steckel JD, Gates RJ. 2007. Energetic carrying capacity of actively and passively managed wetlands for migration ducks in Ohio. Journal of Wildlife Management 71:2532–2541.

Britten MW, Kennedy PL, Ambrose S. 1999. Performance and accuracy evaluation of small satellite transmitters. Journal of Wildlife Management 63:1349–1358.

Chaulk KG, Turner B. 2007. The timing of waterfowl arrival and dispersion during spring migration in Labrador. Northeastern Naturalist 14:375–386.

Conroy MJ, Miller MW, Hines JE. 2002. Identification and synthetic modeling of factors affecting American black duck populations. Wildlife Monographs 150:1–64.

Coulter MW. 1955. Spring food habits of surface-feeding ducks in Maine. Journal of Wildlife Management 19:263–267.

Cox RR Jr., Afton AD. 1998. Effects of capture and handling on survival of female northern pintails. Journal of Field Ornithology 69:276–287.

Cramer DM, Castelli PM, Yerkes T, Williams CK. 2012. Food resource availability for American black ducks wintering in southern New Jersey. Journal of Wildlife Management 76:214–219.

Devries JH, Brook RW, Howerter DW, Anderson MG. 2008. Effects of spring body condition and age on reproduction in mallards (*Anas platyrhynchos*). Auk 125:618–628.

Dubovsky JA, Kaminski RM. 1994. Potential reproductive consequences of winter-diet restriction in mallards. Journal of Wildlife Management 58:780–786.

Ely CR, Douglas DC, Fowler AC, Babcock CA, Derksen DV, Takekawa JY. 1997. Migration behavior of tundra swans from the Yukon-Kuskokwim Delta, Alaska. Wilson Bulletin 109:679–692.

Gaunt AS, Oring LW, Able KP, Anderson DW, Baptista LF, Barlow JC, Wingfield JC, editors. 2010. Guidelines to the use of wild birds in research. The Ornithological Council, Washington, D.C. Available: http://www.nmnh.si.edu/BIRDNET/documents/guidlines/Guidelines_August 2010.pdf (December 2012).

Haukos DA, Miller MR, Orthmeyer DL, Takekawa JY, Fleskes JP, Casazza ML, Perry WM, Moon JA. 2006. Spring migration of northern pintails from Texas and New Mexico, USA. Waterbirds 29:127–136.

Hays GC, Akesson S, Godley BJ, Luschi P, Santidrian P. 2001. The implications of location accuracy for the interpretation of satellite-tracking data. Animal Behaviour 61:1034–1040.

Heitmeyer ME, Fredrickson LH. 1981. Do wetland conditions in the Mississippi Delta hardwoods influence mallard recruitment? Transactions of the 46th North American Wildlife and Natural Resources Conference 46:44–57.

Hindman LJ, Stotts VD. 1989. Chesapeake Bay and North Carolina Sounds. Pages 27–55 in Smith LM, Pederson RL, Kaminski RM, editors. Habitat management for migrating and wintering waterfowl in North America. Lubbock, Texas: Texas Tech University Press.

Jorde DG, Longcore JR, Brown PW. 1989. Tidal and non-tidal wetlands of the northern Atlantic states. Pages 1–26 in Smith LM, Pederson RL, Kaminski RM, editors. Habitat management for migrating and wintering waterfowl in North America. Lubbock, Texas: Texas Tech University Press.

Kaminski RM, Gluesing EA. 1987. Density and habitat related recruitment in mallards. Journal of Wildlife Management 51:141–148.

Krapu GL. 1981. The role of nutrient reserves in mallard reproduction. Auk 98:29–38.

Krementz DG, Asante K, Naylor LW. 2011. Spring migration of mallards from Arkansas as determined by satellite telemetry. Journal of Fish and Wildlife Management 2:156–168.

Krementz DG, Asante K, Naylor LW. 2012. Autumn migration of Mississippi Flyway mallards as determined by satellite telemetry. Journal of Fish and Wildlife Management 3:238–251.

Lindberg MS, Walker J. 2007. Satellite telemetry in avian research and management: sample size considerations. Journal of Wildlife Management 71:1002–1009.

Longcore JR, McAuley DG, Hepp GR, Rhymer JM. 2000. American black duck (*Anas rubripes*) in Poole A, Gill F, Editors. The Birds of North America Online. Cornell Lab of Ornithology. Available: http://bna.birds.cornell.edu/bna/species/481 (October 2008).

Maisonneuve C, Belanger L, Bordage D, Jobin B, Grenier M, Beaulieu J, Gabor S, Filion B. 2006. American black duck and mallard breeding distribution and habitat relationships along a forest-agriculture gradient in southern Quebec. Journal of Wildlife Management 70:450–459.

Malecki RA, Batt BDJ, Sheaffer SE. 2001. Spatial and temporal distribution of Atlantic Population Canada geese. Journal of Wildlife Management 65:242–247.

Malecki R, Sheaffer S, Howell D, Strange T. 2006. Northern pintails in eastern North America: their seasonal distribution, movement patterns, and habitat affiliations. Final Report submitted to the Atlantic Flyway Council 31 July 2006. Available: http://www.ncwildlife.org/Portals/0/Hunting/Documents/northern_pintail_final_report.pdf (March 2009).

McAuley DG, Clugston DA, Longcore JR. 2004. Dynamic use of wetlands by black ducks and mallards: evidence against competitive exclusion. Wildlife Society Bulletin 32:465–473.

Merendino MT, Ankney CD. 1994. Habitat use by mallards and American black ducks breeding in Central Ontario. Condor 96:411–421.

Miller MR, Takekawa JY, Fleskes JP, Orthmeyer DL, Casazza ML, Perry WM. 2005*a*. Spring migration of northern pintails from California's Central Valley wintering area tracked with satellite telemetry: routes, timing, and destinations. Canadian Journal of Zoology 83:1314–1332.

Miller MR, Takekawa JY, Fleskes JP, Orthmeyer DL, Casazza ML, Haukos DA, Perry WM. 2005*b*. Flight speeds of northern pintails during migration determined using satellite telemetry. Wilson Bulletin 117:364–374.

Morton JM, Fowler AC, Kirkpatrick RL. 1989. Time and energy budgets of American black ducks in winter. Journal of Wildlife Management 53:401–410.

Murphy-Klassen HM, Underwood TJ, Sealy SG, Czyrnyj AA. 2005. Long-term trends in spring arrival dates of migrant birds at Delta Marsh, Manitoba, in relation to climate change. Auk 122:1130–1148.

[NOAA] National Oceanic and Atmospheric Administration. 2013. National Climatic Data Center Climate at a Glance. Available: http://www.ncdc.noaa.gov/cag/ (March 2013).

Newton I. 2006. Can conditions experienced during migration limit the population levels of birds? Journal of Ornithology 147:146–166.

[NAWMP] North American Waterfowl Management Plan. 1986. North American waterfowl management plan: a strategy for cooperation. Available: http://www.fws.gov/birdhabitat/NAWMP/files/NAWMP.pdf (March 2009).

Parker GR. 1991. Survival of juvenile American black ducks on a managed wetland in New Brunswick. Journal of Wildlife Management 55:466–470.

Petrie MJ. 1998. The role of interspecific competition in the decline of the black duck. Doctoral dissertation. Columbia: University of Missouri.

Petrie SA, Wilcox KL. 2003. Migration chronology of Eastern Population tundra swans. Canadian Journal of Zoology 81:861–870.

Petrie MJ, Brasher MG, Soulliere GJ, Tirpak JM, Pool DB, Reker RR. 2011. Guidelines for establishing joint venture waterfowl population abundance objectives. North American Waterfowl Management Plan Science Support Team Technical Report 3–10–2011. Available: http://www.fws.gov/birdhabitat/NAWMP/NSST/files/GuidelinesforEstablishingJVPopulationObjectives.pdf (December 2012**)**.

Plattner DM, Eichholz MW, Yerkes T. 2010. Food resources for wintering and spring staging black ducks. Journal of Wildlife Management 74:1554–1558.

Raveling DG, Heitmeyer ME. 1989. Relationships of population size and recruitment of pintails to habitat conditions and harvest. Journal of Wildlife Management 53:1088–1103.

Reed A. 1975. Reproductive output of black ducks in the St. Lawrence estuary. Journal of Wildlife Management 39:243–255.

Rohwer FC. 1992. The evolution of reproductive patters in waterfowl. Pages 486–539 in Batt BDJ, Afton AD, Anderson MG, Ankney CD, Johnson DH, Kadlec JA, Krapu GL, editors. Ecology and management of breeding waterfowl. Minneapolis, Minnesota: University of Minnesota Press.

Rogers JP, Patterson JH. 1984. The black duck population and its management. Transactions of the North American Wildlife and Natural Resources Conference 49:527–534.

Rusch DH, Ankney CD, Boyd H, Longcore JR, Montalbano F III, Ringelman JK, Stotts VD. 1989. Population ecology and harvest of the American black duck: a review. Wildlife Society Bulletin 17:379–406.

Serie JR. 2002. The American black duck: a species of international concern. Pages 2–7 in Perry MC, editor. Black ducks and their Chesapeake Bay habitats: proceedings of a symposium. U.S. Geological Survey, Reston, Virginia. Available: http://www.pwrc.usgs.gov/prodabs/perry/6039_perry_searchable.pdf (March 2009).

Seymour NR. 1991. Philopatry in male and female American black ducks. Condor 93:189–191.

Sokal RR, Rohlf FJ. 1998. Biometry: the principles and practices of statistics in biological research. 3rd edition. New York, New York: W.H. Freeman and Company.

Soulliere GJ, Potter BA, Coluccy JM, Gatti RC, Roy CL, Luukkonen DR, Brown PW, Eichholz MW. 2007. Upper Mississippi River and Great Lakes Region Joint Venture Waterfowl Habitat Conservation Strategy. Fort Snelling, Minnesota: U.S. Fish and Wildlife Service. Available: http://www.uppermissgreatlakesjv.org/docs/UMRGLR_JV_WaterfowlHCS.pdf (March June 2009).

Straub JN, Gates RJ, Schultheis RD, Yerkes T, Coluccy JM, Stafford JD. 2012. Wetland food resources for spring-migrating ducks in the Upper Mississippi River and Great Lakes Region. Journal of Wildlife Management 76:768–777.

Tacha TC, Warde WD, Burnham EP. 1982. Use and interpretation of statistics in wildlife journals. Wildlife Society Bulletin 10:355–362.

[USFWS] U. S. Fish and Wildlife Service. 2012. Migratory Bird Data Center. Mid-Winter Waterfowl Survey. Available: http://mbdcapps.fws.gov/ (June 2012).

Webster MS, Marra PP, Haig SM, Bensch S, Holmes RT. 2002. Links between worlds: unraveling migratory connectivity. Trends in Ecology and Evolution 17:76–83.

Wege ML, Raveling DG. 1983. Factors influencing the timing, distance, and path of migrations of Canada geese. Wilson Bulletin 95:209–221.

Zimpfer NL, Conroy MJ. 2006. Modeling movement and fidelity of American black ducks. Journal of Wildlife Management 70:1770–1777.