2011

FALCONTRAK: Final Report

B. D. Watts
The Center for Conservation Biology, bdwatt@wm.edu

S. M. Padgett
The Center for Conservation Biology

Elizabeth K. Mojica
The Center for Conservation Biology, lmojica@edmlink.com

B J. Paxton
The Center for Conservation Biology, bjpaxt@wm.edu

Recommended Citation

Watts, B. D., S. M. Padgett, E. K. Mojica, and B. J. Paxton. 2011. FALCONTRAK: Final Report. CCBTR-11-07. Center for Conservation Biology Technical Report Series. College of William and Mary, Williamsburg, VA. 33 pp.

PROJECT FALCONTRAK: FINAL REPORT

CENTER FOR CONSERVATION BIOLOGY
COLLEGE OF WILLIAM AND MARY
VIRGINIA COMMONWEALTH UNIVERSITY

PROJECT FALCONTRAK: FINAL REPORT

Bryan D. Watts, PhD, Shawn M. Padgett, Elizabeth K. Mojica, Barton J. Paxton
Center for Conservation Biology
College of William and Mary
Virginia Commonwealth University

Recommended Citation:

Watts, B. D., S. M. Padgett, E. K. Mojica, and B. J. Paxton. 2011. FALCONTRAK: Final Report. Center for Conservation Biology Technical Report Series. CCBTR-11-07. College of William and Mary, Williamsburg, VA. 33 pp.

Cover Photo by: Bryan Watts

Project Funded By:

Dominion
National Aeronautics and Space Administration
Virginia Department of Game & Inland Fisheries
National Park Service
United States Fish & Wildlife Service
Center for Conservation Biology

The Center for Conservation Biology is an organization dedicated to discovering innovative solutions to environmental problems that are both scientifically sound and practical within today's social context. Our philosophy has been to use a general systems approach to locate critical information needs and to plot a deliberate course of action to reach what we believe are essential information endpoints.

Table of Contents

EXECUTIVE SUMMARY

FalconTrak is a cooperative project designed to answer questions about the movements and survival of Peregrine Falcons (*Falco peregrinus*) within the mid-Atlantic region. We tracked 61 falcons between 2001 and 2011 with solar-powered, satellite transmitters to investigate the spatial dynamics of their annual cycle and to identify causes of mortality. Birds included 40 females and 21 males from coastal bridges (20), nesting towers (36), a high-rise building (2), and a captive breeder (3). Birds were either released from mountain hack sites (31) or allowed to fledge *in situ* (30). We received 66,343 signals of usable quality from transmitters. Movement patterns were used to subdivide the annual cycle into biologically meaningful units. Periods used included 1) Pre-dispersal, 2) post-dispersal, 3) fall migration, 4) winter, 5) spring migration, and 6) summer.

More than half of the falcons that survived into the fall period migrated south of the mid-Atlantic region. Individuals did not change their migratory status between years. On average, southbound migration lasted 23 days and birds traveled 3,106 km. Fledging location had a dramatic influence on both migratory route and the location of winter home ranges. Birds that were fledged on the coast were the only birds to migrate to the tropics. Two of these birds crossed over to the Pacific Coast and wintered in Panama and Columbia. Birds from Shenandoah National Park and Harpers Ferry remained in the mid-Atlantic or migrated relatively short distances to the southern Piedmont. Birds fledged from the New River Gorge were the only birds to migrate down the Appalachians and winter along the Gulf Coast.

Birds that did not migrate settled within winter home ranges 1.5 months earlier than those that migrated. Birds established winter home ranges over a wide geographic area ranging from western Long Island, NY to Buenaventura, Columbia (3 to 41° N. latitude). All of the non-migratory birds moved north and east of their fledging sites, most wintering near water in the northern mid-Atlantic Coastal Plain. Some of these birds established permanent home ranges. Most of the migratory birds moved to southern latitudes and established home ranges near major coastlines. Winter home ranges (50% kernel) varied widely between individuals ranging from 101 to 2,362 km^2

Spring migration was more rapid and direct compared to fall migration averaging only 15 days. Arrival within the summer home range was in May following the first spring migration and in March following the second. Summer home ranges were confined to the mid-Atlantic region and were distributed from Virginia to upstate New York. Five individuals were tracked to breeding territories along the eastern shore of Virginia, near Charles Town, WV, near Baltimore, MD, and on Long Island, NY.

Cause of death was assigned to 24 falcons. Of these 11 were believed to be predated, 7 flew into man-made structures, 3 were killed in storms, 1 was hit by a truck, 1 drowned, and 1 was lost at sea. Predators believed to account for the most mortality included Great Horned Owls and adult Peregrine Falcons. Birds flew into transmission lines, towers, a high-rise building, and the side of a barn. The bird lost at sea was flying out over the open ocean and was lost near Bermuda.

BACKGROUND

Context

The Peregrine Falcon (*Falco peregrinus*) is essentially cosmopolitan in its distribution (Brown and Amadon 1968). Three races have been described in North America including *F. p. pealei, F. p. tundrius and F. p. anatum* (White 1968). *F. p. pealei* is a large, dark, sedentary form inhabiting the island chains of the Pacific Northwest. *F. p. tundrius* is a paler-colored, smaller, highly migratory form with a breeding distribution limited to the nearctic tundra region. *F. p. anatum* is a large, forest-inhabiting race that is variable in its migratory behavior. Its range spans the continent, intergrading with *tundrius* to the north and limited to north-central Mexico to the south (Palmer 1988).

The original population of Peregrine Falcons in the eastern United States was estimated to contain approximately 350 breeding pairs (Hickey 1942). Peregrines that nested in Virginia historically were a *F. p. anatum* subpopulation referred to as the Appalachian peregrine, and the population was comprised of individuals larger and darker than the other subpopulations of the race. The historic status and distribution of Peregrine Falcons in Virginia is not completely known because no systematic survey of the species was completed prior to the loss of the population. From published records and accounts, there have been 24 historical peregrine eyries documented in the Appalachians of Virginia (Gabler 1983). Mountain nest sites were open rock faces. These nesting areas are particularly skewed to the upper portions of Shenandoah National Park and Blue Ridge Mountains (possibly reflecting the skewed nature of the information resources). In addition to the mountain eyries, two nesting sites were documented on old osprey nests along the Delmarva Peninsula (Jones 1946).

Throughout the 1950s, and into the 1960s Peregrine Falcon populations throughout parts of Europe and North America experienced a precipitous decline (Hickey 1969). A survey of 133 historic eyries east of the Mississippi River in 1964 failed to find any active sites (Berger et al. 1969). The Peregrine Falcon was believed to be extinct in Virginia as a breeding species by the early 1960s. Broad-scale declines resulted from reproductive rates that were insufficient to offset natural adult mortality. The cause of reproductive failure was the extensive use of chlorinated-hydrocarbon pesticides such as DDT. These compounds are persistent in the environment and bio-accumulate through the food chain. Breeding females with high levels of these compounds in their tissues produced eggs that had thin shells and were less viable (Cade et al. 1971, Peakall et al. 1975, Ratcliffe 1980).

Both *F. p. anatum* and *F. p. tundrius* were listed as endangered under the Endangered Species Conservation Act of 1969 (P.L. 91-135, 83, Stat. 275) and, subsequently, under the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq). In 1975, the U.S. Fish and Wildlife Service appointed an Eastern Peregrine Falcon Recovery Team to develop and implement a Recovery Plan (Bollengier et al. 1979). Among other actions, the plan called for the establishment of a new Peregrine Falcon population within the vacant, eastern breeding range that would be self-sustaining and reach 50% of the estimated size of the original population in the 1940's. Previously in 1970, a captive breeding program had been initiated at Cornell University to provide a source of birds for re-introduction (Cade 1974, Cade and Fyfe 1978). The breeding stock used for the captive program was of mixed heritage and contained individuals from non-indigenous subspecies (*F. p. cassini*, *F. p. brookei*, *F. p. pealei*, *F. p. peregrinus*, *F. p. tundries*, and *F. p. macropus*), as well as, native *F. p. anatums* (Barclay and Cade 1983). The first experimental releases were conducted in 1974 (Cade and Fyfe 1978). Since that time, approximately 6,000 falcons have been released into the historic North

American range (Mesta 1999). Reintroduction efforts have been successful in establishing a new breeding population within the historic eastern range (Barclay 1988). The breeding population in eastern North America continues to increase at a rate of approximately 10%/year (Enderson et al. 1995). Between 1978 and 1993, approximately 250 captive-reared falcons were released in Virginia (see http://ccb-wm.org/vafalcons/vacons/reintro.htm) including phases on the coast (1978-1985) and mountains (1985-1993). Since 2000, nearly 200 wild-reared falcons have been translocated from the coast to the mountains of Virginia (Mojica et al. 2010).

The Virginia breeding population of Peregrine Falcons has had a slow but steady recovery. From a single breeding pair in 1981, the Virginia population has increased to 23 known pairs in 2010 (Mojica et al. 2010). Although close to reaching the population size estimated from historic accounts, only 2 breeding pairs were on natural sites within the mountains. All remaining pairs nested on artificial structures within the Coastal Plain. Ongoing translocation efforts from coastal pairs to mountain hack sites are intended to re-establish breeding pairs within the historic range.

F. p. tundrius was shown to be "recovered" and was removed from the federal list of threatened and endangered species on 5 October 1994 (Swem 1994). On 30 June 1995, the U.S. Fish and Wildlife Service published an Advance Notice of Intent to remove *F. p. anatum* from the list of threatened and endangered wildlife. This notice provoked considerable debate within the conservation community (Pagel et al. 1996, Cade et al. 1997, Pagel and Bell 1997, Millsap et al. 1998). On 25 August 1999, *F. p. anatum* was officially removed from the federal list of threatened and endangered species (Mesta 1999). Peregrine Falcons continue to be listed as threatened in the state of Virginia.

More than 30 years after the first re-nesting of Peregrine Falcons in the mid-Atlantic region, we still know very little about the ecology of this emerging population. In particular, we know almost nothing about portions of the annual cycle outside of the breeding season. Several questions that are important to the future management of the mid-Atlantic population remain unanswered. When do birds disperse from their natal sites? Do birds from the Virginia population migrate? Where do migratory birds spend the winter season? What routes are used for migratory movements? How many birds produced in Virginia survive their first year or make it to reproductive age? What are some of the causes of mortality?

Objectives

FalconTrak was a cooperative project designed to answer a series of questions about the movements and survival of mid-Atlantic peregrines. The project utilized satellite telemetry to track young falcons throughout their annual cycle. Our objectives in tracking these birds were to 1) monitor the timing and rate of dispersal from natal sites, 2) investigate the pattern of local and migratory movements, 3) document factors contributing to mortality, and 4) assess site selection and recruitment into the breeding population.

METHODS

Falcons

A total of 61 birds was included in the tracking study between 2001 and 2010 (Table 1). Twenty of these birds originated on coastal bridges, 36 on peregrine nesting towers, 2 from a high-rise building and 3 from a captive breeder. Birds from the captive breeding program were from *F. p. anatum* stock. All of the captive-produced birds, 17 of the bridge-produced birds, 10 of the tower-produced birds, and 1 of the building birds were hacked from mountain release sites. Birds remaining at nests were allowed to fledge *in situ*. Release sites included Hawksbill Mountain within Shenandoah National Park, Maryland Heights Cliffs within Harpers Ferry National Historical Park, and the Endless Wall at New River Gorge National River Park. Procedures used to release and provision birds generally followed those used throughout the history of the reintroduction program (Sherrod et al. 1981). All falcons used in this study were hatching-year birds with the exception of 1 ASY male that was tracked after rehabilitation following a West Nile Virus infection. These included 40 females and 21 males.

Birds were fitted with U.S. Fish and Wildlife Service aluminum tarsal bands on the right leg. These bands were anodized with a green color for Virginia and a black color for New Jersey. An alpha-numeric, bi-colored, auxiliary band (ACRAFT sign and nameplate, Edmonton, Alberta, CAN) was riveted on the left leg. In addition, all birds were fitted with satellite transmitters or PTTs (Platform Transmitter Terminal). The PTTs used in this study were 17-28 g, solar-powered units (Northstar Science and Technology, LLC King George, VA). These transmitters were programmed with a duty cycle allowing the unit to transmit a signal every 60 sec as long as they received enough light to power the transmission. PTTs were attached to the back of falcons using a standard backpack configuration (Kenward 1987). Strips of 1/8" thick neoprene were used as mounting straps and each bird was custom fitted into their harness. During 2001, transmitter harnesses were individually sewn on using dental floss. In all other years, harnesses were attached using brass upholstery grommets. Transmitters deployed in 2007 at New River Gorge had harnesses of ¼" tubular Teflon ribbon (Bally Ribbon Mills, Bally, PA).

Table 1. Peregrine Falcons included in the satellite tracking study. Color bands are either Black over green or black over red.

USGS Band	Color Band	Transmitter	Sex	Natal Site	Fledging Site	Outcome
0987-51248	BL-GR *9/*A	27408b	F	James River Bridge	Hawksbill	Dead
0987-51249	BL-GR *9/*B	36485a	F	Ben Harrison Bridge	Hawksbill	Unknown
0987-51252	BL-GR *9/*E	27400b	F	Norris Bridge	Hawksbill	Assumed Dead
0987-51253	BL-GR *9/*H	27404b	F	Norris Bridge	Hawksbill	Harness Failure
0987-51257	BL-GR *9/*R	08172a	F	Turner's Marsh	Turner's Marsh	Dead
0987-51258	BL-GR *9/*S	08248a	F	Watts Island	Watts Island	Assumed Dead
0987-51259	BL-GR *9/*U	08175a	F	Watts Island	Watts Island	Harness Failure
0987-51260	BL-GR *9/*V	24090a	F	Watts Island	Watts Island	Dead
0987-51261	BL-GR *9/*W	36493b	F	Wallops Island	Wallops Island	Unknown
0987-51262	BL-GR *9/*X	36492a	F	Wallops Island	Wallops Island	Assumed Dead
0987-51263	BL-GR *9/*Y	36487a	F	Chincoteague Island	Hawksbill	Assumed Dead
0987-51264	BL-GR *A/*C	08147	F	Chincoteague Island	Chincoteague Island	Assumed Dead
0987-51266	BL-GR *C/*C	24090b	F	Richmond	Hawksbill	Dead
0987-51267	BL-GR *C/*D	27412b	F	Watts Island	Watts Island	Dead
0987-51269	BL-GR *C/*H	27404C	F	Wallops Island	Wallops Island	Dead
0987-51270	BL-GR *C/*K	27407c	F	Norris Bridge	Hawksbill	Dead
0987-51273	BL-GR *C/*R	27404D	F	Ben Harrison Bridge	Hawksbill	Unknown
0987-51276	BL-GR *C/*V	27396b	F	Cobb Island	Cobb Island	Dead
0987-51277	BL-GR *C/*W	36491b	F	Cobb Island	Cobb Island	Dead
0987-51280	BL-GR 8/A	36486a	F	Metomkin Island	Metomkin Island	Assumed Dead
0987-51281	BL-GR 8/B	27412c	F	James River Bridge	James River Bridge	Dead
0987-51287	BL-GR 8/K	36491c	F	Mockhorn Island	Mockhorn Island	Unknown
0987-76881	BL-RD *6/E	27399a	F	James River Bridge	Hawksbill	PTT Failure
0987-76882	BL-RD *6/K	-----	F	James River Bridge	Richmond	Dead
0987-76883	BL-RD *6/P	27400a	F	Mills Godwin Bridge	Hawksbill	PTT Failure
0987-76884	BL-RD *6/R	27395a	F	Mills Godwin Bridge	Hawksbill	PTT Failure
0987-76887	BL-RD *6/V	27404a	F	Benjamin Harrison Bridge	Hawksbill	Dead
0987-76888	BL-RD *6/Y	27411a	F	Watts Island	Watts Island	PTT Failure
0987-76889	BL-RD *8/3	27396a	F	Wallops Island	Wallops Island	Dead
0987-76890	BL-RD *8/4	27403a	F	Wallops Island	Wallops Island	PTT Failure
0987-76891	BL-RD *8/5	27402a	F	Metomkin Island	Hawksbill	PTT Failure
0987-76894	BL-RD *6/3	27408a	F	Captive Breeder	Hawksbill	Dead
0987-76911	BL-RD *B/*A	27412a	F	Hart Miller Island, MD	Harpers Ferry	PTT Failure
0987-76912	BL-RD *B/*B	27407a	F	Hart Miller Island, MD	Harpers Ferry	Dead
0987-76922	BL-GR 9/C	27407b	F	Clay Island, MD	Harper's Ferry	Assumed

USGS Band	Color Band	Transmitter	Sex	Natal Site	Fledging Site	Outcome
						Dead
0987-76925	BL-GR 9/G	08146a	F	South Marsh Island, MD	Harpers Ferry	Dead
0987-76926	BL-GR 9/H	08204a	F	South Marsh Island, MD	Harper's Ferry	Unknown
0987-76938	BL-GR X/3	08172c	F	Maryland	Harper's Ferry	Dead
0987-95679	BL-GR *1/*U	54495	F	Betsy Ross Bridge, NJ	New River Gorge	Live
1807-02755	BL-GR 20/U	41300d	F	Upsher Bay	New River Gorge	Dead
2206-07450	BL-GR 7/3	27398a	M	Mills Godwin Bridge	Hawksbill	Dead
2206-07451	BL-GR 7/4	27394a	M	Benjamin Harrison Bridge	Hawksbill	Dead
2206-07453	BL-RD 7/6	27397a	M	Elkins Marsh	Elkins Marsh	Dead
2206-07454	BL-RD 7/7	27410a	M	Watts Island	Watts Island	PTT Failure
2206-07455	BL-RD 7/8	27401a	M	Watts Island	Watts Island	PTT Failure
2206-07460	BL-RD *7/*4	27406a	M	Captive Breeder	Hawksbill	PTT Failure
2206-07468	BL-GR *3/*P	41300c	M	Finney's Island	Finney's Island	Dead
2206-07475	BL-RD *7/*5	27409a	M	Captive Breeder	Hawksbill	Dead
2206-43458	BL-GR *7/*K	08145a	M	Chincoteague Island	Chincoteague Island	Dead
2206-43459	BL-GR *7/*M	36491a	M	Cobb Island	Cobb Island	Dead
2206-43460	BL-GR *7/*P	08172b	M	West Norfolk Bridge	West Norfolk Bridge	Dead
2206-43464	BL-GR *7/*V	27403b	M	Richmond	Richmond	Dead
2206-43465	BL-GR *7/*W	41301a	M	Watts Island	Watts Island	Dead
2206-43468	BL-GR *2/*A	41300a	M	Wallops Island	Wallops Island	Dead
2206-43469	BL-GR *2/*B	41299a	M	Wallops Island	Wallops Island	Dead
2206-43475	BL-GR *2/*M	36492b	M	Metomkin Island	Metomkin Island	Dead
2206-43476	BL-GR *2/*P	41300b	M	Finney's Island	Hawksbill	Assumed Dead
2206-75743	BL-GR 1/S	54496a	M	Sea Isle Tower, NJ	New River Gorge	Dead
2206-81653	BL-GR 95/S	08175b	M	Norris Bridge	New River Gorge	Dead
2206-81664	BL-GR X/12	27408c	M	Ben Harrison Bridge	New River Gorge	Dead
2206-81672	BL-GR X/24	09908b	M	Ben Harrison Bridge	New River Gorge	Dead

Tracking

Birds were located using NOAA satellites with onboard tracking equipment operated by Service ARGOS Inc. (Toulouse, France) (Fancy et al. 1988). Locations in latitude and longitude decimal degrees, date, time, location error, and other data were received from ARGOS within 24 hr of satellite contact with a bird. Falcon locations were estimated by the ARGOS system (Service ARGOS 2001). The system estimates location using the Doppler shift in signal frequency, and calculates the distribution within which the location estimate lies. The standard deviation of this distribution gives an estimate of the location accuracy and assigns it to a “location class” (LC): LC3 = < 150 m, LC2 = 150-350 m, LC1 = 350-1000 m, LC0 > 1000 m, LCA, B, and Z = no location accuracy. Locations were processed by Argos satellites (CLS America, Largo, MD) and stored online with the Satellite Tracking and Analysis Tool (STAT) (Coyne and Godley 2005).

PTT Performance

One of the design specifications for PTTs was to transmit signals for a 3-yr period. This period was chosen so that birds could be tracked until recruitment into the breeding population. Ten of the PTTs in the 2001 cohort failed in the first several months. One of the units had a defective oscillator such that it gave erroneous locational data and was removed from service on 26 July, 2001. All of the remaining units apparently had a logic error in the programming that resulted in premature shut down. The majority of the active units stopped transmitting signals by late November 2001. Two units continued to transmit until January of 2002. One of these birds was captured in January and refitted with a new transmitter. In addition to transmitter malfunctions, 2 harnesses were believed to have failed after extended periods of time due to degradation of the neoprene. Remaining transmitters were believed to have performed until birds died.

A total of 66,343 signals of usable quality were received from transmitters between 2001 and 2010. Variation in the rate of usable signals with season and between individual transmitters was assessed for the early transmitters deployed in this study (Watts et al. 2002).

Movement Patterns

Locational information received from ARGOS was screened according to accuracy estimates (LC), entered into databases, and plotted using ArcMap 9.3 (Environmental Systems Research Institute, Inc, Redlands, CA) for each individual bird. We filtered data using STAT to exclude any data point with a location class value of B or Z. An additional filter was also used to exclude any location where a falcon would have flown over 90 km/hr to reach, a speed greater than the maximum recorded migratory speed (62 km/hr) (Cochran and Applegate 1986).

Annual Cycle

Movement patterns were used to break the annual cycle up into biologically relevant units. Periods used included 1) Pre-dispersal, 2) post-dispersal, 3) fall migration, 4) winter, 5) spring migration, and 6) summer. Transition dates between these periods were delineated based on movement patterns and their context. The pre-dispersal period is bounded by fledging and dispersal where fledging is the first flight and dispersal is movement away from the natal area. Fledging was estimated using the hatching date and gender-specific values for fledging age. Hatching date was determined by direct observation or by backdating from estimates of chick ages. Breeding activity was monitored with regularity to improve estimates of hatching date. Average fledging ages of 41 and 45 days were used for male and female chicks respectively (Sherrod 1983).

Dispersal was defined as a break-out flight where for the first time the bird did not return to the natal or hack site for a period of at least 2 days. This rule seemed to consistently mark the end of the dependency period. The majority of birds that did not return for 2 days dispersed from the site. For migratory birds, the post-dispersal period ended when birds initiated directional flights toward ultimate wintering areas. For non-breeding birds the post-dispersal period ended when birds settled within winter home ranges. The first winter period began when birds settled within winter home ranges. For migratory birds, winter ended when birds initiated northward flights to the summer areas. The spring migration period ended when birds settled on summer home ranges. For non-migratory resident birds, winter (after the first year) and summer periods were defined by average migration dates from migrants.

Home Range Analysis

Fixed kernel (50 and 90%) home range estimates were derived from the utilization distribution using Hawth's Tools extension in ArcMap (Beyer 2004) with a fixed smoothing parameter of 5000 m. Winter and summer ranges were estimated using locations that fell within these time periods for all individuals with adequate sample sizes (>40 locations). Centroid coordinates were derived from 50% kernels to illustrate the distribution of wintering and summering birds.

Mortality

Mortality of birds was assessed using information provided by ARGOS and by the context of the situation. Birds that were stationary for long periods of time and that had no readings from activity sensors were considered to be down or dead. Birds that abruptly ended transmissions were also considered to be dead depending on the transmitter sensor data over previous time periods. When birds were suspected to be down, every effort was made to recover the bird and determine the cause of death. The last satellite location was used to determine the general search area. Within the search area a 401.65 MHz receiver was used with a Yagi antenna to systematically search for down transmitters. A large portion of transmitters were recovered and recycled from downed birds.

RESULTS

Annual Cycle

Following the breeding season, falcons exhibited patterns of movement that included stable periods (pre-dispersal, winter, summer) integrated with periods of high movement (fall migration, spring migration). In addition to these typical elements, some individuals exhibited periods between migration and stable periods that appear to be "prospecting" for home ranges. Due to the attrition of tracked birds, the sample size available to characterize these periods varied considerably.

Fledging – Estimated fledging dates for birds included in the tracking study (N = 61) ranged from 27 May through 29 July with a mean date of 16 June ± 1.64 (SE) (Appendix 1).

Pre-dispersal – The pre-dispersal period was characterized by relatively short flights centered on the natal or hack site. This is a period when falcons are learning to fly and hunt and are dependent on provisioning from parents or hack attendants. Estimated date of dispersal (N = 36) varied from 12 July through 29 August with a mean date of 1 August ± 2.13 (SE). Estimated age at the time of dispersal varied from 72 to 118 days with a mean of 92 ±2.09 (SE). Time between estimated fledging date and dispersal varied from 27 to 73 days with a mean of 47.2 ± 2.08 (SE). Although males were older at dispersal (N = 25, Mean = 92.6 ± 3.96 SE) compared to females (N = 10, Mean = 91.8 ± 2.51 SE) the samples were not significantly different (One-way ANOVA, df = 1, 34, F = 0.34, p = 0.86). Age at dispersal was significantly influenced by whether the bird was reared by parents or released from a hack site (One-way ANOVA, df = 1, 34, F = 4.7, $p < 0.05$). On average, hacked birds were 9 days younger at dispersal compared to wild-reared birds (Figure 1).

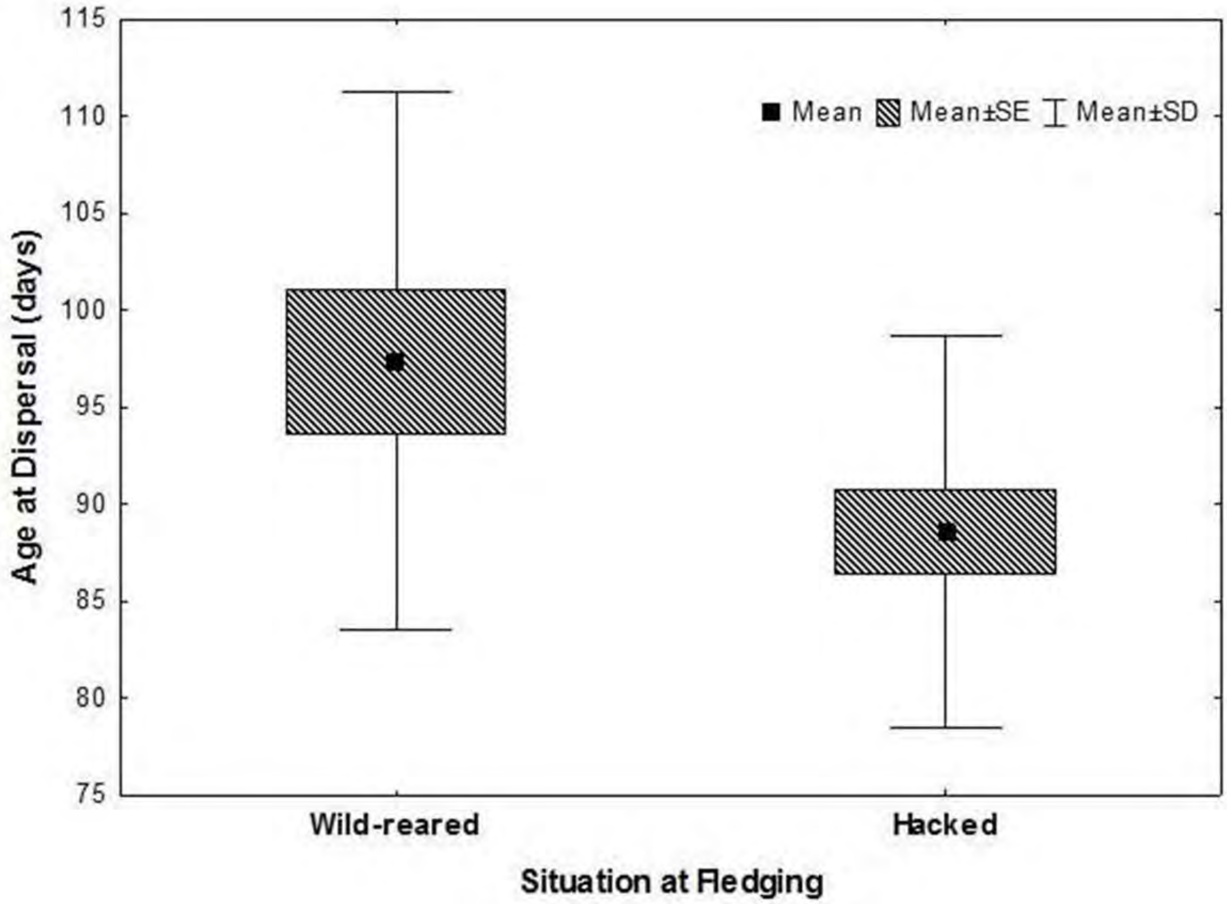

Figure 1. Comparison of age at dispersal for wild-reared and hacked peregrines. Wild-reared birds were significantly older at dispersal compared to hacked birds.

Post-dispersal – The post-dispersal period is characterized by long movements that are increasingly distant from the natal site and wide-ranging exploration. During this phase, birds wandered throughout the entire eastern half of North America (Figure 2). The length of this period varied between 11 and 98 days with a mean of 47.7 ± 4.85 SE. Birds that remained within the mid-Atlantic region had shorter post-dispersal periods (N = 8, mean = 47.9 ± 10.28 SE) compared to those that migrated south (N = 14, mean = 58.6 ± 7.77 SE) but these differences were not statistically significant (Mann-Whitney U statistic = 42.0, p = 0.34).

Birds wandered widely during the post-dispersal period visiting 23 states. Inland movements were bounded by the Great Lakes to the north and the Mississippi River and one of its major tributaries the Wabash to the west. Birds fledged on the coast or hacked at Harpers Ferry or Shenandoah moved widely throughout coastal areas of the mid-Atlantic and New England. Birds were attracted to major metropolitan areas including Washington, Baltimore, Pittsburg, Philadelphia, New York City, Boston, Cleveland, and Detroit.

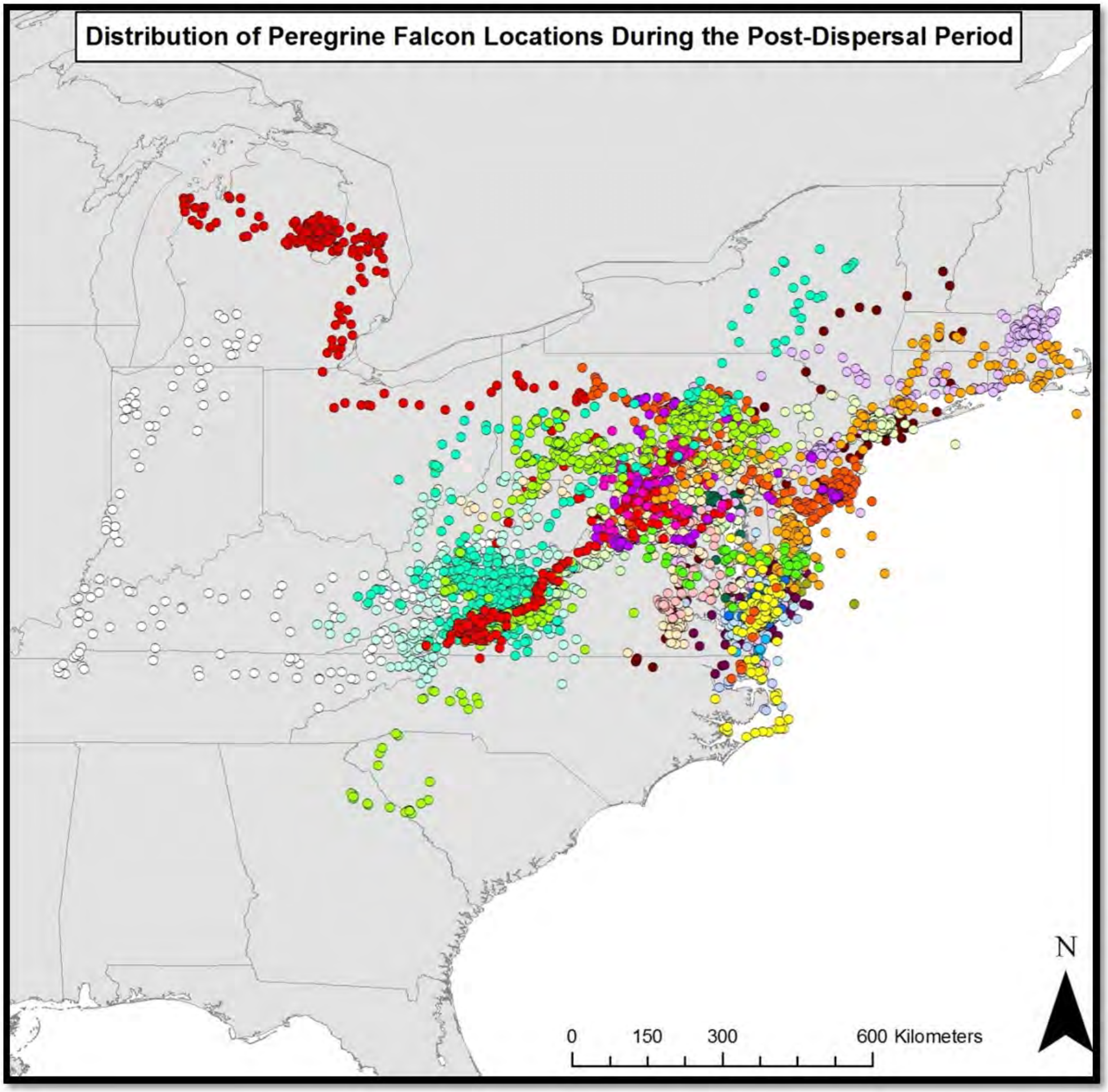

Figure 2. Distribution of Peregrine Falcon locations during the post-dispersal period (*n*=38 falcons).

<u>Fall Migration</u> – More than half (15 of 27) of the falcons that survived into the fall period migrated south out of the mid-Atlantic region. This included 6 males and 9 females. A higher proportion of males migrated than females (67 vs 50%) but this difference was not statistically significant due to low sample size (Fisher's Exact Test for Independence, $p = 0.34$). Individuals did not change migratory status between years. Of 5 migratory birds that survived through their second summer, all migrated. Likewise, of 4 non-migratory birds that survived their second summer, none migrated.

The date when migratory flights were initiated (N = 20) ranged from 27 July through 18 November with a mean date of 2 October. On average, birds were migrating for 22.7 ± 2.43 SE days. Average movement rates were high during the migratory period with maximum movements per day ranging from 240 to 951 km (Table 2). Mean movement rate across all birds and days was 154 ± 14.2 SE km/d. Mean total distance traveled during fall migration was 3,106 ± 435.5 SE km.

Birds that migrated south of the mid-Atlantic region followed either a coastal or inland route (Figure 3). Birds following the coastal route flew along the contour of the south Atlantic Coast either through the Southeastern Coastal Plain or offshore. Some of these birds moved considerable distances out over the open ocean including one individual that was lost at sea near Bermuda. One bird made landfall on the Bahamas before moving on to the Greater Antilles. Three birds moved off the southern tip of Florida, over to western Cuba, west to the Yucatan Peninsula, and south along the Pacific Coast. These were the longest migrations tracked during the study. With the exception of one individual that flew through the Piedmont to the Gulf Coast, the remaining migrants followed the southern Appalachians to their terminus in Georgia and then flew southwest toward the Gulf Coast. Eighteen migratory stopover sites were delineated where birds stayed for 2 days or more during the migratory period (Figure 4). Most of these sites are along the major migration routes along the coast or along the Appalachians.

Following fall migration, 7 individuals including both migrants and non-migrants exhibited exploratory behavior where they went on wide-ranging forays that appeared to be “prospecting” for home ranges (Figure 5). Some of these individuals later used visited areas for either winter or summer home ranges. Prospecting episodes lasted between 5 and 59 days.

Winter – Birds settled on winter home ranges over a wide span of dates ranging from 29 July through 29 November with a mean date of 11 October ± 9.1 SE. Migratory status had a significant influence on the date of settlement ($df = 1,11$, $F = 256.1$, $p < 0.01$). On average, migratory birds settled more than 1.5 months later compared to non-migratory birds (2 November ± 9.8 SE vs 14 September ± 10.9 SE). Presumably, settlement differences reflect relative distance between summering and wintering sites.

Birds established winter home ranges over a wide geographic area ranging from western Long Island, NY to Buenaventura Columbia (3 to 41° N. latitude) (Figure 6). All of the non-migratory birds moved north and east of their fledging sites, most wintering near water in the northern mid-Atlantic Coastal Plain. Most of the migratory birds moved to southern latitudes and established home ranges near major coastlines.

Table 2. Migration distances traveled per day

Transmitter	Season	Year	Total km traveled	Average km per day	Min km per day	Max km per day	Days traveled
08146a	fall	1	1,132	283	4	490	4
08146a	fall	2	3,723	98	1	284	38
08147	fall	1	7,919	184	19	663	43
08175a	fall	1	5,020	136	3	512	37
08175a	fall	2	3,476	204	6	628	17
27406a	fall	1	1,531	170	8	408	9
27408c	fall	1	2,497	86	7	303	29
27410a	fall	1	5,212	137	7	665	38
27412a	fall	1	3,167	122	3	522	26
36486a	fall	1	2,068	37	2	951	56
36493b	fall	1	2,346	130	6	454	18
36493b	fall	2	1,247	208	22	435	6
36493b	fall	3	1,157	83	15	285	14
41300d	fall	1	5,227	238	7	484	22
41300d	fall	2	2,642	176	54	372	15
41301a	fall	1	1,115	93	55	240	12
54496a	fall	1	5,567	155	7	452	36
54496a	fall	2	2,276	228	23	255	10
08175b	fall	1	1,696	154	2	331	11
08146a	spring	1	2,896	121	7	314	24
08146a	spring	2	1,585	158	27	363	10
08175a	spring	1	5,594	329	35	723	17
08175a	spring	2	6,016	207	20	843	29
08175b	spring	1	1,214	243	25	329	5
36493b	spring	1	2,077	346	17	360	6
36493b	spring	2	1,165	194	137	431	6
41300d	spring	1	1,331	190	85	393	7
41300d	spring	2	1,610	201	5	515	8
54496a	spring	1	2,131	237	126	407	9

For most birds tracked, the winter months were characterized by relatively lower movement rates compared to the post-dispersal and migratory periods. Most birds formed single focal home ranges where birds were utilizing a stable area over the winter months. A few individuals used multi-focal home ranges or multiple home ranges where they moved between areas for the winter months. Home ranges (50% kernel) varied widely between individuals from 101 to 2,362 km^2, averaging 582 ± 9.1 SE km^2 (Table 3). Although non-migratory birds had nearly 20% larger home ranges on average (635 vs. 536 km^2), this difference was not statistically significant (one-way ANOVA, df 1,28, $F = 0.24$, $p = 0.63$).

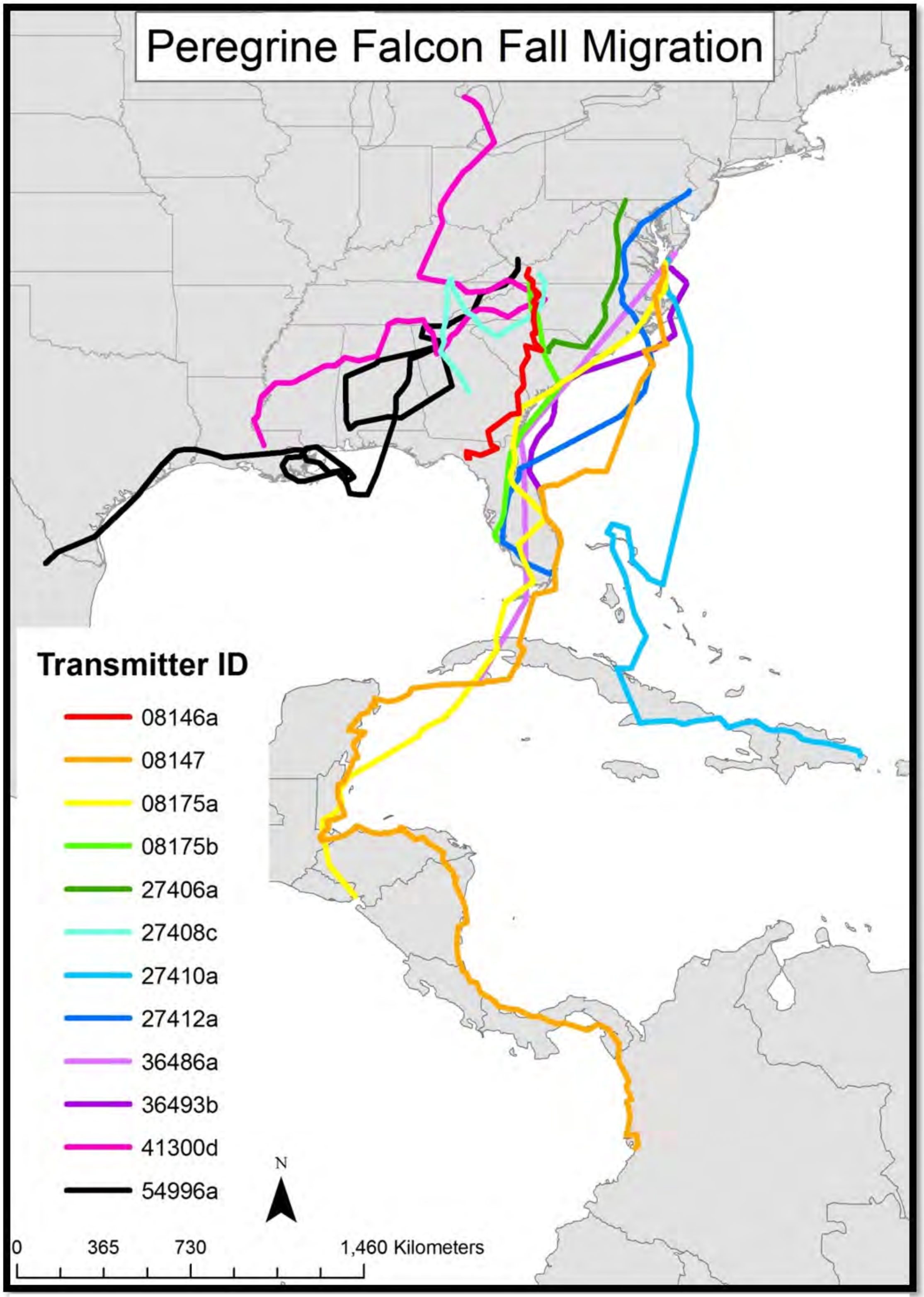

Figure 3. Map of fall migration routes for Peregrine Falcons during the first year after dispersal.

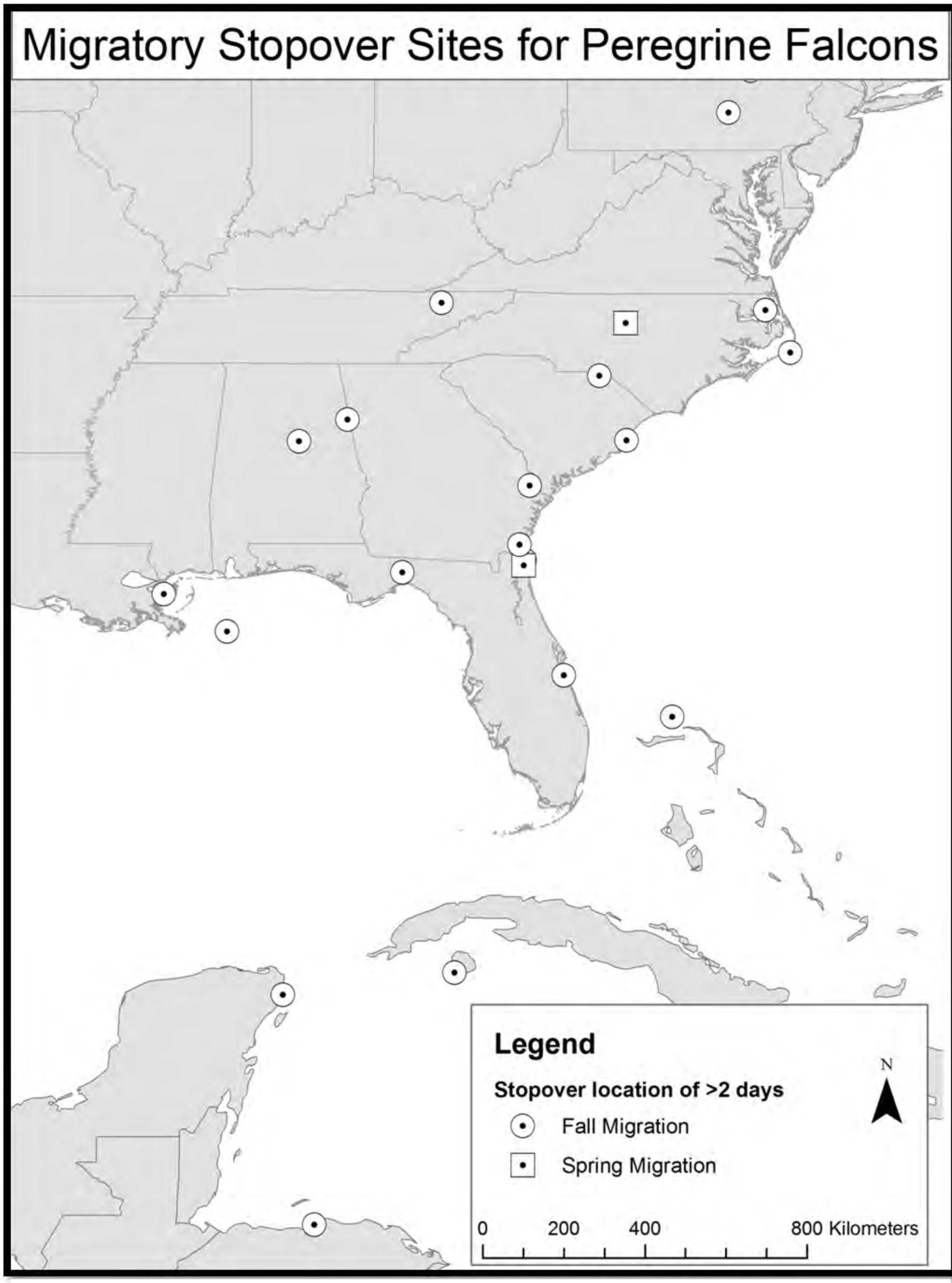

Figure 4. Map of migratory stopover sites for Peregrine Falcons.

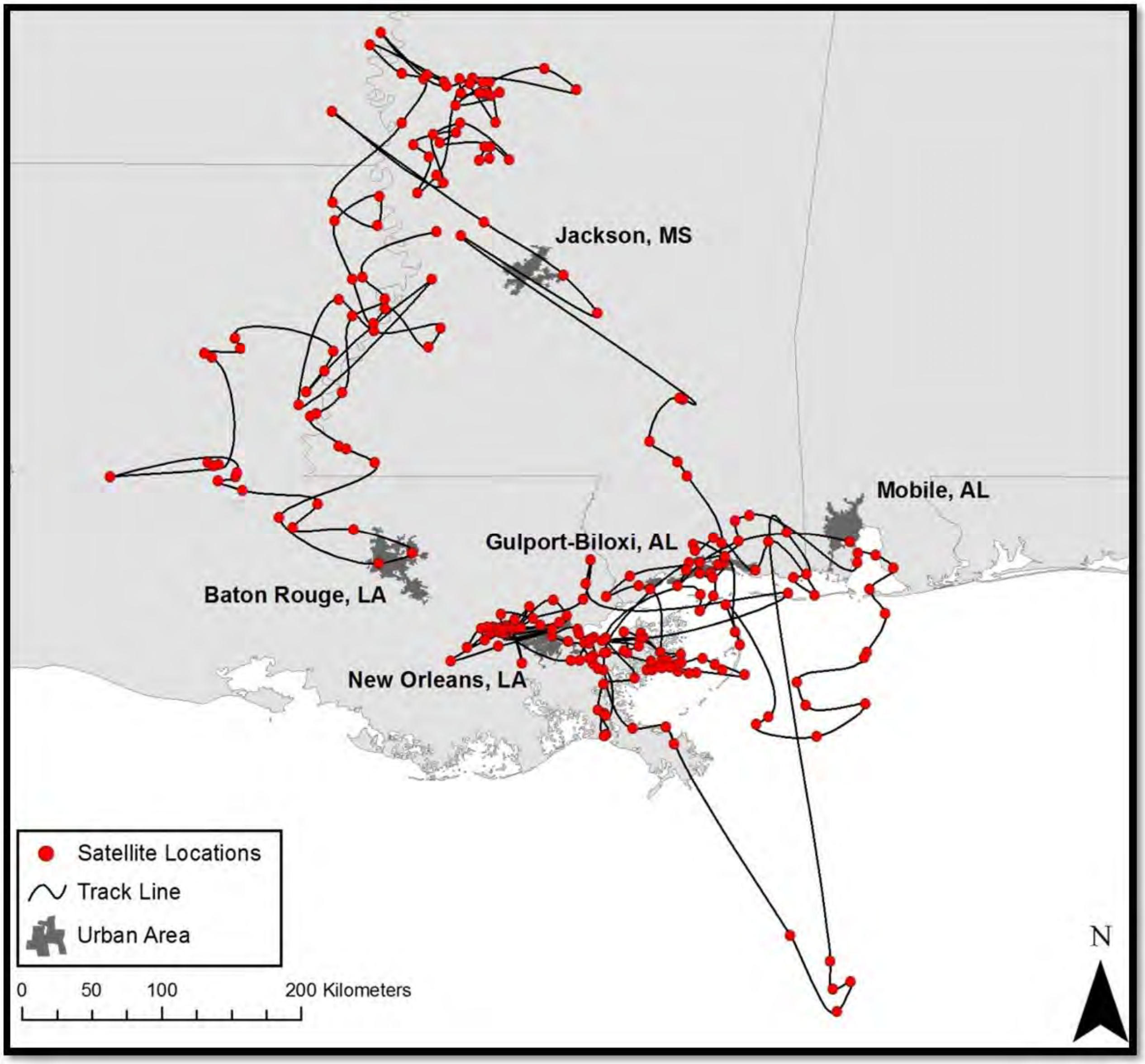

Figure 5. Prospecting flight behavior in one female Peregrine Falcon between fall migration and settling on her first winter territory in Mobile, AL.

Figure 6. Map of centroids for Peregrine Falcon winter home ranges.

Table 3. Statistics and locations of Peregrine Falcon winter home ranges.

Transmit-ter	Year	n	90% kernel km2	50% kernel km2	Latitude	Longitude	City	State	Country
08146a	1	318	5,206	929	27.51868	-81.72900	Zolfo Springs	FL	USA
08146a	2	556	4,012	754	28.30529	-81.87343	Polk City	FL	USA
08147	1	71	420	101	3.75417	-77.16943	Buenaventura	Valle Del Cauca	Columbia
08172b	1	1,150	17,313	2,362	39.26364	-75.80169	Millington	DE	USA
08175a	1	92	8,463	2,083	11.03196	-85.14254	El Cairo	Rio San Juan	Nicaragua
08175a	2	10	1,399	422	8.83032	-82.65960	Volcan	Chiriqui	Panama
08175b	1	295	3,472	368	30.41702	-84.19397	Tallahassee	FL	USA
09908b	1	145	5,116	1,204	36.08080	-79.67090	Greensboro	NC	USA
27399a	1	744	4,114	276	39.41814	-74.46195	Absecon	NJ	USA
27400a	1	924	7,222	461	39.31236	-76.43544	Essex	MD	USA
27400a	2	265	9,480	1,042	39.32210	-76.37128	Bowleys Quarters	MD	USA
27402a	1	105	2,288	252	40.61111	-73.62281	Barnum Island	NY	USA
27404d	1	495	4,766	800	40.71033	-73.89111	Queens	NY	USA
27406a	1	66	3,418	650	34.05042	-80.05694	Lynchburg	SC	USA
27407c	1	344	1,505	275	40.70404	-73.79813	Queens	NY	USA
27410a	1	63	1,251	175	18.69782	-68.60555	La Otra Banda	La Altragra	Domini-can Republic
27412a	1	73	2,944	529	26.03449	-80.13063	Hollywood	FL	USA
36485a	1	151	2,482	241	40.69865	-73.75450	Queens	NY	USA
36485a	2	203	5,785	531	40.44424	-79.86056	Wilkinsburg	PA	USA
36491c	1	236	1,354	151	39.34533	-76.67272	Baltimore	MD	USA
36493b	1	624	732	127	28.80421	-80.75924	Oak Hill	FL	USA
36493b	2	284	1,571	135	28.79739	-80.74687	Oak Hill	FL	USA
36493b	3	86	897	111	28.80089	-80.75616	Oak Hill	FL	USA
41300d	1	457	2,499	303	30.50651	-88.02850	Gaillard Island	AL	USA
41300d	2	200	1,762	283	30.50843	-88.03767	Gaillard Island	AL	USA
54495	1	200	4,190	1,091	39.47639	-77.76780	Sharpsburg	MD	USA
54495	2	111	3,272	655	39.33253	-77.88939	Charles Town	WV	USA
54495	3	87	2,087	392	39.26075	-77.83809	Charles Town	WV	USA
54495	4	42	1,569	360	39.24285	-77.90199	Charles Town	WV	USA
54496a	1	334	2,635	401	29.47882	-96.15794	East Bernard	TX	USA

Fledging location had a dramatic influence on both migratory route and the location of winter home ranges (Figure 7). Birds that were fledged on the coast were the only birds to migrate to the tropics. With the exception of a single bird from Harpers Ferry that migrated to Florida, all of the other birds from Shenandoah National Park and Harpers Ferry remained in the mid-Atlantic or migrated relatively short distances to the southern Piedmont. Birds fledged from the New River Gorge were the only birds to migrate down the Appalachians and winter along the Gulf Coast.

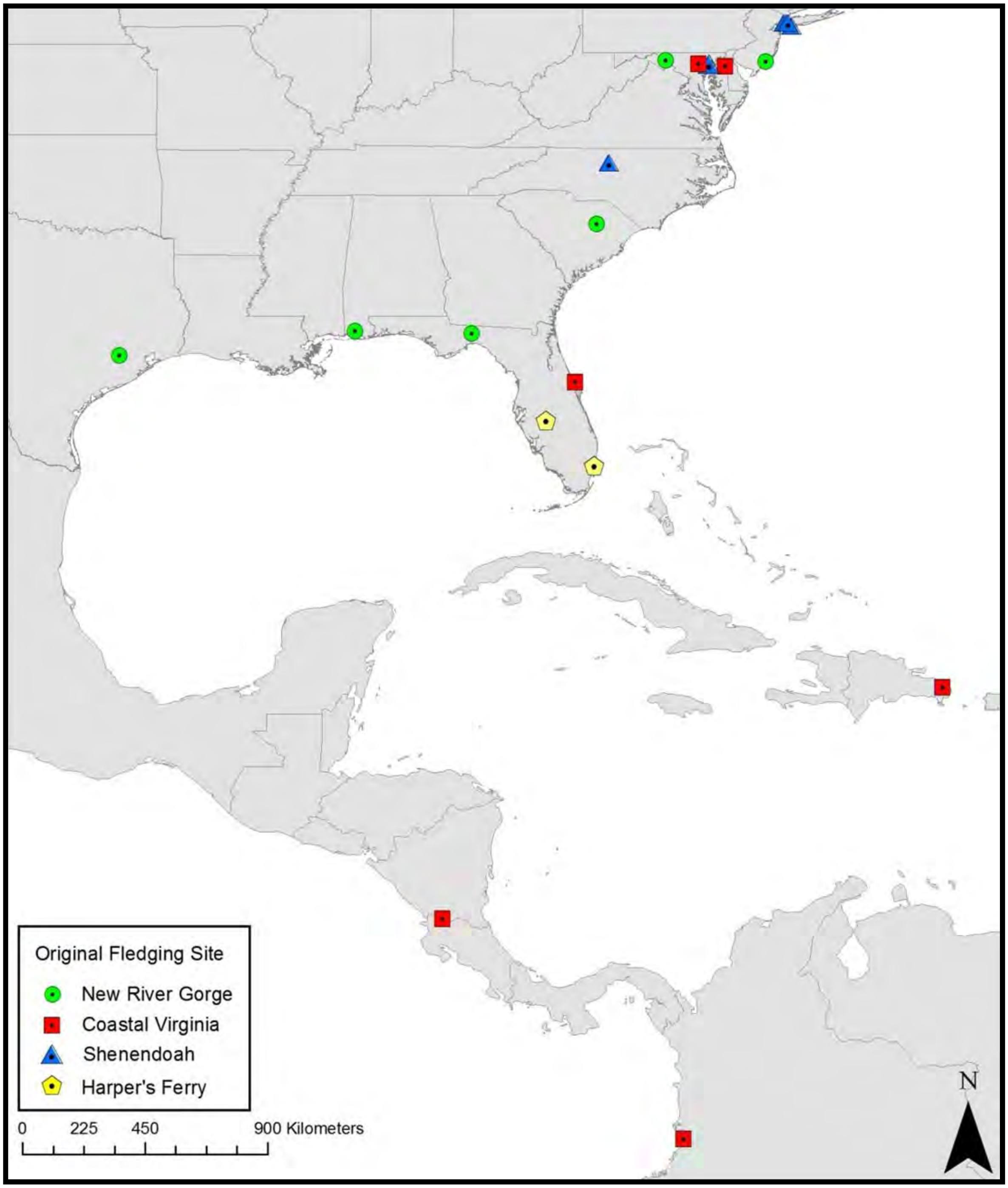

Figure 7. Linkages between fledging sites and winter home ranges. Icons represent wintering home ranges for first year Peregrine Falcons.

Spring Migration – With some notable exceptions, birds reversed the routes followed in the fall during spring migration (Figure 8). Inland migrants followed the Appalachians north and coastal migrants followed the coast back to the mid-Atlantic. The southernmost bird surviving the winter (08175a) flew up to the Yucatan Peninsula and then across the Gulf of Mexico following a well-known raptor migration route. The only migrant (08146a) from the New River Gorge that migrated south through the Piedmont, did not return to the vicinity of the Gorge but instead flew up the Piedmont to upstate New York. Compared to fall, spring routes were more direct.

The dates when spring migration were initiated (N = 11) ranged from 20 February to 9 April with a mean date of 19 March. On average, birds were migrating for 14.7 ± 2.43 SE days which is notably less than the duration of fall migration (one-way ANOVA, f 1,27, F = 3.81, p = 0.06) (Figure 9).

Only 2 stopover sites were delineated for birds during spring migration compared to 18 for fall migration (Figure 4). This difference seems to support the more direct and rapid northward migration.

Summer – As with the winter, birds settled on summer home ranges over a wide span on dates ranging from 28 February through 24 May with a mean data of 15 April 7.1 SE. In part, the wide range of dates reflects differences in migratory status and age. Several non-migratory birds remained on year-round territories throughout the year. Even for those non-migratory birds that did not remain on winter territories, mean settlement date was 4 April compared to compared to 3 May for migratory individuals returning after their first year. Migrants that survived their second spring migration returned earlier than their first year by 1.5 months in one case and more than 2 months in the other. Birds established summer home ranges over a much narrower latitudinal range compared to the winter season (Figure 10). Also, compared to the winter, birds were much less associated with the coast.

Summer home ranges were variable ranging from 127 to 2,135 km^2 (Table 4). Mean home range (50% kernel) was very comparable to that documented in winter (574 vs 582 ± 9.1 SE for summer and winter respectively. Values were not statistically distinguishable (one-way ANOVA, df 1,49, F = 0.003, p = 0.96).

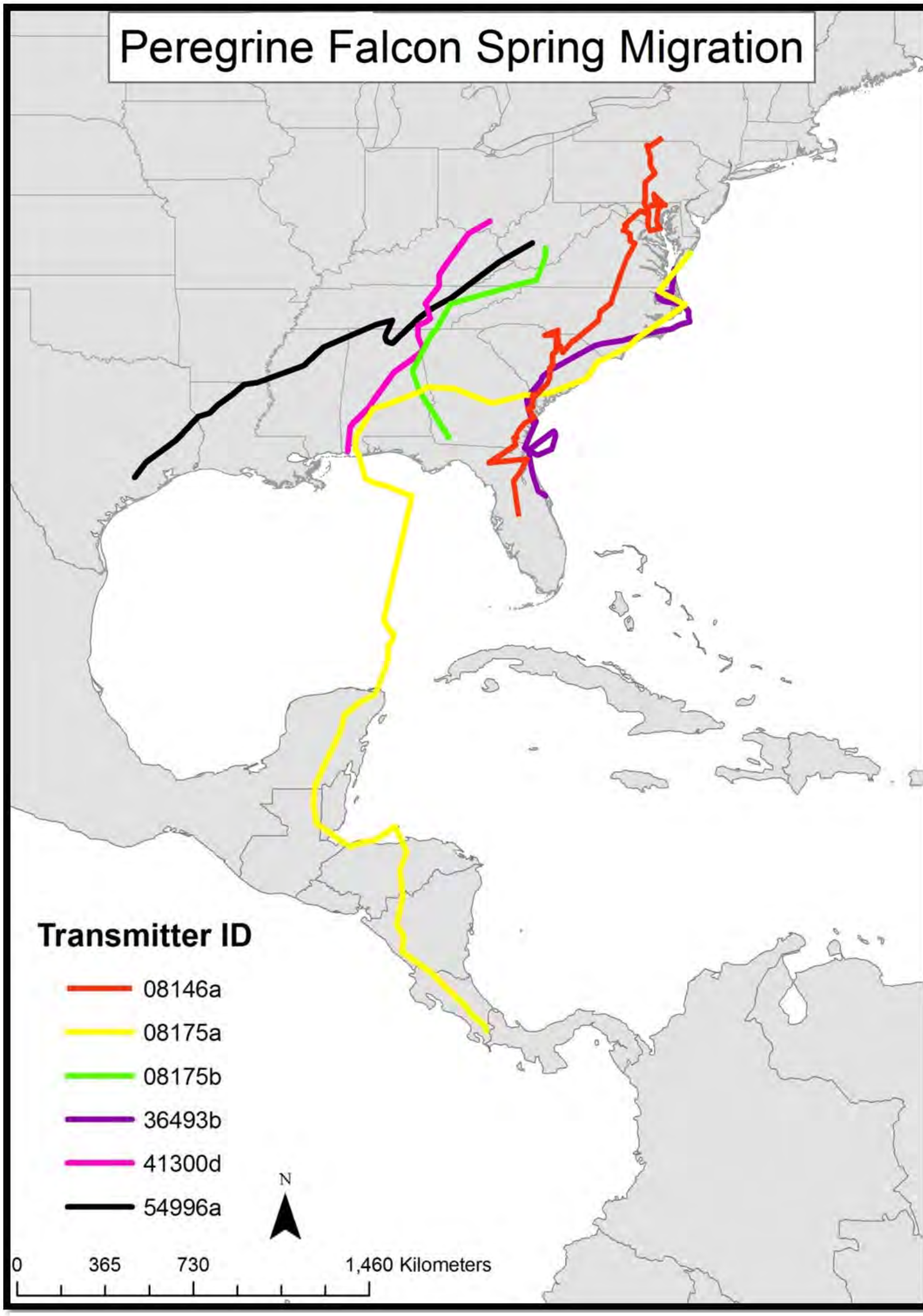

Figure 8. Map of spring migration routes for Peregrine Falcons that survived their first winter.

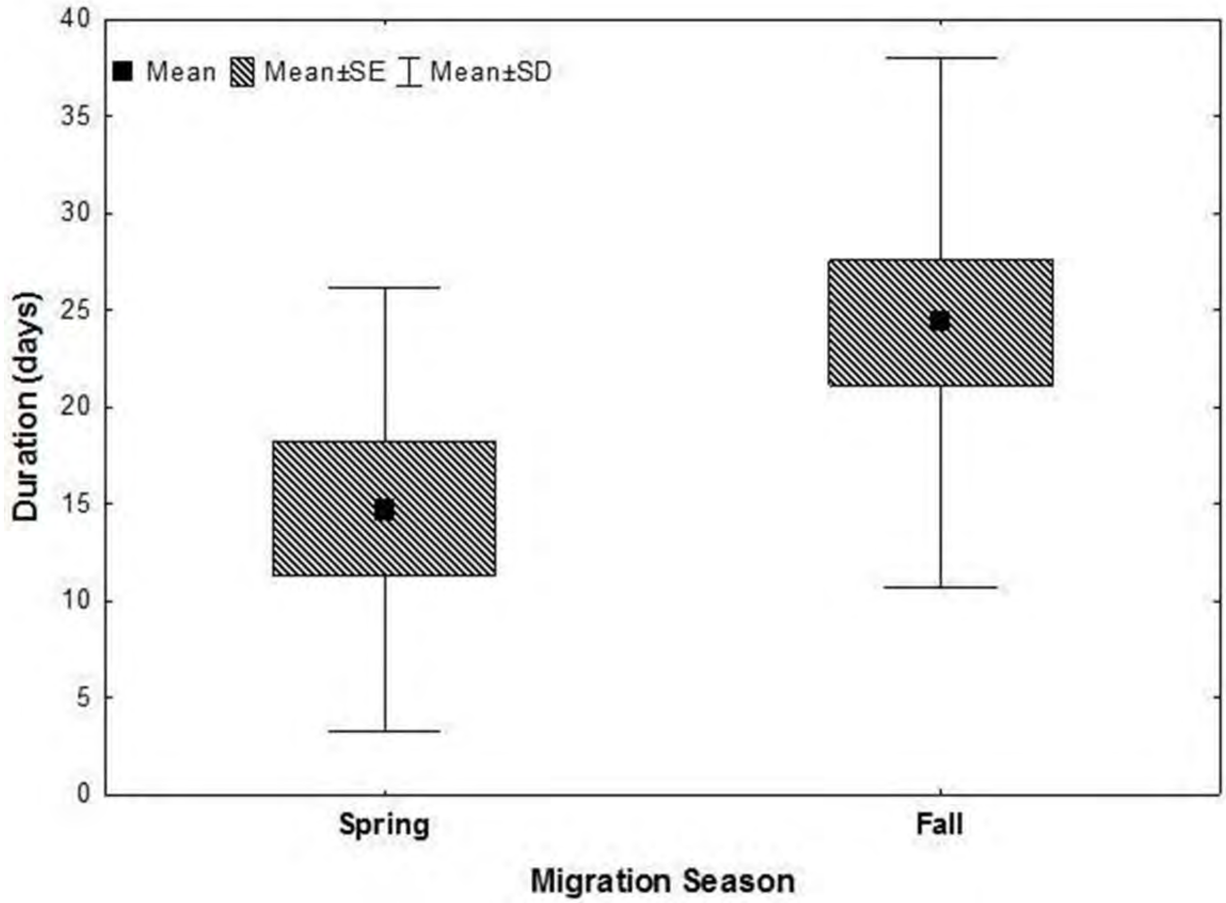

Figure 9. Mean length of migratory periods for Peregrine Falcons. Fall migration was significantly longer than spring migration.

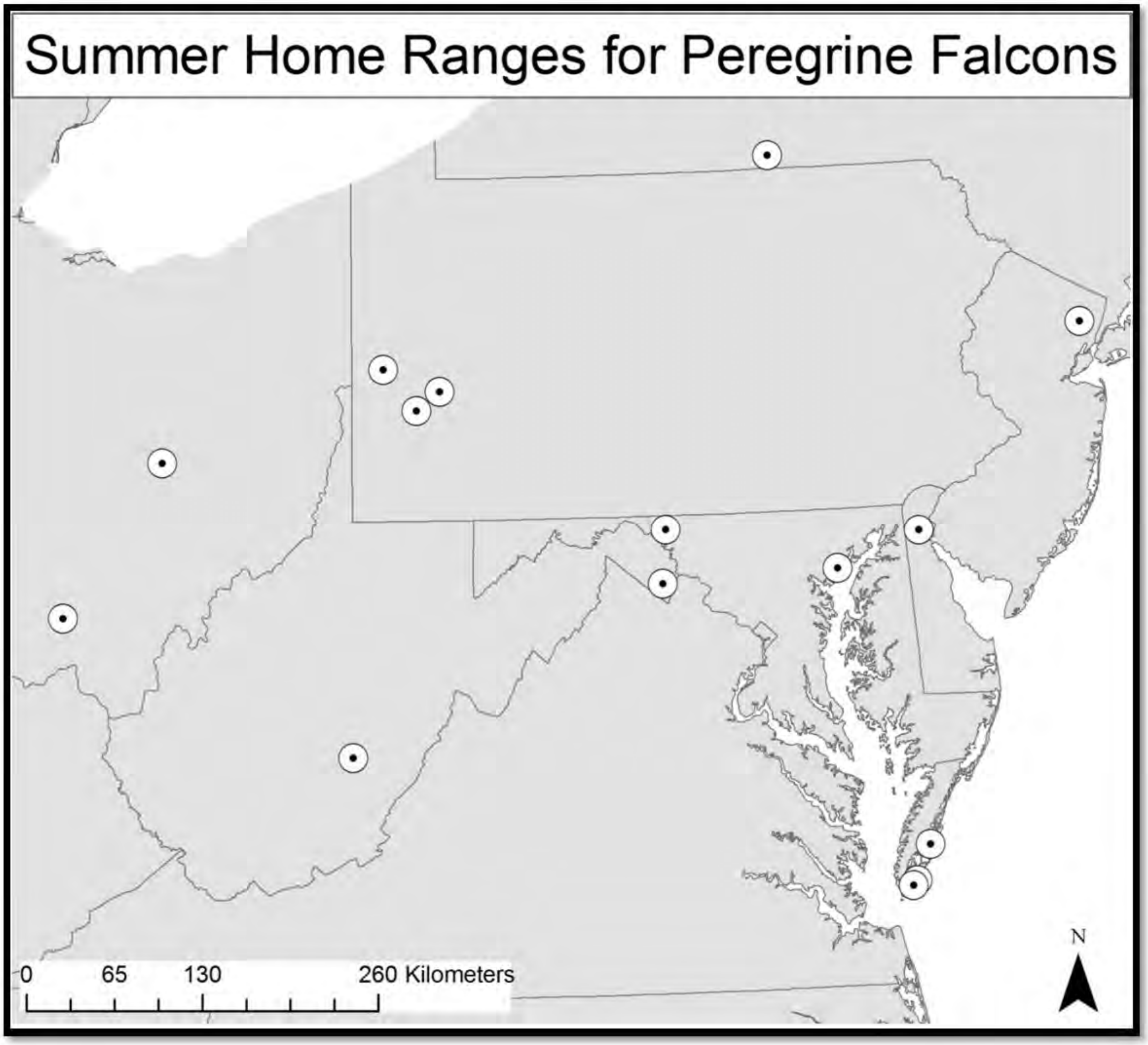

Figure 10. Map of centroids for Peregrine Falcon summer home ranges.

Table 4. Statistics and coordinates for Peregrine Falcon summer home ranges.

Transmitter	Year	n	90% kernel km2	50% kernel km2	Latitude	Longitude	City	State	Country
08146a	1	396	1,255	197	42.09115	-76.80015	Elmira	NY	USA
08146a	2	387	3,305	445	40.86044	-74.14594	Clifton	NJ	USA
08172b	1	425	3,463	378	39.54959	-75.65573	St. Georges	DE	USA
08175a	1	300	2,094	177	37.22981	-75.83380	Godwin Island	VA	USA
08175a	2	255	1,428	333	37.31903	-75.80431	Cobb Bay	VA	USA
08175b	1	138	9,433	2,135	38.15285	-80.52269	Richwood	WV	USA
27400a	1	594	4,724	281	39.32584	-76.36978	Bowleys Quarters	MD	USA
27400a	2	258	10,163	842	39.31507	-76.45041	Essex	MD	USA
27407c	1	37	1,075	174	40.58697	-79.75547	Arnold	PA	USA
36485a	1	365	8,772	736	40.73581	-80.24742	Rochester	PA	USA
36485a	2	285	8,838	913	40.46154	-79.95726	Pittsburgh	PA	USA
36491c	1	231	952	127	37.19687	-75.86969	Mockhorn Island	VA	USA
36493b	1	848	841	169	37.46344	-75.71113	Tar Bay	VA	USA
36493b	2	694	1,887	158	37.61497	-75.65540	Wachapreague	VA	USA
41300d	1	858	10,136	1,157	39.06342	-82.99607	Piketon	OH	USA
41300d	2	31	1,029	281	40.10834	-82.16730	Frazeysburg	OH	USA
54495	1	314	9,953	1,149	39.62967	-77.82671	Hagerstown	MD	USA
54495	2	166	2,072	278	39.26979	-77.86888	Charles Town	WV	USA
54495	3	151	2,621	480	39.29463	-77.86789	Charles Town	WV	USA
54495	4	53	2,011	530	39.31791	-77.85254	Charles Town	WV	USA
54496a	1	683	8,003	1,121	37.90811	-81.06234	Mt Hope	WV	USA

Breeding Territories

Five falcons were tracked from fledging until they established a breeding territory (Figure 11). Two falcons tracked in the study are currently breeding in Virginia and West Virginia (Table 5).

Table 5. Known breeding territories for satellite tracked Peregrine Falcons.

Transmitter	Breeding Location	Fate	Years on Territory
08175a	Godwin Island, VA	Currently nesting successfully on fishing shack ruins	2004-2011
27400a	Carroll Island Power Plant, MD	No nesting attempt documented before bird died.	2002-2003
27402a	Marine Nature Study Area, Oceanside, NY	documented breeding in Osprey nest	2004-2010
36493b	Wachapreague Island, VA	only documented breeding in 2004, never returned from Florida wintering area in 2005	2004

Transmitter	Breeding Location	Fate	Years on Territory
54495	Millville Quarry, WV	Raised 2 young in 2010 but nest was depredated before fledging. Territory occupied in 2011 but no breeding attempt documented.	2010-2011

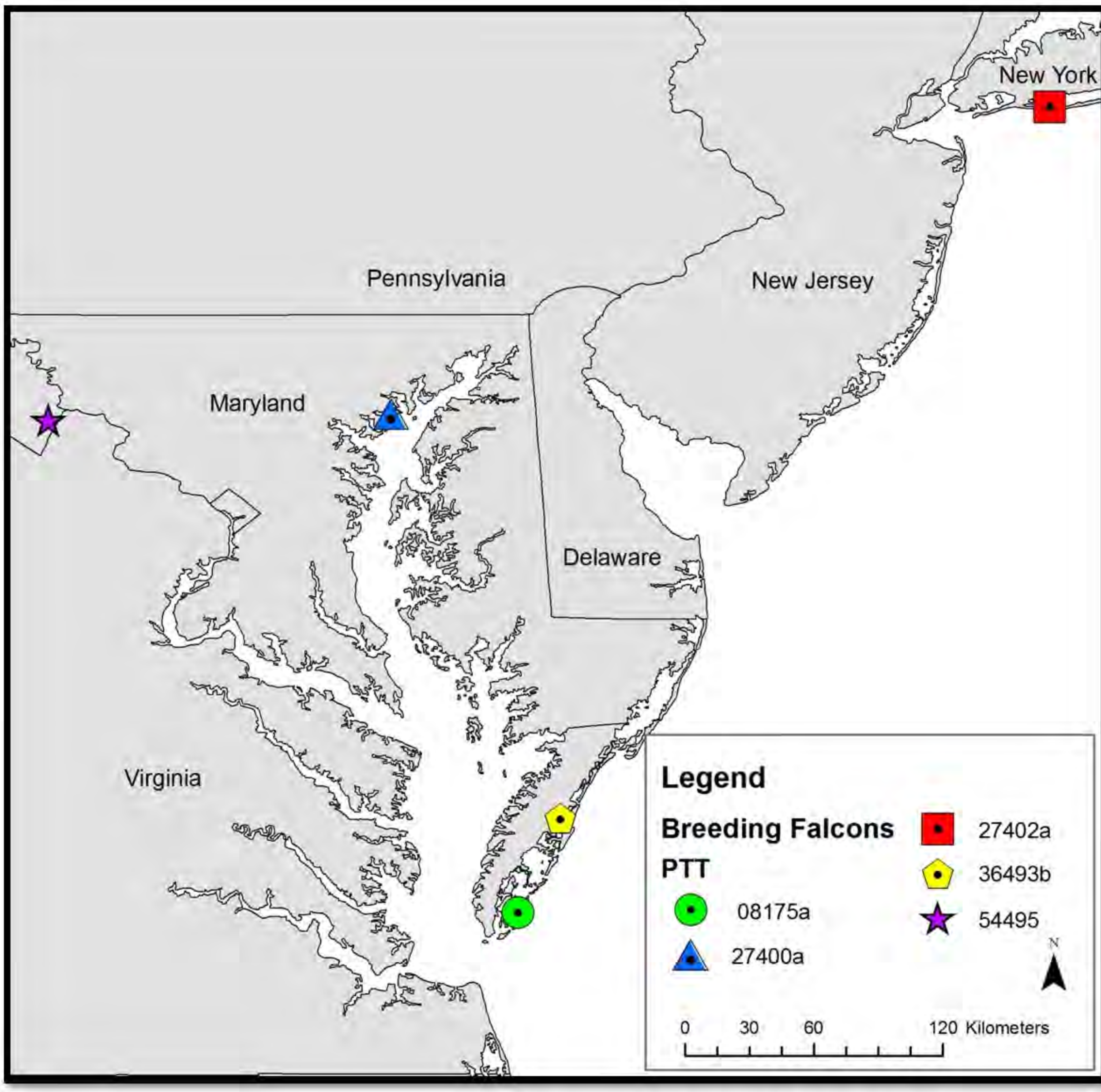

Figure 11. Breeding territories for Peregrine Falcons tracked with satellite telemetry.

Mortality

Cause of death could be reasonably assigned to 24 falcons included in the tracking study (Table 6). Of these 11 were believed to be depredated, 7 flew into man-made structures, 3 were killed in storms, 1 was hit by a truck on the bridge, 1 was drown after its first flight, and 1 was lost at sea. Predators believed to account for the most mortality included Great Horned Owls and adult Peregrine Falcons. Birds flew into transmission lines, towers, a high-rise building, and the side of a barn. The bird lost at sea was flying out over the open ocean and was lost near Bermuda.

Table 6. Age at death and causes of mortality for Peregrine Falcons.

Transmitter	**Outcome**	**Age at Death (days)**	**Cause**
08147	Assumed Dead	232	Unknown
-----	Dead	45	Flew into building at fledging
08145a	Dead	55	Great Horned Owl Predation
08146a	Dead	785	Collision with industrial tower
08172a	Dead	43	Blown off nest tower in storm and killed by raccoon
08172b	Dead	41	Drown at fledging
08172c	Dead	170	Believed to be predated at Fort Delaware
08175b	Dead	409	Unknown
08248a	Assumed Dead	61	Unknown
09908b	Dead	281	Killed in thunderstorm
24090a	Dead	136	Unknown
24090b	Dead	496	Believed to be predated near hack site
27394a	Dead	78	Unknown, lost near hack site
27396a	Dead	91	Unknown
27396b	Dead	99	Great Horned Owl Predation
27397a	Dead	40	Blown off nest tower in summer storm
27398a	Dead	48	Lost at fledging at hack site
27403b	Dead	39	Flew into building at fledging
27404a	Dead	97	Flew into tower or guy wire
27404C	Dead	434	Killed by adult Peregrine
27407a	Dead	75	Flew into transmission line
27407b	Assumed Dead	78	Unknown
27407c	Dead	391	Believed to be killed by adult Peregrine
27408a	Dead	60	Unknown
27408b	Dead	113	Flew into side of barn
27408c	Dead	233	Unknown
27409a	Dead	105	Flew into transmission line
27412b	Dead	155	Unknown
27412c	Dead	53	Hit by truck on bridge
36486a	Assumed Dead	179	Unknown

Transmitter	Outcome	Age at Death (days)	Cause
36487a	Assumed Dead	62	Unknown
36491a	Dead	106	Unknown
36491b	Dead	61	Great Horned Owl predation
36492a	Assumed Dead	179	Unknown
36492b	Dead	58	Great Horned Owl predation
41299a	Dead	428	Killed by adult Peregrine
41300a	Dead	424	Killed by adult Peregrine
41300b	Assumed Dead	47	Unknown, lost shortly after release at hack site
41300d	Dead	691	Killed by raptor
41301a	Dead	162	Lost at sea near Bermuda
54496a	Dead	612	Unknown

Tracking maps for individual falcons can be found online at http://ccb-wm.org/vafalcons/falcontrak/falcontrak_about.cfm.

DISCUSSION

After fledging, young falcons remained focused on the natal or hack site between 27 and 73 days. This period presumably reflects a time when the young require food supplements as they are learning to hunt on their own prior to dispersal. The length of the pre-dispersal period was significantly shorter for birds hacked in the mountains compared to wild-reared birds on the coast. Sherrod (1983) quantified fledgling behavior and documented similar variability in time to dispersal. The values recorded in this study fall cleanly within the range reported by Sherrod (1983). Sherrod compared time to independence for hacked birds in North America to wild-reared falcons in Greenland and Australia. As in the present study, he also documented a difference in the length of the pre-dispersal period with wild-reared birds remaining on the natal site longer. Sherrod suggests that this difference reflects the fact that wild-reared falcons are conditioned to food beg and that they will frequently remain within the natal territory until parents begin to exhibit aggressive behavior that compels them to disperse.

Very little is known about the post-dispersal period in Peregrine Falcons (White et al. 2002). Birds tracked in this study moved over very large areas before either migrating or settling on winter territories. Birds appeared to go on exploratory flights of hundreds of kilometers. Several birds visited large metropolitan areas. Virtually all of the birds went to areas where other peregrines were known to occur. One of the birds from the Hawksbill hack flew to the Harpers Ferry hack on several occasions before returning to Hawksbill. Other birds appeared to trapline prominent cliffs within the Appalachians where falcons are likely to be. Prospecting flights may serve to familiarize young falcons with both the regional landscape and occupied breeding locations.

The mid-Atlantic region falls within a transitional latitude for many bird species in terms of migratory status. Populations to the south are year-round residents while populations to the north are migratory. Very little is known about the migratory status of the emerging population of breeding Peregrines within the region. More than half of the birds that survived into the fall season migrated south. This mixture of migration strategies is consistent with winter recoveries made during the early period of the hacking program (Barclay and Cade 1983). Some individuals were known to have over wintered along the mid-Atlantic coast while others made southerly movements of various distances. Many of the birds in this study that were hacked in the mountains and remained in the region moved both east and north to the coast. Barclay and Cade (1983) analyzed the dispersal patterns of birds hacked in the mid-Atlantic region (1975-1981) using band recoveries and demonstrated an identical pattern. White (1968) plotted the recovery locations of a sample of peregrines banded as nestlings at various locations in the eastern United States and documented a similar pattern of dispersal for the historic peregrine population. All of these observations are in general agreement with an analysis by Bonney (1979) of Audubon Christmas Bird Count records showing that peregrines wintering in the east tend to be concentrated along the coast. Barclay and Cade (1983) suggest that the general movement to the coast is a response to prey availability which is highest in coastal areas during the late fall and winter. The concentration of winter home ranges along coastal areas of the region documented here supports this suggestion.

The average leaving date for birds migrating out of the region was 2 October which is consistent with the passage time of northern birds migrating through the mid-Atlantic region of North America. Fall migration on the Eastern Shore of Virginia peaks during the first 2 weeks of October (Ward and Berry 1972, Ward et al. 1988). Birds that have fledged along the coast may join in with migrating groups during their southbound migration. Both the coastal route of migration and the winter destinations are consistent with birds moving through this area from the north (Fuller et al. 1998).

One of the most striking findings of the migration tracking in this study is that migratory route and the subsequent location of winter home range was influence by the location of fledging. Birds fledged on the outer coast, migrated along a coastal route and into the tropics. Birds fledged from the Shenandoah mountains migrated relatively short distances to the Piedmont. Birds that fledged from the New River Gorge migrated down the Appalachians and in a more westerly direction to the Gulf Coast. The relatively short distance between the Hawksbill and New River Gorge hack sites (approx.240 km) appears to make a difference in post-dispersal movements. This has some management implications for the design of future releases. Birds hacked at New River disperse to the west into the Kanawha and Ohio River valleys and do not return to Virginia. Birds from Shenandoah remain on the east side of the Appalachians.

Non-migratory individuals settled into winter home ranges significantly earlier than did migratory individuals. Several of the non-migratory birds became year-round residents on their winter home ranges after their first fall. Presumably this provides some advantage to these birds in establishing and maintaining breeding territories. Birds did not change migratory status in subsequent years. However, migratory birds did return earlier after their second spring migration compared to their first. This is a common pattern with migratory raptors that have delayed age to first reproduction. Birds do not typically breed in their first year and so are slow to return. In subsequent years, there is more incentive to return early to secure a breeding territory. Differences between fall and spring migration in terms of duration may reflect the need to return early in the spring.

The dominant mortality factors observed in this study are consistent with recent reports from other populations (Cade et al. 1988, Cade and Bird 1990, Bird et al. 1996). The largest source of mortality was predation by raptors. This was primarily Great Horned Owls that will often kill entire broods. Birds were also killed by adult peregrines. Most of there were from a single brood at Wallops in 2003 when the breeding male was lost and quickly replaced. The replacement male Peregrine killed the brood which is a common outcome of mate turnover in raptors. The second largest source of mortality was birds colliding with artificial structures. These collisions apparently occurred as birds were developing their ability to fly and hunt. Cade and Bird (1990) discuss the role of artificial structures within urban environments in the mortality of young falcons. Tall buildings, utility wires, and bridges may be particularly dangerous to inexperienced falcons when winds are gusty and unpredictable. Virtually all of the young falcons gravitated to metropolitan areas and came into contact with urban environments. During the 2002 season a series of storms moved through the area at just the wrong time and blew chicks off towers just before fledging. Several chicks were lost in these events.

ACKNOWLEDGEMENTS

The FalconTrak project would not have been possible without the efforts of many individuals and partnership organizations. Dominion played a key role in spearheading the effort to launch FalconTrak and provided financial and logistical support to the project. We thank T. E. Capps, Bill Bolin and Dan Genest for leadership, as well as, Cindy Balderson, Charlie Donato, Ed Bush, and Larry Comstock for their assistance and important role in bringing the project to the public. The Virginia Department of Game & Inland Fisheries provided financial, advisory and logistical support to the project. We thank Bill Woodfin, David Whitehurst, Ray Fernald, Don Schwab, and Jeff Cooper for supporting and guiding the project. Jeff Trollinger headed up the mapping portion of the project. The National Aeronautics and Space Administration provided critical financial support. We thank Odean Serrano and Joel Mitchell for supporting the project. The National Park Service has had a long history of supporting re-introduction of falcons in the mountains and played a critical role in managing hack sites at Shenandoah National Park, Harpers Ferry National Historical Park, New River Gorge National Scenic River Park. We appreciate the support of superintendents Doug Morris and Donald Campbell. Rolf Gubler and Bill Hebb coordinated the hacks at Hawksbill Mountain and Maryland Heights Cliffs respectively. Kim Miller and Garrick Bryant coordinated logistics and attended birds at Hawksbill Mountain. We thank the interpretive staff of the Byrd Visitor Center for their support of the project. Dale Nisbet and David Gilbert conducted the hack at Maryland Heights Cliffs. Matthew Varner from New River Gorge (NPS) and Craig Stihler from WV DNR managed the hack at New River Gorge. Wendy and Ron Perrone from Three Rivers Avian Center and others also assisted with the New River Gorge site. The U.S. Fish & Wildlife Service provided financial and logistical support. We thank John Schroer and Irvin Ailes from Chincoteague National Wildlife Refuge , Sue Rice and Pam Denmon of Eastern Shore of Virginia National Wildlife Refuge, and John Morton from Blackwater National Wildlife Refuge for their assistance with the project. As he has done for many years, Craig Koppie provided falcon expertise and ground support, particularly in coordinating the translocation of Maryland birds to Harper’s Ferry. The Virginia Department of Transportation has been a partner in falcon conservation for several years. We thank Jeff Southard, Steve Long, and Don West for their continued support and cooperation. We also thank Jack Meredith and Mike Dangerfield for assistance in the field accessing nests. Northstar Science and Technology, LLC supplied the solar-powered PTTs for the project. We thank Bill Seegar and Blake Henke for their support of the tracking portion of the project. We thank Jim Dayton for providing his expertise in satellite telemetry and training us on how to attach the satellite units. We thank Glenn Therres of the Maryland Department of Natural Resources for supporting the project and allowing translocations within Maryland. Kathy Clark of New Jersey Division of Fish and Wildlife banded and coordinated the NJ falcons in 2007 and Tri-state Bird Rescue transported the falcons to the hack site. Brad Bashara provided air transport in 2007 to harness falcons at New River Gorge. Mitchell Byrd, Dana Bradshaw, Marian Watts, and Catherine Markham provided logistical support from the Center for Conservation Biology.

LITERATURE CITED

Barclay, J. H. 1988. Peregrine restoration in the eastern United States. Pp. 549-558 in T. J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White Eds. Peregrine Falcon populations – their management and recovery. The Peregrine Fund, Inc., Boise, Idaho.

Barclay, J. H. and T. J. Cade. 1983. Restoration of the Peregrine Falcon in the Eastern United States. Bird Conservation 1:3-37.

Berger, D. D., C. R. Sindelar, Jr., and K. E. Gamble. 1969. The status of breeding peregrines in the eastern United States, in J. J. Hickey ed., *Peregrine Falcon Populations: Their Biology and Decline*. University of Wisconsin Press. Madison, Wisconsin. Pp. 165-173.

Beyer, H. L. 2004. Hawth's Analysis Tools for ArcGIS. http://www.spatialecology.com/htools

Bird, D., D. Varland, and J. Negro, eds. Raptors in human landscapes. Academic Press, New York.

Bollengier, R. M., Jr., J. Baird, L. P. Brown, T. J. Cade, M. G. Edwards, D. C. Hagar, B. Halla, and E. McCaffrey. 1979. Eastern Peregrine Falcon recovery plan. U.S. Fish and Wildlife Service. 147 pp.

Bonney, R. E., Jr. 1979. Wintering Peregrine Falcon population in the eastern United States, 1940-1975: A Christmas Bird Count analysis. American Birds 33:695-697.

Brown, L. and D. Amadon. 1968. Eagles, Hawks and Falcons of the World. McGraw Hill. New York, New York. 945 pp.

Cade, T. J. 1974. Current status of the peregrine in North America. Pp. 3-12 in Proceedings of the Conference on Raptor Conservation Techniques, Fort Collins, Colorado. Raptor Research Report No. 3.

Cade, T. J., J. L. Lincer, C. M. white, D. G. Roseneau, and L. G. Swartz. 1971. DDE residues and eggshell changes in Alaskan falcons and hawks. Science 172:955-957.

Cade, T. J., M. Martell, P. Redig, G. Septon, and H. B. Tordoff. 1996. Peregrine Falcons in urban North America. Pages 3-13 in Raptors in human landscapes. (Bird, D. M., D. E. Varlan, and J. J. Negro, Eds.) Academic Press, London, U.K.

Cade, T. J. and R. W. Fyfe. 1978. What makes Peregrine Falcons breed in captivity. Pp. 251-262. in Endangered Birds: Management techniques for preserving threatened species (S. A. Temple, Ed.) Univ. of Wisconsin Press, Madison, WI.

Cade, T. J., J. H. Enderson, C. G. Thelander, and C. M. White, eds. 1988. Peregrine Falcon populations; their management and recovery, The Peregrine Fund, Inc., Boise, ID.

Cade, T. J. and D. M. Bird. 1990. Peregrine Falcons, *Falco peregrinus*, nesting in an urban environment: a review. Canadian Field-Naturalist 104:209-218.

Coyne, M. S. and B. J. Godley. 2005. Satellite Tracking and Analysis Tool (STAT): an integrated system for archiving, analyzing and mapping animal tracking data. Marine Ecology Progress Series 301:1-7.

Enderson, J. H., W. Heinrich, L. Kiff, and C. M. White. 1995. Population changes in North American peregrines. Transactions of the North American Wildlife and Natural Resources Conference 60:142-161.

Fancy, S. G., L. F. Pank, D. C. Douglas, C. H. Curby, G. W. Garner, S. C. Amstrup, and W. L. Regelin. 1988. Satellite telemetry: a new tool for wildlife research and management. U.S. Fish & Wildlife Service Resource Publication. 172 pp.

Fuller, M. R., W.S. Seegar, and L. S. Schueck. 1998. Routes and travel rates of migrating Peregrine Falcons *Falco peregrinus* and Swainson's Hawks Buteo swainsoni in the Western Hemisphere. Journal of Avian Biology 29:433-440.

Gabler, J. K. 1983. The Peregrine Falcon in Virginia: Survey of historic eyries and reintroduction effort. Unpublished masters thesis, College of William and Mary, Williamsburg, VA 81 pp.

Hickey, J. J. 1942. Eastern population of the Duck Hawk. Auk 59:176-204.

Hickey, J. J., Ed. 1969. *Peregrine Falcon Populations: Their Biology and Decline*. University of Wisconsin Press. Madison, Wisconsin.

Jones, F. M. 1946. Duck Hawks of eastern Virginia. Auk 63:592.

Kenward, R. 1987. Wildlife radio tagging. Academic Press, London.

Mesta, R. 1999. Final rule to remove the American Peregrine Falcon from the federal list of endangered and threatened wildlife. Federal Register 64:46542–46558.

Millsap, B. A., P. L. Kennedy, M. A. Byrd, G. Court, J. H. Enderson, and R. N. Rosenfield. 1998. Review of the proposal to de-list the American Peregrine Falcon. Wildlife Society Bulletin 26:522-538.

Mojica, E.K., B.D. Watts, and S.M. Padgett. 2010. Virginia Peregrine Falcon monitoring and management program: Year 2010 report. Center for Conservation Biology Technical Report Series, CCBTR-10-10. College of William and Mary & Virginia Commonwealth University, Williamsburg, VA. 21 pp.

Pagel, J. E. and D. A. Bell. 1997. Reply to Cade et al. regarding delisting of the American Peregrine Falcon. Wildlife Society Bulletin 25:739-742.

Pagel, J. E., D. A. Bell, and B. E. Norton. 1996. De-listing the American Peregrine Falcon: is it premature? Wildlife Society Bulletin 24:429-435.

Palmer, R. S. 1988. Handbook of North American birds, Volume 5 (Part 2). Yale University Press. New Haven. 456 pp.

Peakall, D. B., T. J. Cade, C. M. White, and J. R. Haugh. 1975. Organo-chorline residues in Alaskan peregrines. Pesticides Monitoring Journal 8:225-260.

Ratcliffe, D. A. 1980. The Peregrine Falcon. Buteo Books. Vermillion, South Dakota. 416 pp.

Service ARGOS. 2011. Argos User's Manual. Service ARGOS, Toulouse, France. http://www.argos-system.org/documents/userarea/argos_manual_en.pdf

Sherrod, S. K. 1983. Behavior of fledgling peregrines. The Peregrine Fund, Inc., Ithaca, NY. 202 pp.

Sherrod, S. K., W. R. Heinrich, W. A. Burnham, J. H. Barclay, and T. J. Cade. 1981. Hacking: A method for releasing Peregrine Falcons and other birds of prey. The Peregrine Fund, Inc. 62 pp.

Swem, T. 1994. Endangered and threatened wildlife and plants; removal of Arctic Peregrine Falcon from the list of endangered and threatened wildlife. Federal Register 59:50796-50805.

Ward, F. P. and R. B. Berry. 1972. Autumn migrations of Peregrine Falcons on Assateague Island, 1970-71. Journal of Wildlife Management 36:484-518.

Ward, F. P., K. Titus, W. S. Seegar, M. A. Yates, and M. R. Fuller. 1988. Autumn migrations of Peregrine Falcons at Assateague Island, Maryland/Virginia, 1970-1984. Pp. 485-495 in Peregrine Falcon populations: their management and recovery (T. J. Cade, J. H. Enderson, C. G. Thelander and C. M. White, Eds.) The Peregrine Fund, Boise, ID.

Watts, B. D., S. M. Padgett, M. A. Byrd, B. J. Paxton, and J. L. Cooper. 2002. FALCONTRAK: Year 2001 report. Center for Conservation Biology Technical Report Series. CCBTR-02-06. College of William and Mary, Williamsburg, VA. 46pp.

White, C. M. 1968. Biosystematics of North American Peregrine Falcons. Unpublished Ph.D. Thesis. University of Utah.

White, C. M., N. J. Clum, T. J> Cade, and W. G. Hunt. 2002. Peregrine Falcon (*Falco peregrinus*) in The Birds of North America, No. 660 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

APPENDIX 1. Dates and ages of events surrounding Peregrine Falcon dispersal.

Transmitter	Sex	Hatch Date	Fledge Date	Dispersal Date	Age at Dispersal	Dispersal Post fledge
27403a	F	5/3/2001	6/17/2001	8/29/2001	118	73
27396a	F	5/3/2001	6/17/2001			
27400a	F	4/18/2001	6/2/2001	7/26/2001	99	54
27404a	F	4/18/2001	6/2/2001	7/13/2001	86	41
27402a	F	5/15/2001	6/29/2001	8/2/2001	79	34
27408a	F	5/10/2001	6/24/2001			
27395a	F	4/18/2001	6/2/2001			
27399a	F	4/16/2001	5/31/2001	7/17/2001	92	47
27411a	F	5/3/2001	6/17/2001	7/26/2001	84	39
27412a	F	5/10/2001	6/24/2001	7/24/2001	75	30
27407a	F	5/10/2001	6/24/2001	7/21/2001	72	27
-----	F	4/16/2001	5/31/2001			
27394a	M	4/22/2001	6/6/2001			
27398a	M	4/18/2001	6/2/2001			
27406a	M	5/10/2001	6/24/2001	8/6/2001	88	43
27409a	M	5/10/2001	6/24/2001	8/16/2001	98	53
27397a	M	5/3/2001	6/17/2001			
27401a	M	5/3/2001	6/17/2001	7/18/2001	76	31
27410a	M	5/3/2001	6/17/2001	8/18/2001	107	62
27408b	F	4/15/2002	5/30/2002	7/15/2002	91	46
27400b	F	4/13/2002	5/28/2002			
27404b	F	4/13/2002	5/28/2002	7/12/2002	90	45
36485a	F	4/20/2002	6/4/2002	7/20/2002	91	46
08172a	F	4/26/2002	6/10/2002			
08248a	F	4/28/2002	6/12/2002			
08175a	F	4/28/2002	6/12/2002	8/5/2002	99	54
24090a	F	4/28/2002	6/12/2002	7/31/2002	94	49
27407b	F	5/1/2002	6/15/2002			
08204a	F	5/1/2002	6/15/2002	7/20/2002	80	35
36492a	F	4/12/2002	5/27/2002	8/7/2002	117	72
36493b	F	4/12/2002	5/27/2002	7/25/2002	104	59
08147	F	5/15/2002	6/29/2002			
36487a	F	5/15/2002	6/29/2002			
08146a	F	5/1/2002	6/15/2002			
08145a	M	5/15/2002	6/25/2002			
36491a	M	5/21/2002	7/5/2002	8/14/2002	85	40
08172b	M	5/23/2002	7/7/2002			
27412b	F	4/23/2003	6/7/2003	8/19/2003	118	73
24090b	F	4/29/2002	6/13/2002			
27404C	F	5/2/2002	6/16/2002			

Transmitter	Sex	Hatch Date	Fledge Date	Dispersal Date	Age at Dispersal	Dispersal Post fledge
27407c	F	5/10/2003	6/24/2003	7/30/2003	81	36
27404D	F	5/17/2003	7/1/2003	8/14/2003	89	44
36491b	F	5/14/2003	6/28/2003			
27396b	F	5/14/2003	6/28/2003	8/3/2003	81	36
36486a	F	5/26/2003	7/10/2003	8/27/2003	93	48
27403b	M	4/29/2003	6/13/2003			
41301a	M	4/23/2003	6/7/2003	7/26/2003	94	49
41299a	M	5/2/2002	6/16/2002			
41300a	M	5/2/2002	6/16/2002			
36492b	M	5/26/2003	7/10/2003			
41300b	M	6/14/2003	7/29/2003			
41300c	M	ASY-M	ASY-M			
08172c	F	5/5/2004	6/19/2004	7/29/2004	82	40
27412c	F	5/1/2004	6/15/2004			
36491c	F	5/16/2004	6/30/2004	8/17/2004	93	48
54495	F	4/25/2007	6/9/2007	7/30/2007	96	51
41300d	F	4/25/2007	6/9/2007	7/26/2007	92	47
09908b	M	4/25/2007	6/9/2007	7/29/2007	95	50
27408c	M	4/25/2007	6/9/2007	8/2/2007	99	54
54496a	M	4/25/2007	6/9/2007	8/16/2007	113	68
08175b	M	5/15/2007	6/29/2007	7/26/2007	72	27