2002

Project FALCONTRAK Year 2001 report: Investigating the ecology of Mid-Atlantic Peregrines using satellite technology

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Recommended Citation

Watts, B. D., S. M. Padgett, M. A. Byrd, B. J. Paxton, and Jeffrey L. Cooper. 2002. Project FALCONTRAK Year 2001 report: Investigating the ecology of Mid-Atlantic Peregrines using satellite technology. CCBTR-02-06. Center for Conservation Biology Technical Report Series. College of William and Mary, Williamsburg, VA. 46 pp.

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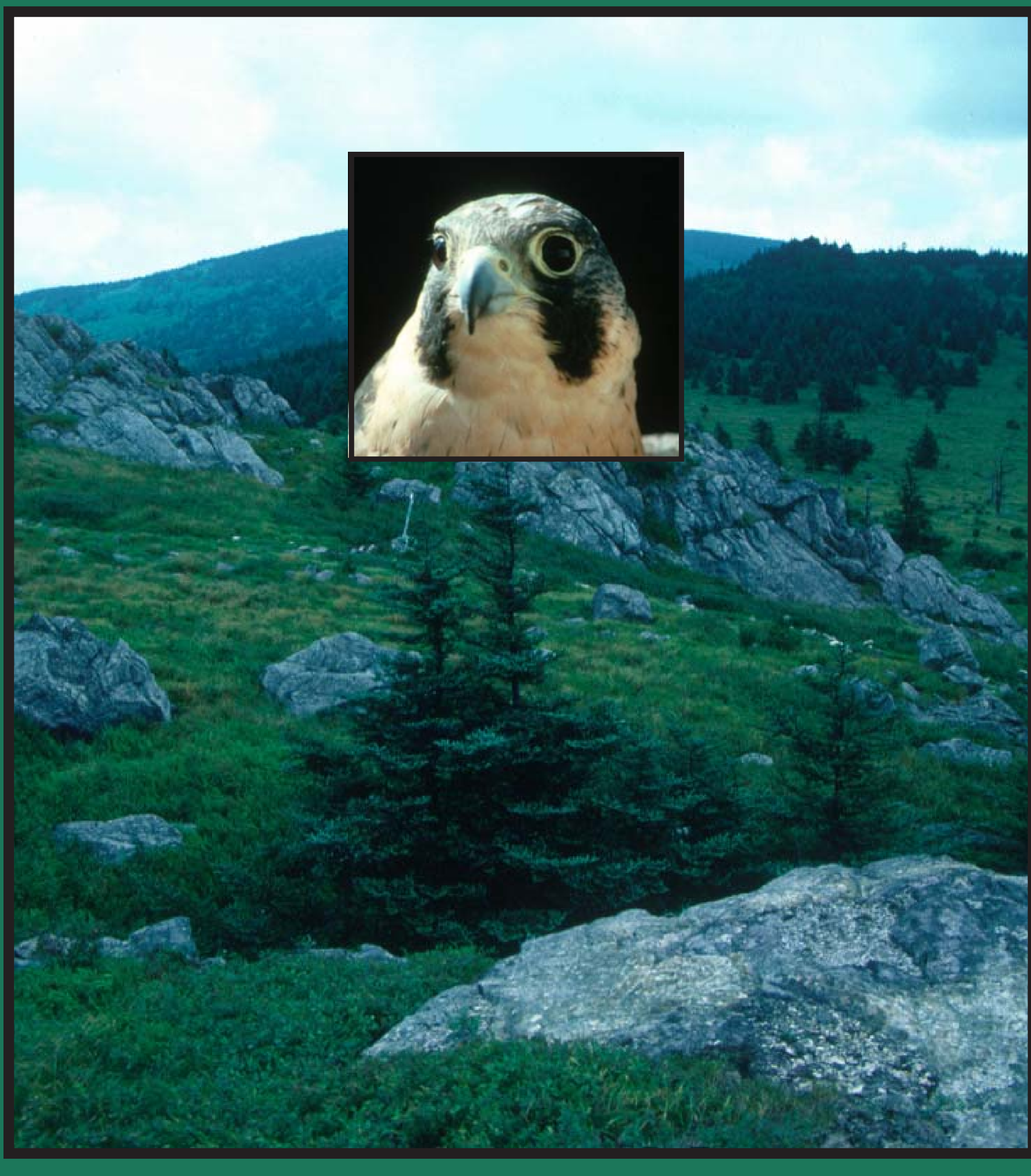

CENTER FOR CONSERVATION BIOLOGY
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PROJECT FALCONTRAK YEAR 2001 REPORT: INVESTIGATING THE ECOLOGY OF MID-ATLANTIC PEREGRINES USING SATELLITE TECHNOLOGY

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Cover Photos by: Craig Koppie and Dana Bradshaw.

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

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EXECUTIVE SUMMARY

FalconTrak is a multi-organizational partnership designed to investigate survivorship and movement patterns of young peregrine falcons in the mid-Atlantic region. The goal of this project is to collect information that may be used to improve the management of this species in the region. During the 2001 breeding season, 19 young falcons were fitted with solar-powered, satellite transmitters and tracked until they died or transmitters failed. These birds included captive-reared birds that were released in the mountains, wild-reared birds that were translocated for release in the mountains, and wild-reared birds that were fledged *in situ* within coastal territories.

Nearly 50% (9 of 19) of the falcons were lost in the first 6 months of tracking. All of these birds were lost in the initial 10 weeks after fledging as they were gaining experience flying and hunting. The largest source of mortality was collisions with artificial structures such as utility lines and buildings. Remaining birds were lost to storms or unknown causes. All birds that survived into the late fall months exhibited the same basic seasonal pattern in movement rates. Birds appear to develop through a pre-dispersal period, a dispersal period, and eventually enter a post-dispersal period that was likely the functional equivalent of a winter range. The pre-dispersal period averaged 50 days in length and was characterized by short movements that were focused on the natal or hack site. This period corresponds to the period of dependency when falcons require food supplements as they learn to hunt on their own. The dispersal period begins with a definitive dispersal flight away from the natal site and is characterized by broad-scale movements that may be punctuated by shorter movements that are focused on temporary staging areas. This period lasted approximately 100 days.

All of the birds that were hacked in the mountains ultimately gravitated to the coast and occupied staging sites for varying periods of time. All of the birds that fledged within coastal sites, remained on the coast through the tracking period. Once on the coast, birds moved both north and south and many birds spent significant periods of time in major metropolitan areas such as Baltimore, Philadelphia, Trenton, New York City, and Boston. Other staging areas included more natural coastal habitats such as barrier islands and extensive complexes of open marshes. The general preference for the coast appears to be a response to prey availability which is highest in coastal areas during the late fall and winter and underscores the importance of coastal habitats in the life cycle of mid-Atlantic peregrines.

Only 3 of the 9 birds that were tracked into the late fall months exhibited definitive southerly migration movements. These 3 birds represented all of the geographic situations included in the project. Two of these birds migrated along a coastal route and made a transoceanic flight from the Outer Banks of North Carolina. One bird made landfall just north of Grand Bahama Island and over the next 2 weeks made its way through Cuba and to the eastern side of the Dominican Republic. The second bird made landfall in northern Florida and over the next month made its way to Miami. The third bird flew along the fall line of the coastal plain south to South Carolina.

BACKGROUND

Context

The peregrine falcon 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 an *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 1950's, and into the 1960's 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 1960's. 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 andreach 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://fsweb.wm.edu/ccb/vafalcons/vacons/reintro.htm). From a single breeding pair in 1981, the Virginia population has increased to 17 known pairs in 2001.

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 20 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 the time period just after fledging. Several questions that are important to the future management of the mid-Atlantic population remain unanswered. How many of the falcons produced in Virginia survive to reproductive age? What are some of the causes of mortality? How and when do birds disperse from their natal sites? Where do birds produced in Virginia go to breed? Do birds in the Virginia population migrate? If they migrate, where do they spend the winter months?

Objectives

FalconTrak is a cooperative project designed to answer a series of questions about the movements and survival of mid-Atlantic peregrines. The project utilizes satellite telemetry to track young falcons throughout their annual cycle. Our objectives in tracking these birds are 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 19 birds was included in the tracking study during the 2001 breeding season (Table 1). Seven of these birds originated on coastal bridges, 7 on peregrine nesting towers, 2 on a light house, and 3 from a captive breeder. Birds from the captive breeding program were from *F. p. anatum* stock. All of the captive and bridge-produced birds, 1 of the tower-produced birds and 2 birds produced on a light house were hacked from mountain release sites. Remaining birds were allowed to fledge *in situ*. Release sites included Hawksbill Mountain within Shenandoah National Park and Maryland Heights Cliffs within Harpers Ferry National Historical 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. These included 12 females and 7 males.

Birds were fitted with U.S. Fish and Wildlife Service aluminum tarsal bands on the right leg and alpha-numeric, bi-colored, auxiliary bands 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 20 g, solar-powered units produced by Northstar Science and Technology, LLC (Baltimore, Maryland). These units were programmed 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 neoprene were used as mounting straps and each bird was custom fit.

Tracking

Birds were located using NOAA satellites with onboard tracking equipment operated by Service ARGOS Inc. (Landover, Maryland) (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 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.

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. None of the PTTs deployed in the spring and summer of 2001 met this design objective. 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.

Table 1: List of young peregrine falcons included in the 2001 tracking project.

FWS Band	Color Band	Transmitter	Sex	Natal Site	Fledging Site
2206-07451	BL-GR 7 / 4	#27394	M	Benjamin Harrison Bridge	Hawksbill
2206-07450	BL-GR 7 / 3	#27398	M	Mills Godwin Bridge	Hawksbill
2206-07460	BL-RD *7 / *4	#27406	M	Captive Breeder	Hawksbill
2206-07475	BL-RD *7 / *5	#27409	M	Captive Breeder	Hawksbill
2206-07453	BL-RD 7 / 6	#27397	M	Elkins Marsh	Elkins Marsh
2206-07455	BL-RD 7 / 8	#27401	M	Watts Island	Watts Island
2206-07454	BL-RD 7 / 7	#27410	M	Watts Island	Watts Island
987-76890	BL-RD *8 / 4	#27403	F	Wallops Island	Wallops Island
987-76889	BL-RD *8 / 3	#27396	F	Wallops Island	Wallops Island
987-76883	BL-RD *6 / P	#27400	F	Mills Godwin Bridge	Hawksbill
987-76887	BL-RD *6 / V	#27404	F	Benjamin Harrison Bridge	Hawksbill
987-76891	BL-RD *8 / 5	#27402	F	Metomkin Island	Hawksbill
987-76894	BL-RD *6 / 3	#27408	F	Captive Breeder	Hawksbill
987-76884	BL-RD *6 / R	#27395	F	Mills Godwin Bridge	Hawksbill
987-76881	BL-RD *6 / E	#27399	F	James River Bridge	Hawksbill
987-76888	BL-RD *6 / Y	#27411	F	Watts Island	Watts Island
987-76911	BL-RD *B / *A	#27412	F	Hart Miller Island	Harpers Ferry
987-76912	BL-RD *B / *B	#27407	F	Hart Miller Island	Harpers Ferry
987-76882	BL-RD *6 / K	-----	F	James River Bridge	Richmond

A total of 13,551 signals were received from transmitters after deployment during the 2001 tracking study. The rate of signal reception varied considerably between transmitters (Table 2). The average number of signals received/day varied between transmitters by nearly an order of magnitude from 1.3 to 9.2. More importantly, the average number of usable signals (LC1 – LC3) varied by more than an order of magnitude from 0.2 to 3.1. Overall, 16.3% of all signals received were of high enough quality to be used in the analysis. The majority of these (representing 15.2%) were LC1 signals. Only 2.1% of the total signals received were LC3 signals. Variation in transmitter performance may be due to bird behavior. For example, birds that roost regularly in the shade may not allow transmitters to become fully charged. However, at least a portion of the observed variation is due to variability in the units themselves. This was evident in January when bird #27400 was captured and refitted with a new transmitter. Signal reception more than doubled after the transmitter was replaced.

In addition to the variation in performance between transmitters, there is a clear seasonality to the rate of signal reception. Figure 1 gives an example of the seasonal pattern in signal detection for a single individual. Signal reception rates changed more than five fold with season. The underlying causes of this seasonal shift are not clear. It is possible that bird behavior or day length may be contributing factors. However, the seasonal shift does not appear to be completely in phase with shifts in day length.

Movement Patterns

Locational information received from ARGOS was screened according to accuracy estimates (LC), entered into databases, and plotted using arcview software (Environmental Systems Research Institute Inc., Redlands, California) for each individual bird. For the purpose of location and movement analyses, we used only data points with location classes of 1-3. For examination of movement rates, the last useable location was used for each day, and linear distances were measured between successive days. Distances were then plotted using 5-d running averages to examine the pattern in movement rates across season. Transitions in movement rates along with spatial patterns were used to delineate functional periods. Pre-dispersal was considered to be the time period between fledging and a break-out, dispersal flight where the bird did not return to the natal or hack site for at least a 2-d period. 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. Inspection of movement rates, also indicates that this event triggers a different phase where birds make long-ranging flights that are less focused. The dispersal period begins with a definitive dispersal flight and ends when movement rates fell and remained low. Birds in the post-dispersal period moved over distances comparable to that of pre-dispersal birds and their movements were more focused on a small area.

Table 2. Summary of performance for individual satellite transmitters.

Transmitter Code	Total Signals	Total Signals/Day	Useable Signals/Day	LC1 (%)	LC2 (%)	LC3 (%)
#27394	180	5.1	1.7	21.7	8.3	2.8
#27395	240	4.1	0.3	5.4	2.1	0.8
#27396	259	5.2	1.6	23.2	6.6	1.5
#27397	23	1.8	0.4	21.7	0.0	0.0
#27398	11	1.6	0.7	9.1	18.2	18.2
#27399	1,593	9.2	2.7	17.9	9.1	2.8
#27400	1,453	6.7	1.2	11.9	4.3	1.6
#27401	1,407	8.5	2.0	15.9	5.0	2.1
#27402	1,170	6.0	0.9	11.1	3.3	0.4
#27403	788	7.2	1.6	14.2	5.8	2.0
#27404	227	3.6	0.7	15.4	4.0	0.4
#27406	1,189	7.9	1.1	9.8	3.7	1.0
#27407	322	1.5	0.3	9.3	9.3	3.1
#27408	127	1.3	0.2	11.8	3.1	0.8
#27409	466	2.5	0.5	12.7	4.5	1.5
#27410	1,910	9.1	3.1	19.8	10.7	4.1
#27411	918	7.5	2.4	20.0	10.0	2.4
#27412	1,268	8.6	1.9	15.9	3.8	1.7
Total	13,551	6.1	1.4	15.2	6.3	2.1

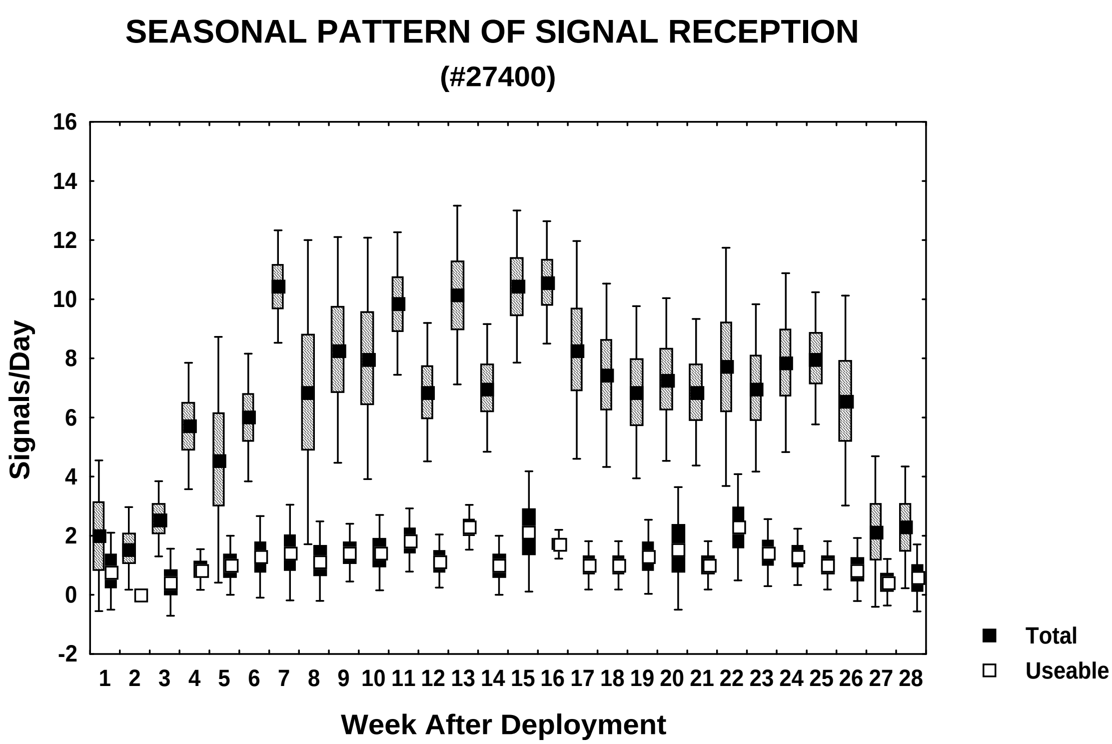

Figure 1. Seasonal pattern of signal reception for bird #27400. Total refers to all signals received. Useable refers to LC1-3 signals received. Boxes indicate 1SD unit, wiskers indicate 1SE unit.

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 behavior 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. Of 9 birds that were lost, 7 were observed to go down, recovered by citizens, or recovered by the search team.

RESULTS

Movements

Temporal Patterns

Falcons that could be tracked throughout the fall months exhibited a pattern of movement that contained 3 basic phases and was consistent across individuals (see Appendix I for a complete treatment of temporal patterns for individual birds). These phases included 1) pre-dispersal, 2) dispersal, and 3) post-dispersal. The pre-dispersal period was characterized by relatively short movements (<30 km) that were focused on the natal (or hack) site. This period corresponds to the “dependency” period when the birds likely require food supplements from the parents or from the hack site. The pre-dispersal period ends with a flight away from the natal site and at least a few days without returning. Nearly all of the birds made a definitive dispersal flight that lead to a change in movement pattern. The dispersal period is somewhat variable between individuals but involves a series of long-distance flights that may be separated by discrete staging periods. This period appears to be exploratory and often involves movements over large geographic areas. The post-dispersal period appears to relate to settlement on a winter range.

Pre-dispersal – Length of the pre-dispersal period ranged from 39 to 73 days with an average of 50.5 + 3.93 (mean $\pm$ SE). Time to dispersal was significantly longer for coastal birds (62.3 $\pm$ 7.78 d) compared to birds hacked in the mountains (43.7 $\pm$ 1.51) (t-statistic = -3.09, df = 9, $p < 0.05$) (Figure 2). During this period, movement distances recorded were relatively short with a mean of only 4.7 $\pm$ 0.38 km (N = 358) (Figure 3). Greater than 90% of all movements recorded were less than 10 km from the natal site.

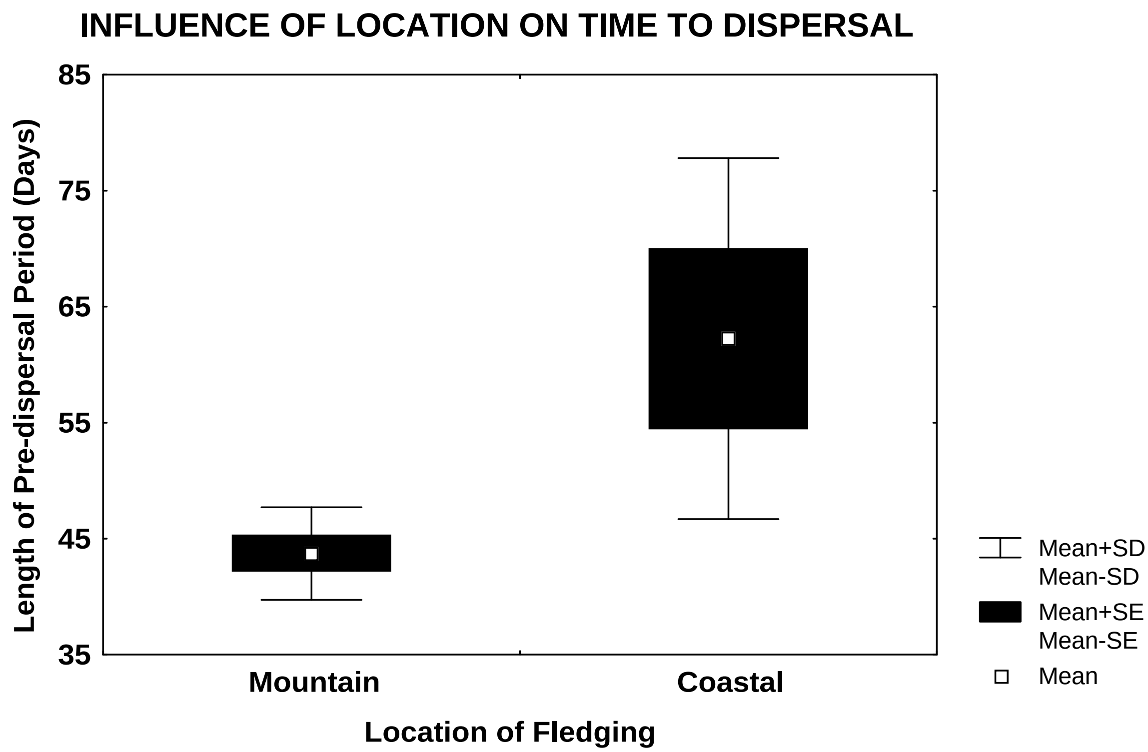

Figure 2. The influence of location on the average length of the pre-dispersal period.

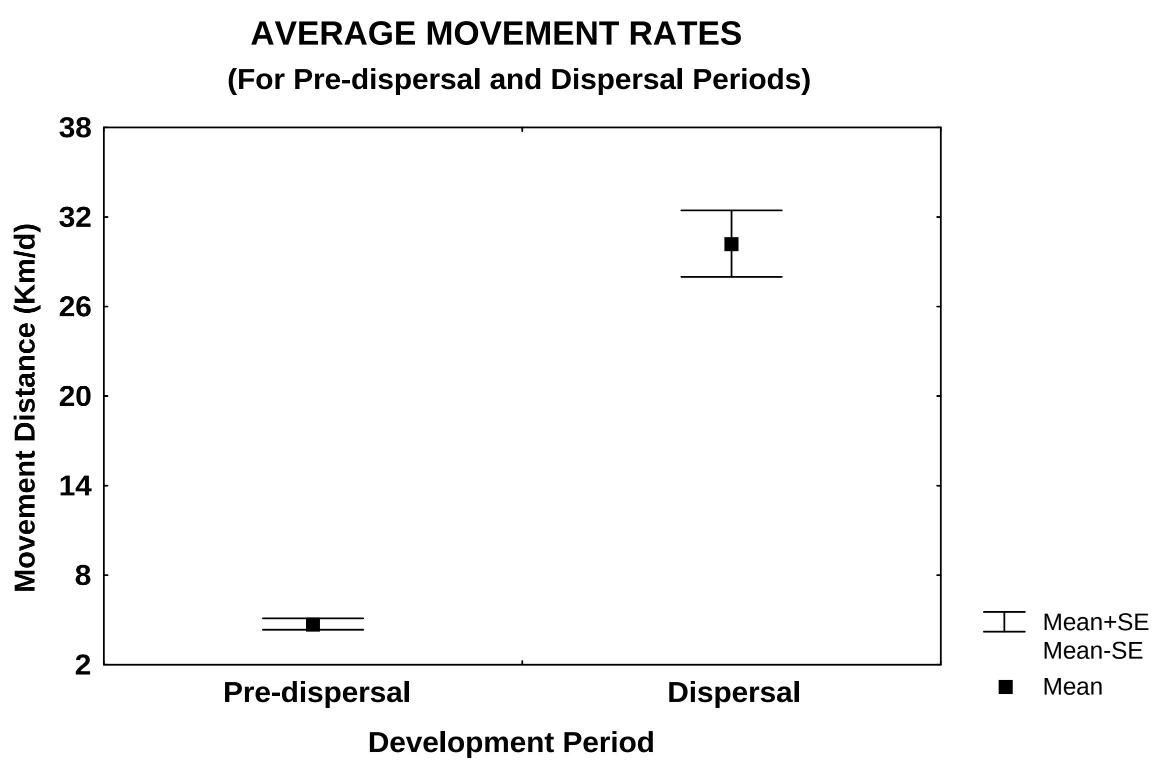

Figure 3. Average movement rates (km/d) during pre-dispersal and dispersal periods.

Dispersal – For those birds that were tracked into the early winter and that showed evidence of stabilizing on a winter range, the dispersal period ranged from 90 to 110 days (96.7 $\pm$ 9.43 d, mean $\pm$ SE) long. This period was characterized by wanderings throughout the mid-Atlantic and migration south for a few individuals. Movement distances were variable with a mean of 30.2 $\pm$ 2.22 km (N = 468) (Figure 3). However, many movements were considerably longer with 40 events longer than 100 km and 10 longer than 200 km. Although a few incidences suggested longer movements, the longest movement documented using the methods described above was 364 km.

Post-dispersal – Due to transmitter failures, relatively little information was collected on the post-dispersal or winter range. Several birds appear to have become more focused on an area that likely became the winter range. Movement distances were reduced at this point down to values comparable to those seen in the pre-dispersal period. The timing of this change in movement pattern varied between individuals from mid-September through the end of October.

Spatial Patterns

Over the course of the 2001 tracking season, broad-scale movements were documented that were both longitudinal and latitudinal (see Appendix II for summary maps for all birds tracked during 2001 for more than 3 days). After the pre-dispersal period, nearly all birds eventually gravitated to the coast. All birds that were hacked in the mountains and tracked through the dispersal period ultimately moved to the Atlantic Coast. The nature of this west to east movement varied among individuals (Appendix II). Some individuals moved quickly and directly to the coast while others took circuitous routes and longer periods of time. All of the birds that fledged within coastal sites, remained on the coast through the tracking period.

Birds that reached the coast during the early fall months, often utilized a series of staging areas along the coastal fringe (Figure 4). Some individuals appeared to settle on sites that would ultimately become winter areas in the mid-Atlantic, while others visited several sites for varying lengths of time before moving on. Many of the staging areas were either barrier islands with extensive marsh complexes or major metropolitan areas. Birds had extended stays in cities such as Baltimore, Philadelphia, Trenton, New York City, and Boston. Some individuals also appeared to be attracted to sites with other falcons. At least some of the staging areas along the coast were known to be breeding sites and to have produced broods during the summer of 2001.

The latitudinal movement of birds along the Atlantic Coast had both northerly and southerly components. Nearly all of the birds hacked in the mountains arrived on the coast north of their original latitude. Some of these birds moved north into southern New England. Birds that fledged on the coast took forays away from the Delmarva Peninsula that were both north and south. These movements were bounded by the Delaware Bay to the north and the Outer Banks of North Carolina to the south.

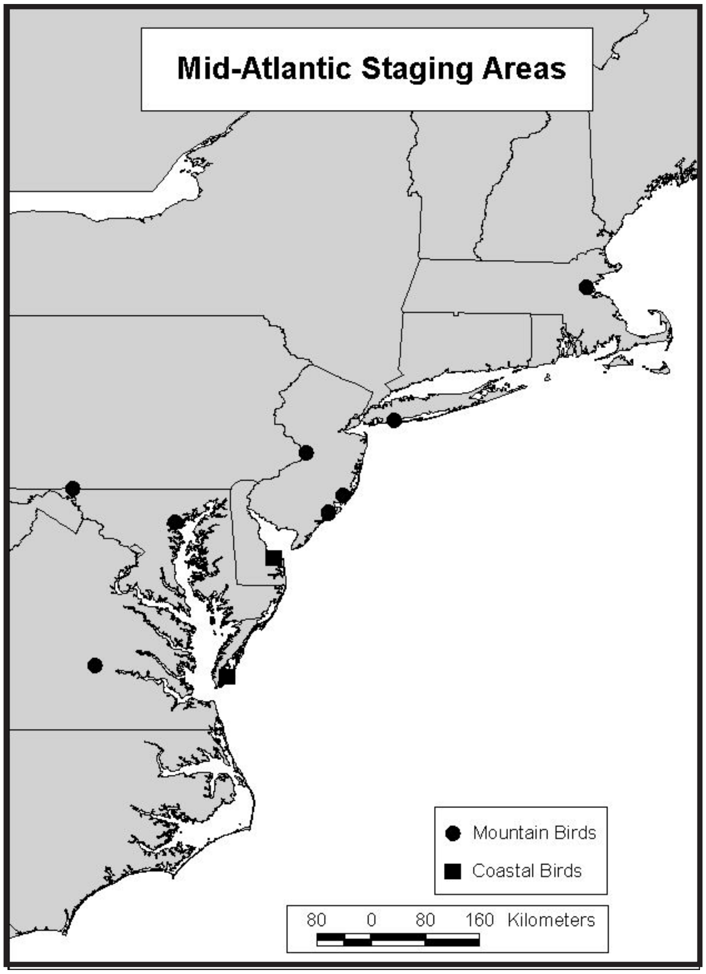

Figure 4. Distribution of locations where young falcons spent > 7d after dispersing and before migration.

Only 3 of the 9 birds that were tracked into the late fall months exhibited definitive southerly migration movements. Interestingly, these 3 birds represented all of the geographic situations included in the project (i.e. bird #27410 fledged on the Eastern Shore, bird #27406 was released from Shenandoah National Park, and bird #27412 was released from Harpers Ferry National Historical Park). Two of these birds migrated along a coastal route and made a transoceanic flight from the Outer Banks of North Carolina (Figure 5). Bird #27410 left the Eastern Shore at the end of September and moved south to the Outer Banks. This bird made a transoceanic flight in early October, making landfall just north of Grand Bahama Island. Over the next 2 weeks, the bird made its way to Cuba and then settled on the eastern side of the Dominican Republic. Bird #27412 left the Baltimore/Washington D.C. area in mid-October and made a transoceanic flight south off the outer Banks, only to turn west and make landfall in Florida. Over the next month, the bird moved around Florida, making its way down to Miami. Bird #27406 left central Pennsylvania in late October and took a route following the fall line of the coastal plain south to South Carolina (Figure 5). This bird appeared to be heading toward the Atlantic Coast when the transmitter failed.

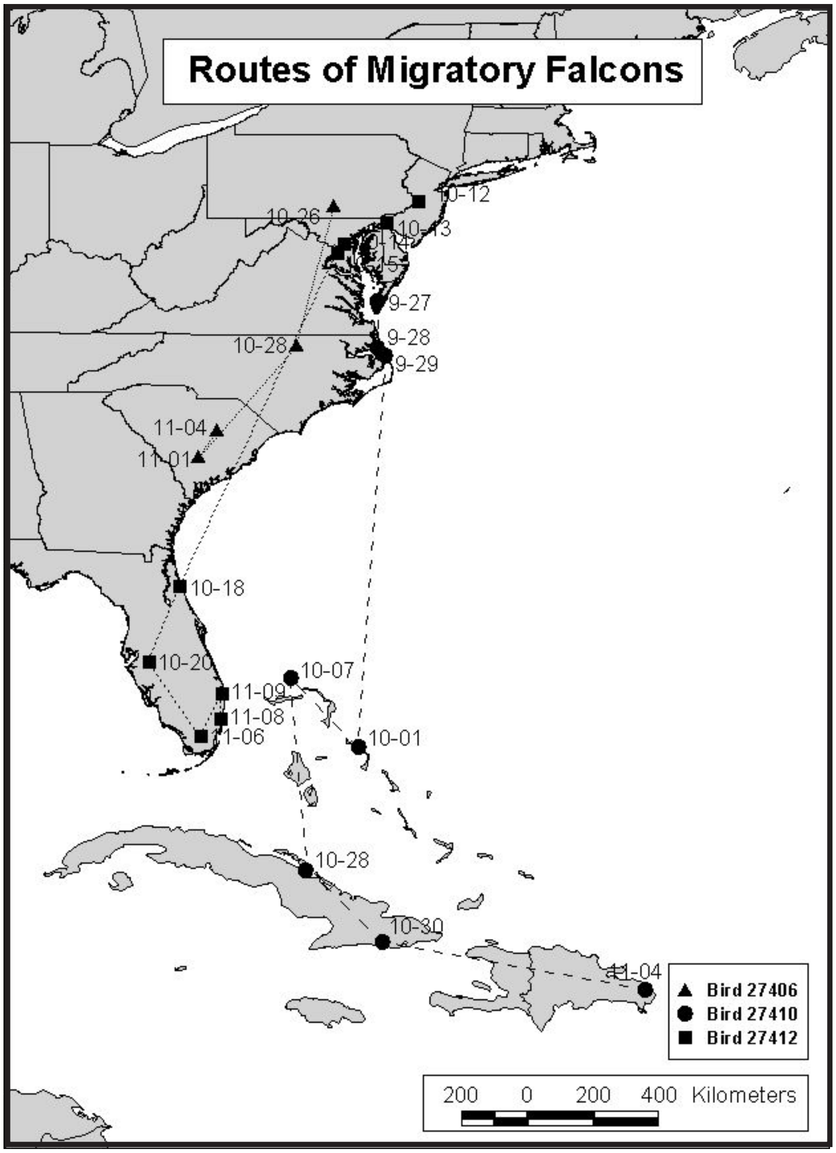

Figure 5. Routes of movement for the 3 birds that showed definitive southerly migrations.

Survivorship

Of the 19 falcons included in the project, 9 (47.4%) were known to be lost in the first 6 months after fledging. This is a conservative estimate of mortality since 3 of the transmitters failed prior to either a mortality event or the end of the 6-month period. Survivorship dropped rapidly in the first 10 wks after fledging and then became flat (Figure 6). Most of the mortality was focused on the pre-dispersal period. This included 3 birds that were lost at fledging and 4 additional birds that were lost after fledging but before dispersal from the natal site. Of the 11 birds that dispersed from natal sites, only 2 (18.2%) were lost. These 2 birds were lost during the dispersal phase. No birds that appeared to settle on winter ranges were lost prior to transmitter failures.

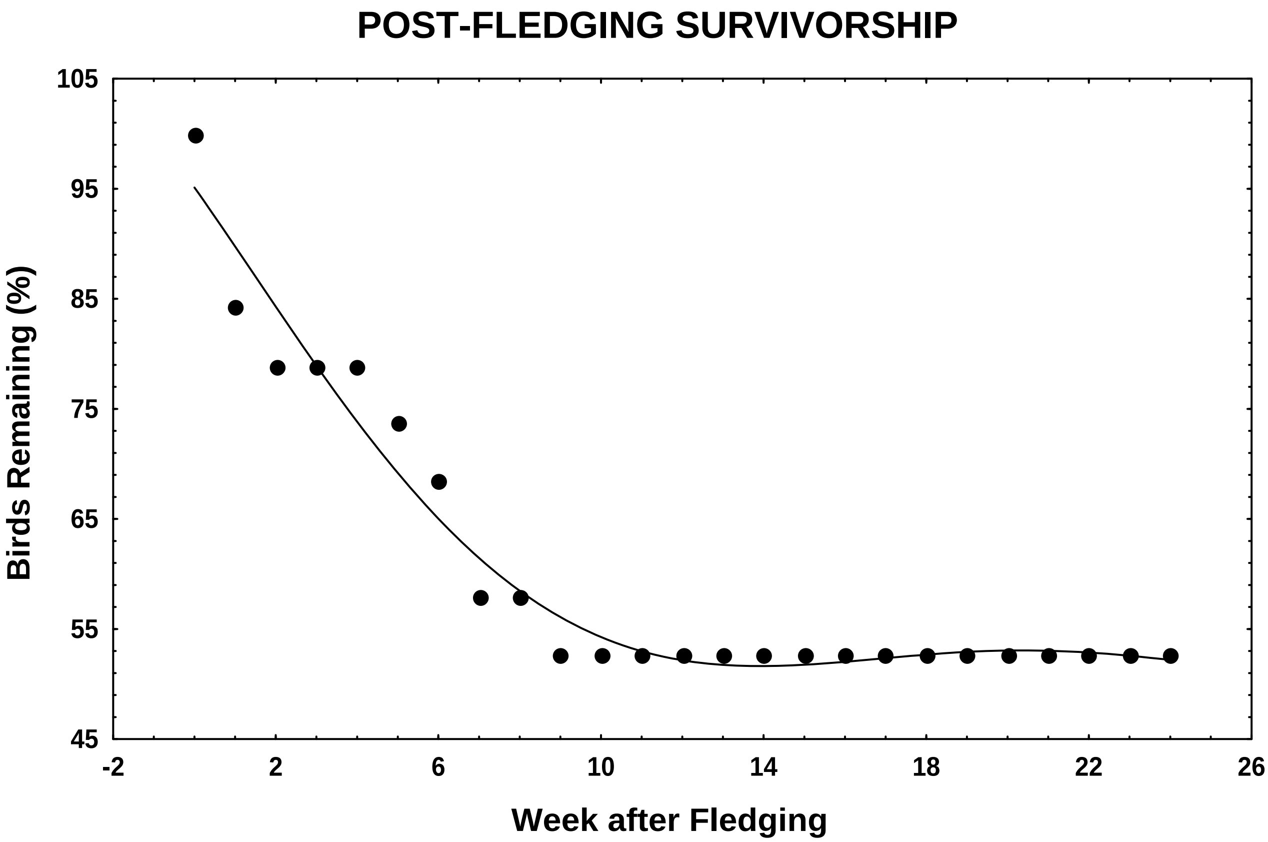

Figure 6. Post-fledging survivorship for birds peregrine falcons included in tracking study.

Cause of mortality was determined for the majority of birds lost. The largest source of mortality appeared to be flight accidents with artificial structures (see individual descriptions below).

#27394 – This bird was lost in the forest near the Hawksbill hack site in Shenandoah National Park. Periodic signals were received from this transmitter throughout the fall months but the carcass was never recovered. The cause of death is unclear.

#27398 – This bird flew out of site upon release at the Hawksbill hack site. A single signal was received from the bird near the hack site the day following the release. It is unclear whether the bird was lost in the surrounding forests or was taken by a predator.

#27409 – Clear signals from this transmitter placed the bird near a secondary road with associated utility lines. Both the transmitter and carcass were recovered from a standing cornfield. Circumstances suggested that the bird hit a utility line and was carried into the cornfield by a scavenger.

#27397 – A severe summer storm passed over the natal site on Elkins Marsh with winds in excess of 30 mph. No further signals were received from the transmitter after the storm passed. It is believed that the storm may have blown the bird into the water or surrounding marsh. Similar storm-related mortality has been documented within other coastal nesting sites in recent years.

#27396 – The cause of mortality for this bird is unclear. The bird was likely near dispersal age when it went down on the north end of Assateague Island. The transmitter was recovered by a tourist on the island in the spring of 2002. There was no evidence of the carcass.

#27404 – This bird was recovered still alive by a citizen in downtown Petersburg with a wing injury. The bird was taken to a rehabilitation center and determined to have a fractured radius. Circumstances suggest that the bird flew into some structure within the city.

#27408 – This bird was recovered on a farm within the Shenandoah Valley near the Hawksbill hack site. The bird had a broken neck and appeared to have flown into the side of a barn.

#27407 – This bird appeared to have flown into a transmission line. The carcass and transmitter was recovered below the transmission line in a right-of-way surrounded by farmland.

———— - This bird died upon release from an office building in Richmond, VA. A young, resident pair of falcons repeatedly stooped on the bird as it took its first flight and drove it into the side of a glass office building. The bird was recovered with a broken neck from the roof of an entryway.

DISCUSSION

Nearly 50% of all birds tracked were known to be lost in the first 6 months after fledging. Although an annual survival rate could not be calculated due to transmitter failure, this value is reasonably consistent with what would be expected based on other investigations of first-year survivorship. Based on band recoveries, Enderson (1969) estimated that 30% of birds survive their first year in North America. First-year survival estimates for other populations include 29% and 44% for Finland and Germany respectively (Mebs 1971) and 41% for Sweden (Lindberg 1977). Newton and Mearns (1988) calculated survival between fledging and recruitment into the breeding population (typically at 2-3 years of age) at 44% in Scotland.

All of the mortality documented in this study occurred in the first 10 weeks after fledging. The single 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.

After fledging, young falcons remained focused on the natal or hack site between 39 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. It is interesting to note that within the brood from Watts Island, one dispersed 41 days after fledging, one 60 days after fledging, and the last bird 73 days after fledging. This observation indicates that, even with the same parentage, time to dispersal is quite variable.

All of the birds that were hacked in the mountains and that survived to disperse ultimately gravitated to the coast. Most of these birds moved both east and north. 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. Several of the sites where hacked birds were recovered were used intensively by birds tracked in 2001. 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). Using records from Audubon Christmas Bird Counts, Bonney showed 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. Taken together, these findings underscore the role that the coast plays in the life cycle of mid-Atlantic peregrines.

Only 3 of 9 young falcons made definitive southerly migration movements. 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. It is interesting to note that one of the birds reared on Watts Island remained on the Eastern Shore into the late fall while another brood member migrated to the Dominican Republic. Fall migration on the Eastern Shore of Virginia peaks during the first 2 weeks of October for peregrines (Ward and Berry 1972, Ward et al. 1988). Two of the three birds tracked during this study left during this peak period. The third bird left in late October. The final location of migrant peregrines were also consistent with the latitudinal range of recoveries of hacked birds during the winter months.

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, and Don Schwab 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 both Shenandoah National Park and Harpers Ferry National Historical Park. We thank superintendents Doug Morris and Donald Campbell for their support of this project. 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. 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. 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. Northstar Science and Technology, LLC supplied the solar-powered PTTs for the project. We thank Bill Seegar and Blake Henke for their support of this 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. Dana Bradshaw, Marian Watts, and Catherine Markham provided logistical support from the Center for Conservation Biology. Carlton Adams, Renee Peace, Lydia Whitaker, Anne Womack, Cheryl Pope, Mark Roberts, Gloria Sciole, Laura Sherman, and Bonnie Willard provide administrative assistance from the College of William and Mary.

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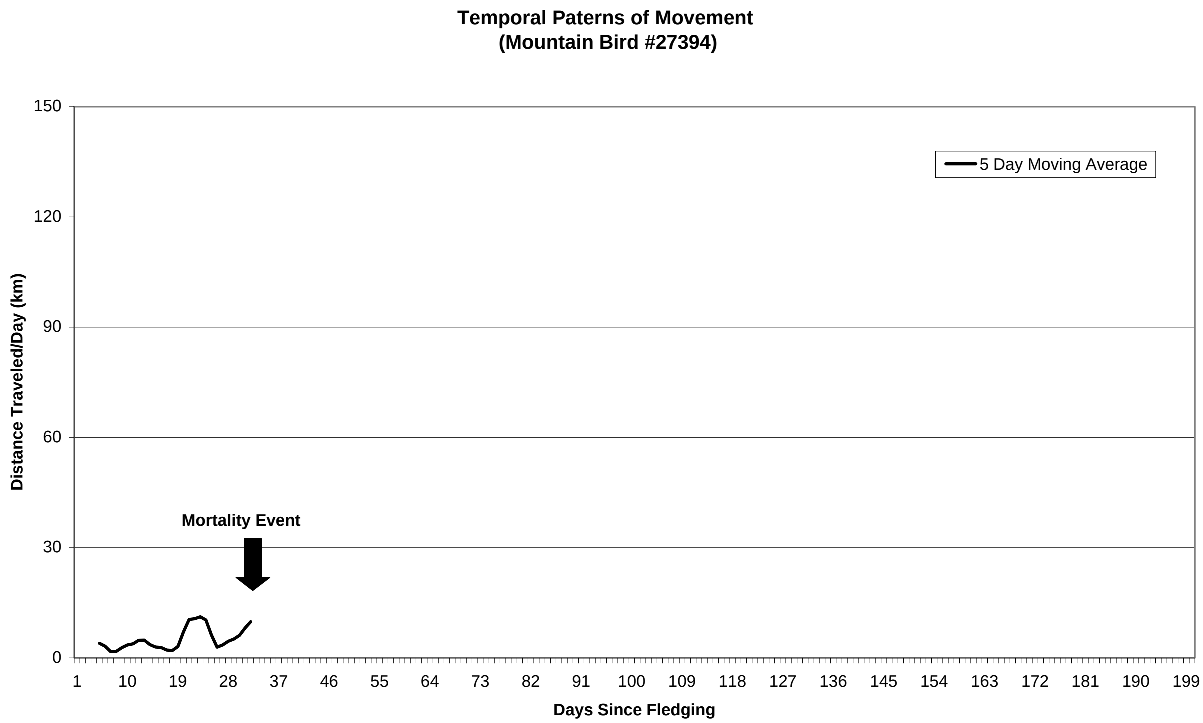
APPENDIX I: Summaries of seasonal patterns in movement rates for individual birds. Patterns have been smoothed using 5-d moving averages.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5 Day Moving Average
Mortality Event
Distance Traveled/Day (km)
Days Since Fledging
0
30
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90
120
150
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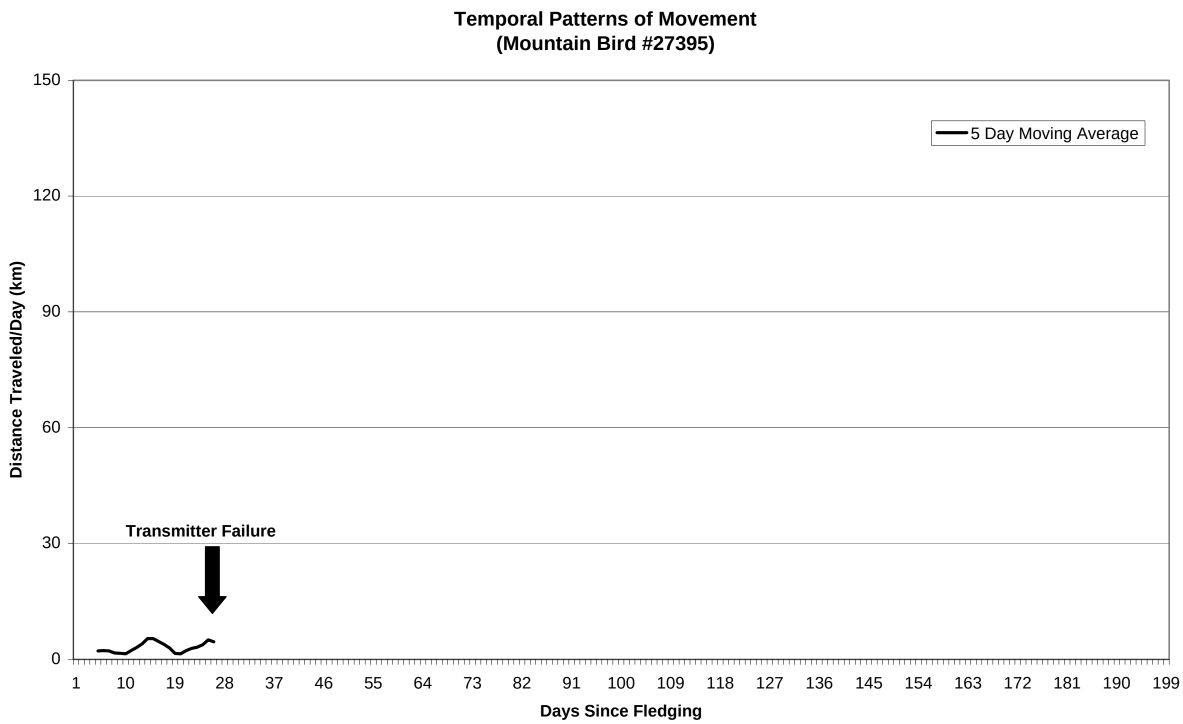
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5 Day Moving Average
Transmitter Failure
Distance Traveled/Day (km)
Days Since Fledging
0
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120
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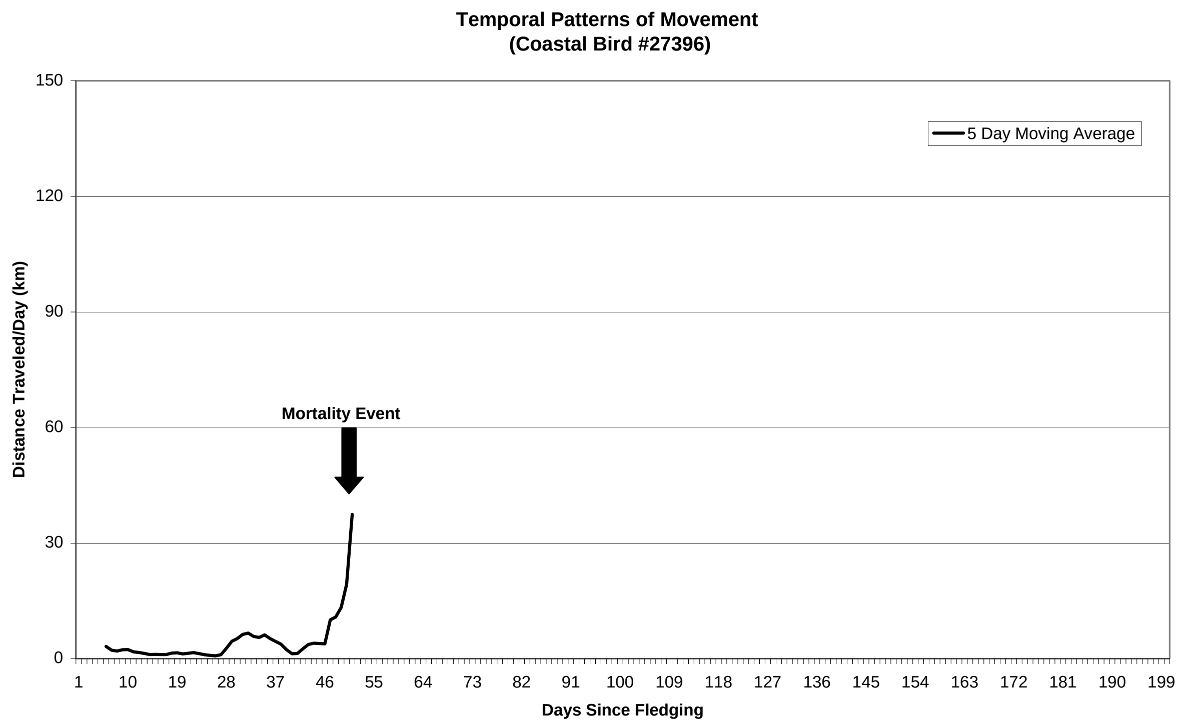
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5 Day Moving Average
Mortality Event
Distance Traveled/Day (km)
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120
150
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19
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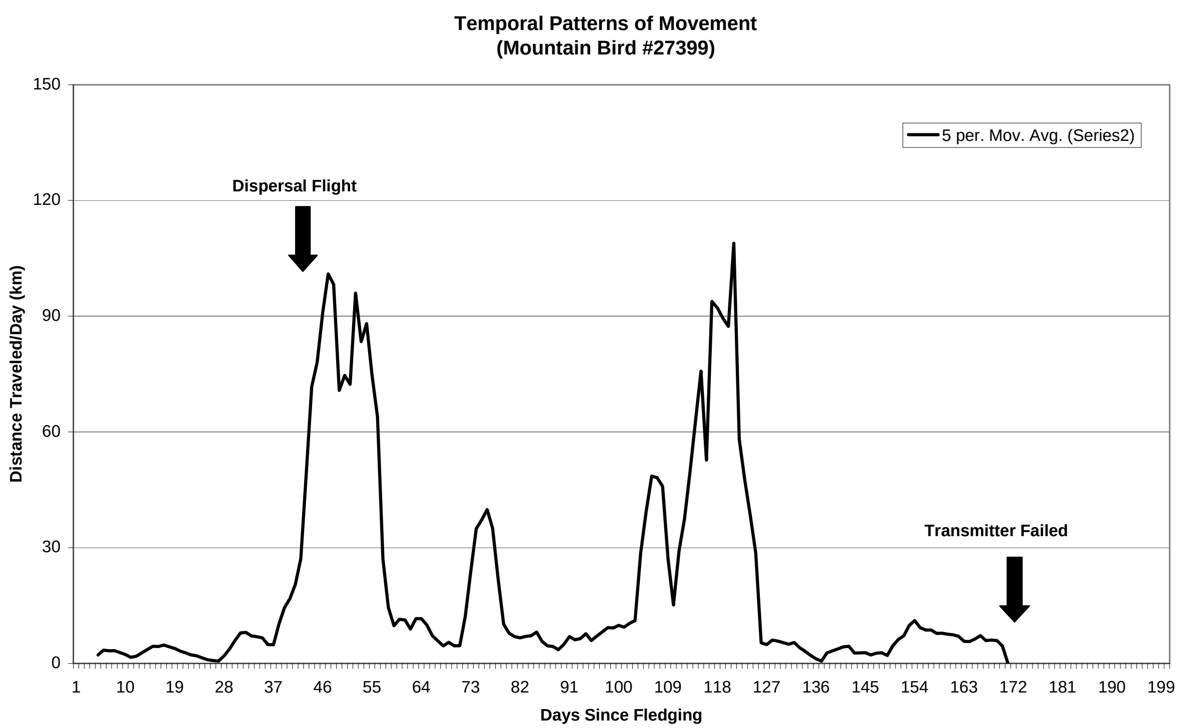
190
199
Days Since Fledging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5 per. Mov. Avg. (Series2)
Dispersal Flight
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Distance Traveled/Day (km)
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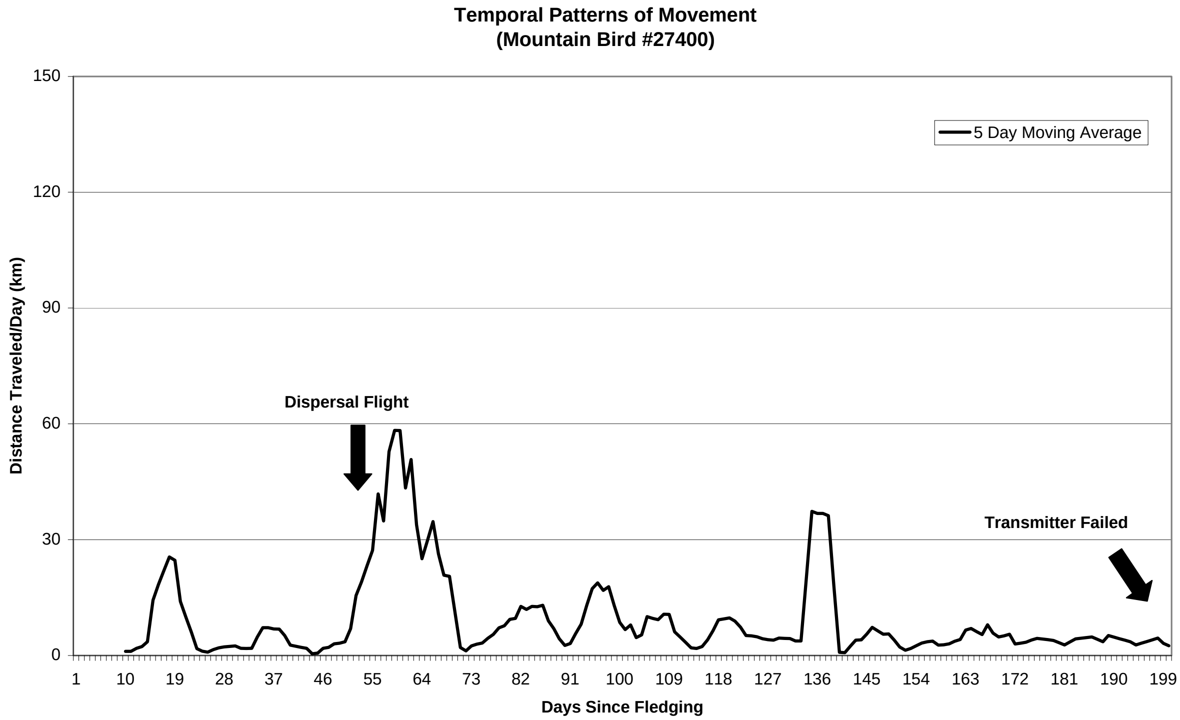
Days Since Fledging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5 Day Moving Average
Dispersal Flight
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Distance Traveled/Day (km)
Days Since Fledging
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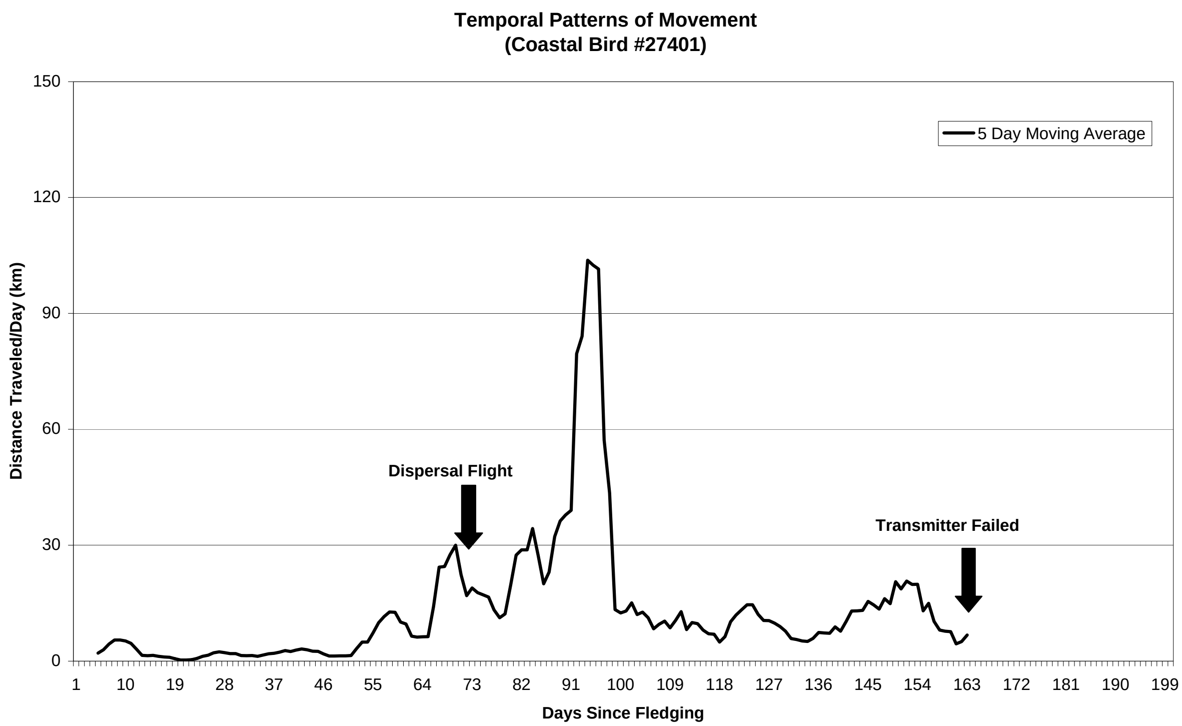
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5 Day Moving Average
Dispersal Flight
Transmitter Failed
Distance Traveled/Day (km)
Days Since Fledging
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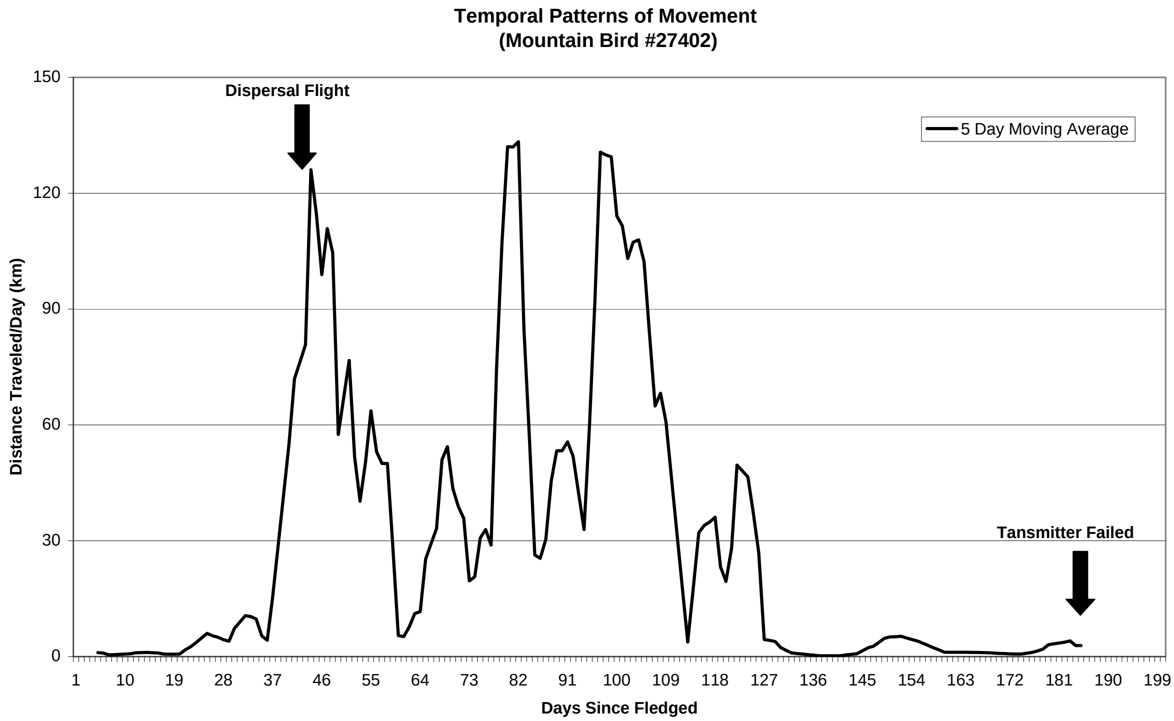
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Dispersal Flight
5 Day Moving Average
Tansmitter Failed
Distance Traveled/Day (km)
Days Since Fledged
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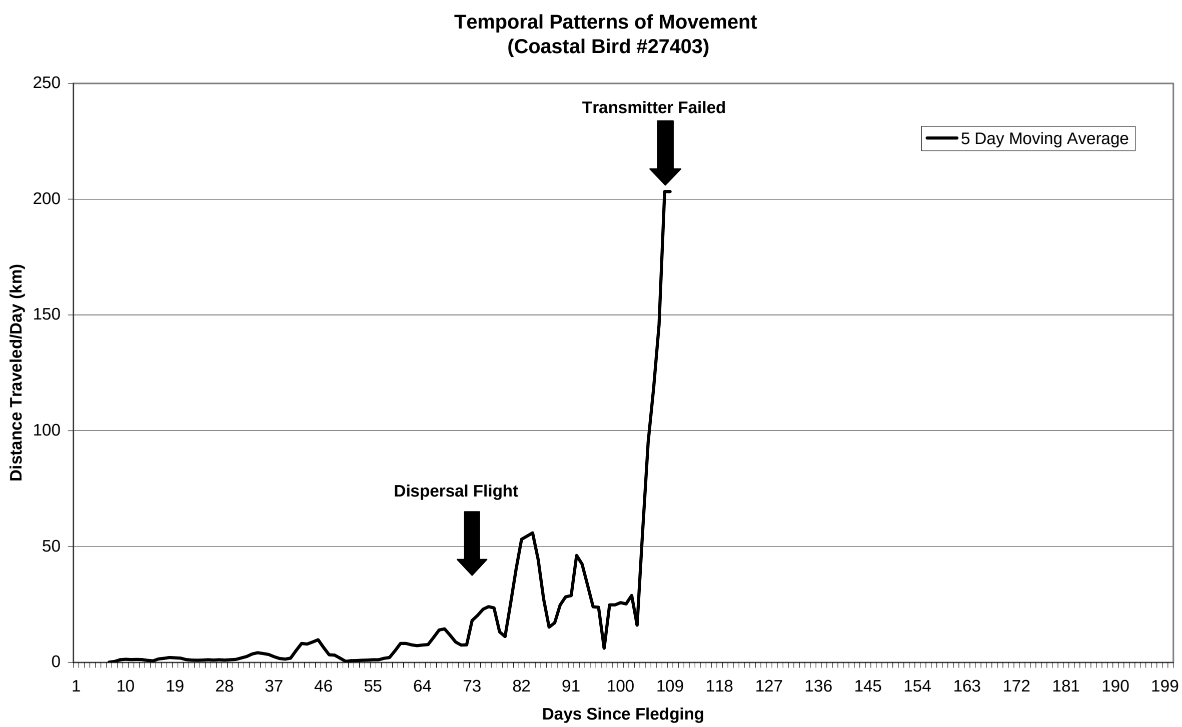
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Dispersal Flight
Distance Traveled/Day (km)
Days Since Fledging
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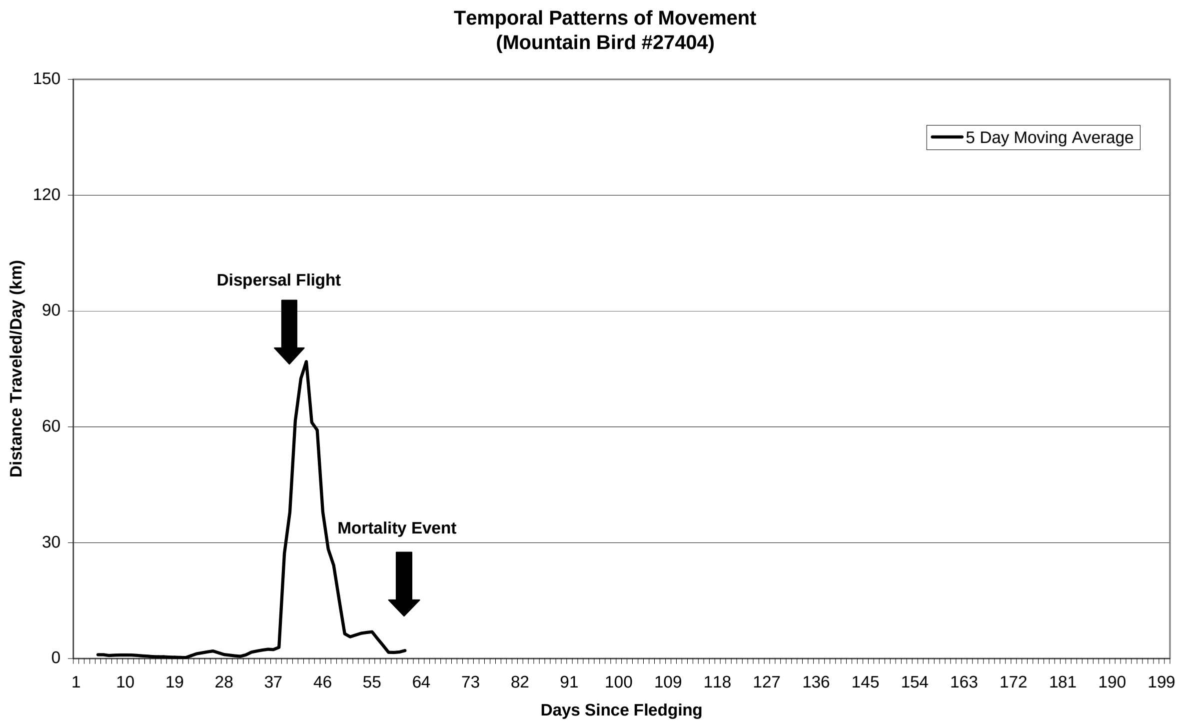
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5 Day Moving Average
Dispersal Flight
Mortality Event
Distance Traveled/Day (km)
Days Since Fledging
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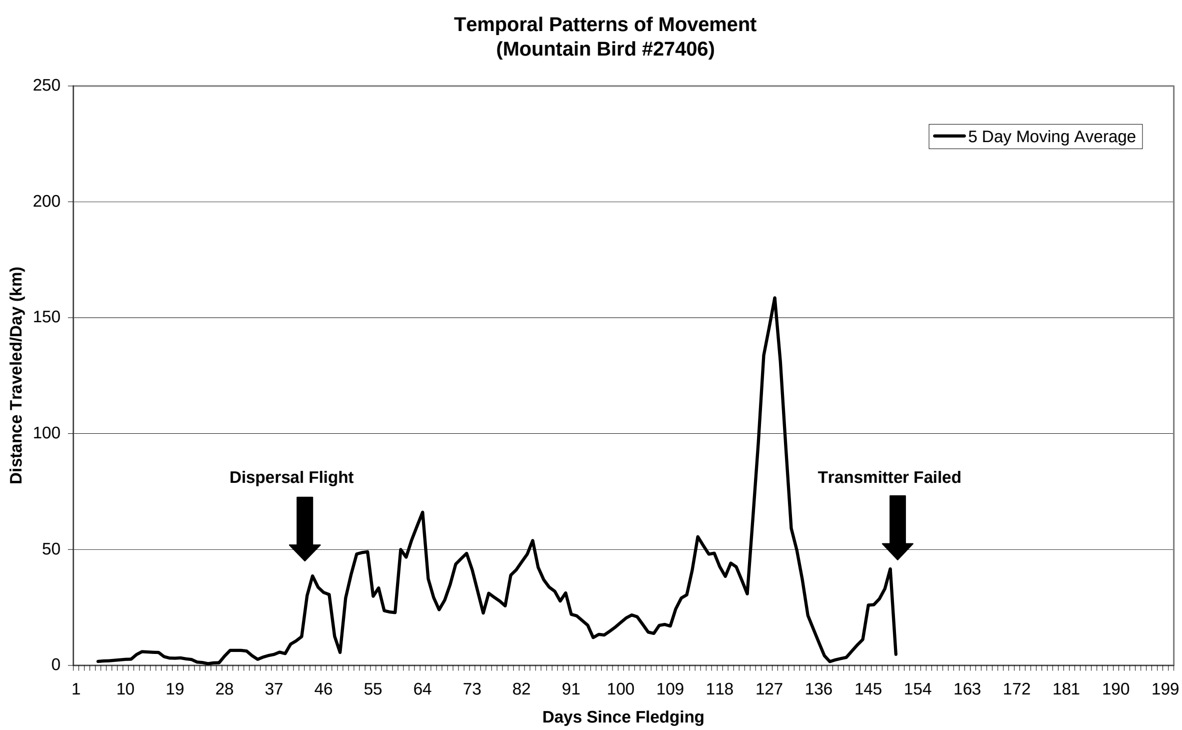
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(Mountain Bird #27406)
5 Day Moving Average
Dispersal Flight
Transmitter Failed
Distance Traveled/Day (km)
Days Since Fledging
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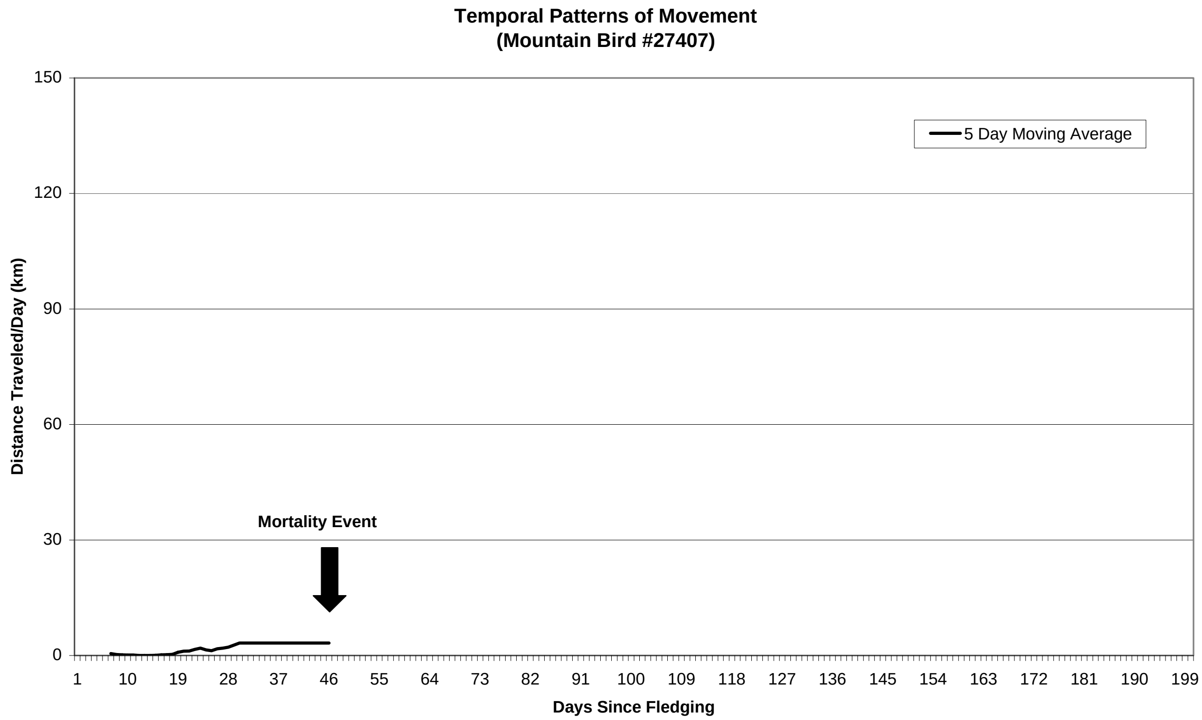
Temporal Patterns of Movement
(Mountain Bird #27407)
5 Day Moving Average
Mortality Event
Distance Traveled/Day (km)
Days Since Fledging
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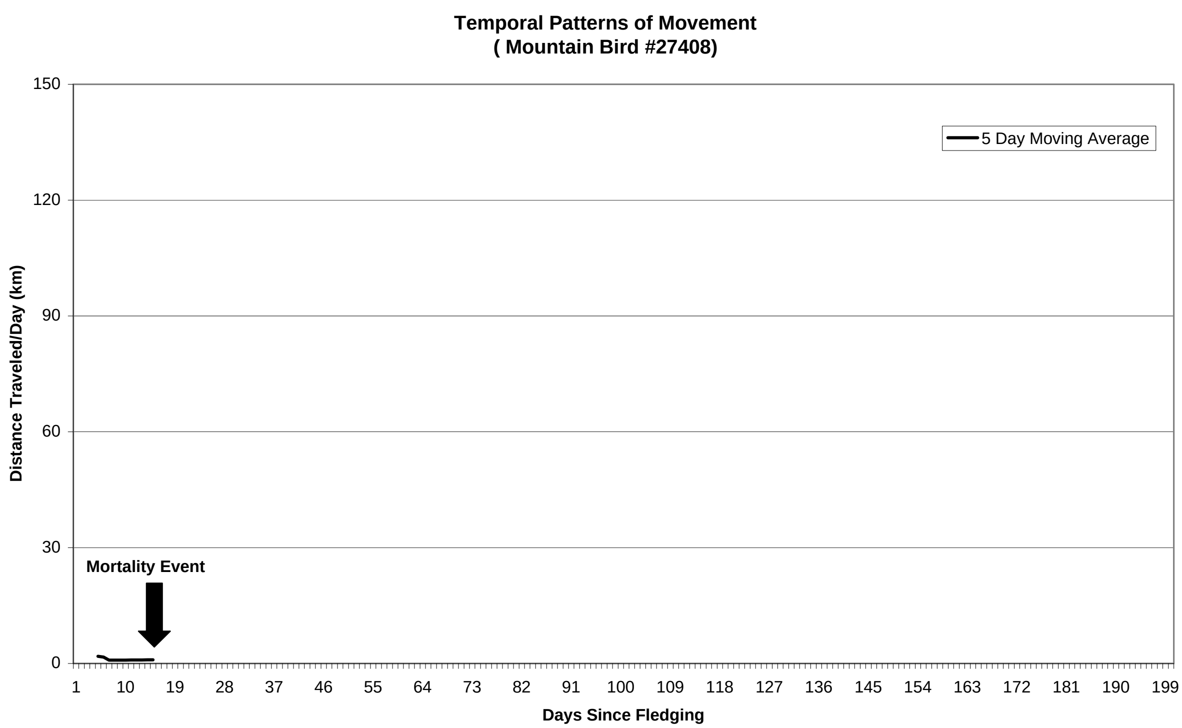
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5 Day Moving Average
Mortality Event
Distance Traveled/Day (km)
Days Since Fledging
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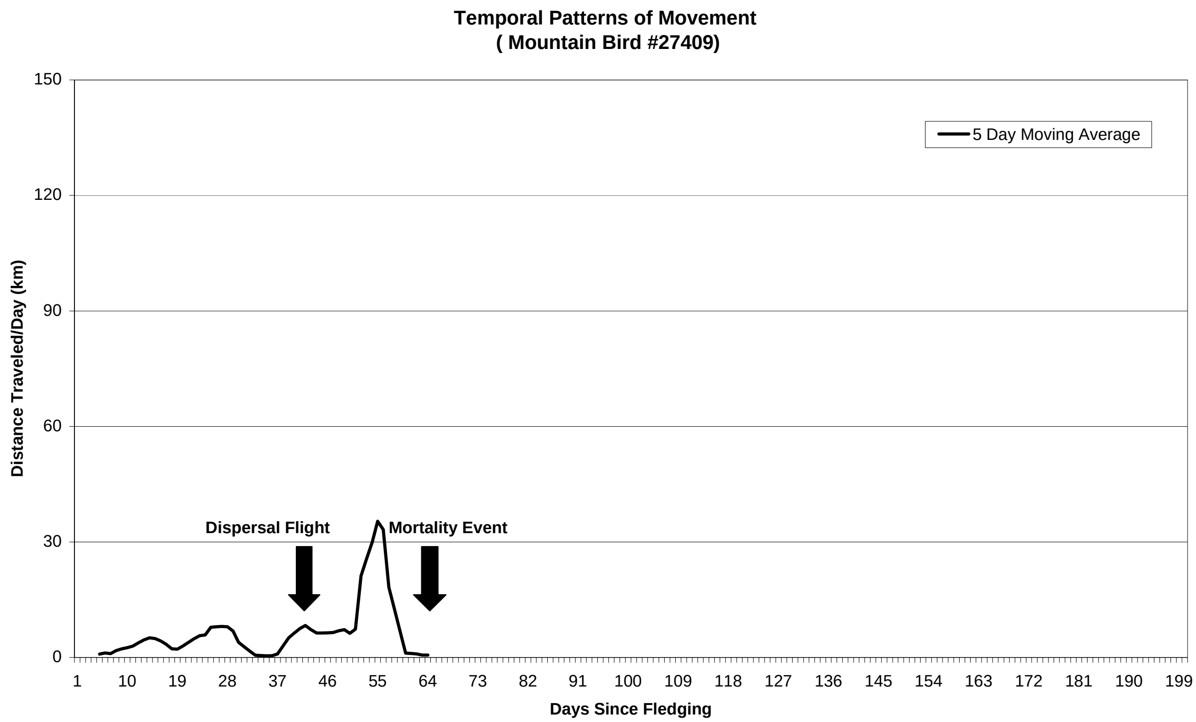
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5 Day Moving Average
Distance Traveled/Day (km)
Days Since Fledging
Dispersal Flight
Mortality Event
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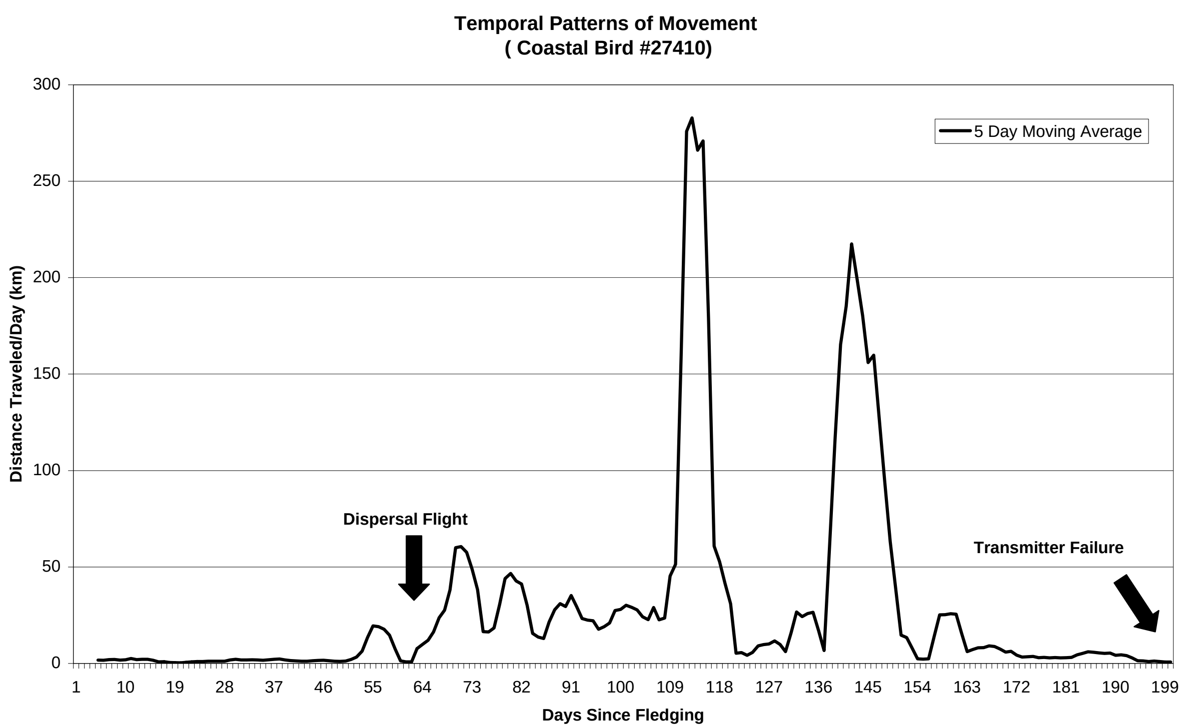
Temporal Patterns of Movement
(Coastal Bird #27410)
5 Day Moving Average
Distance Traveled/Day (km)
Days Since Fledging
Dispersal Flight
Transmitter Failure
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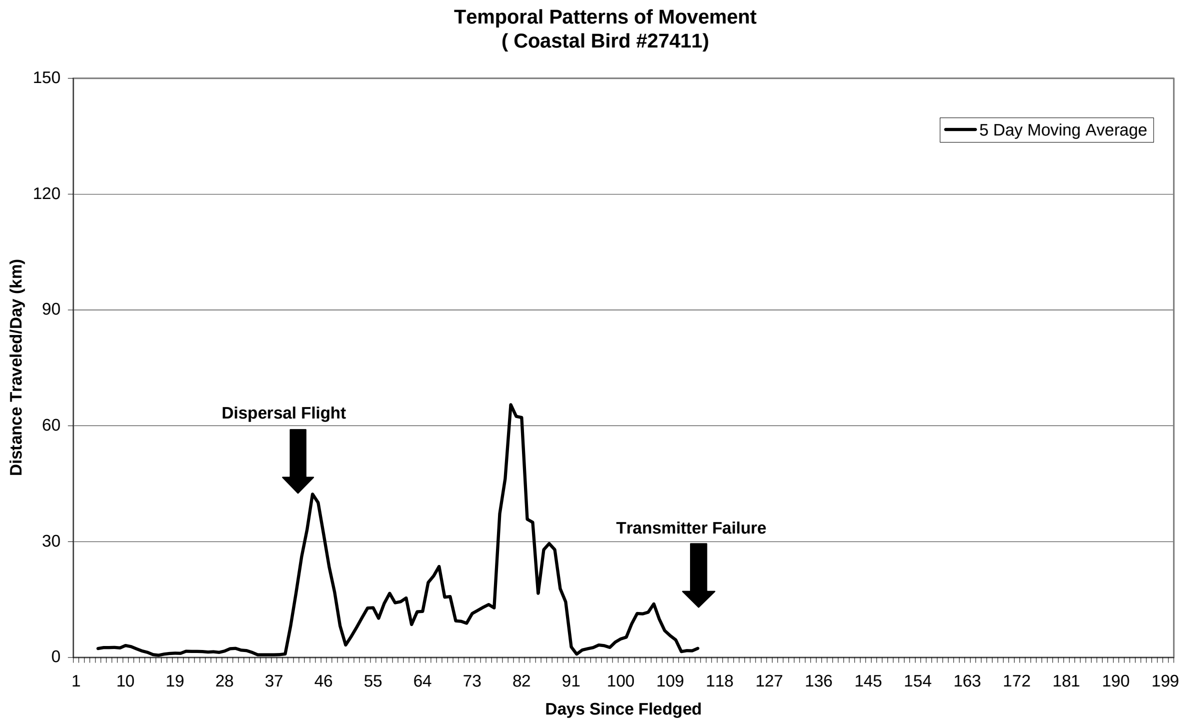
Temporal Patterns of Movement
(Coastal Bird #27411)
5 Day Moving Average
Dispersal Flight
Transmitter Failure
Distance Traveled/Day (km)
Days Since Fledged
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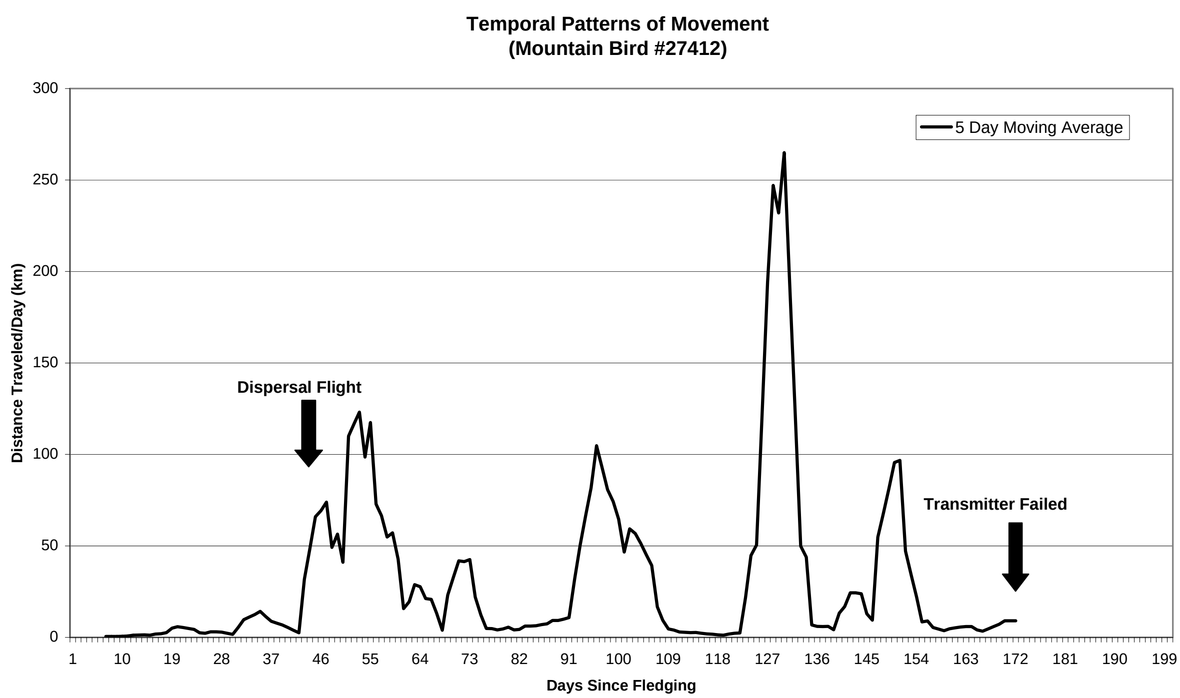
Temporal Patterns of Movement
(Mountain Bird #27412)
5 Day Moving Average
Dispersal Flight
Transmitter Failed
Distance Traveled/Day (km)
Days Since Fledging
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150
200
250
300
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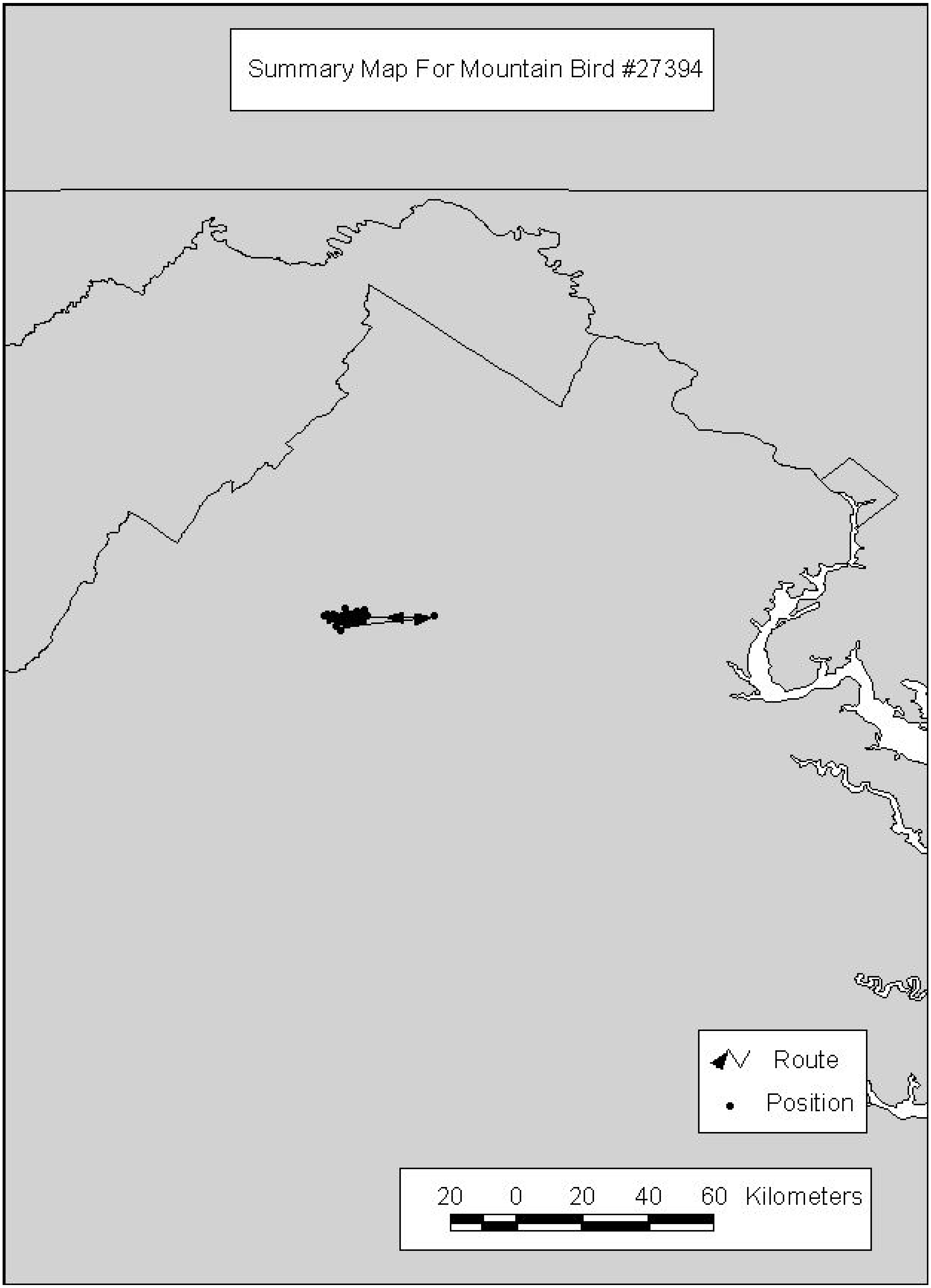
APPENDIX II: Summary maps of movements for all birds that were tracked for at least 3 days.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Route
Position
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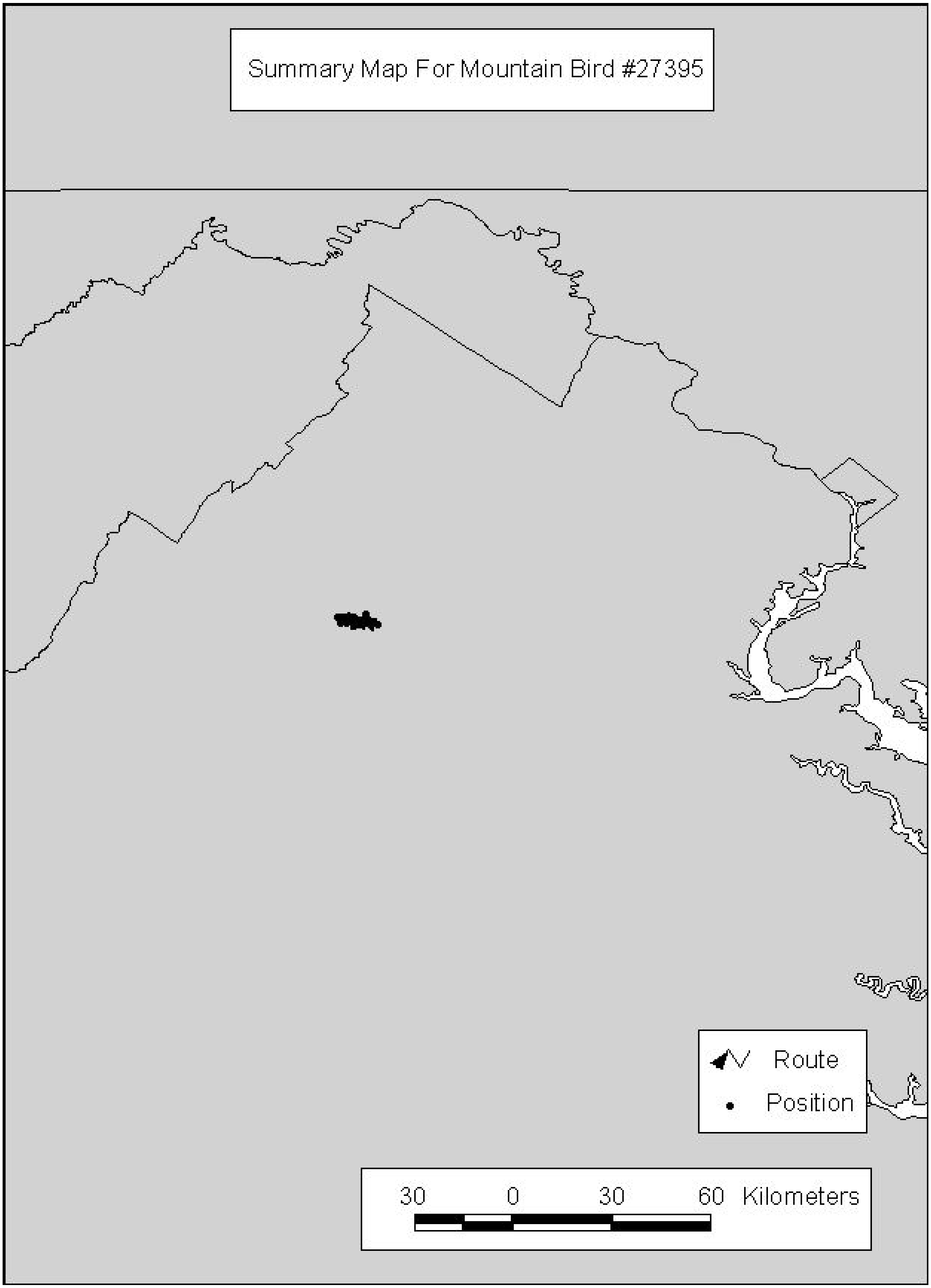
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Position
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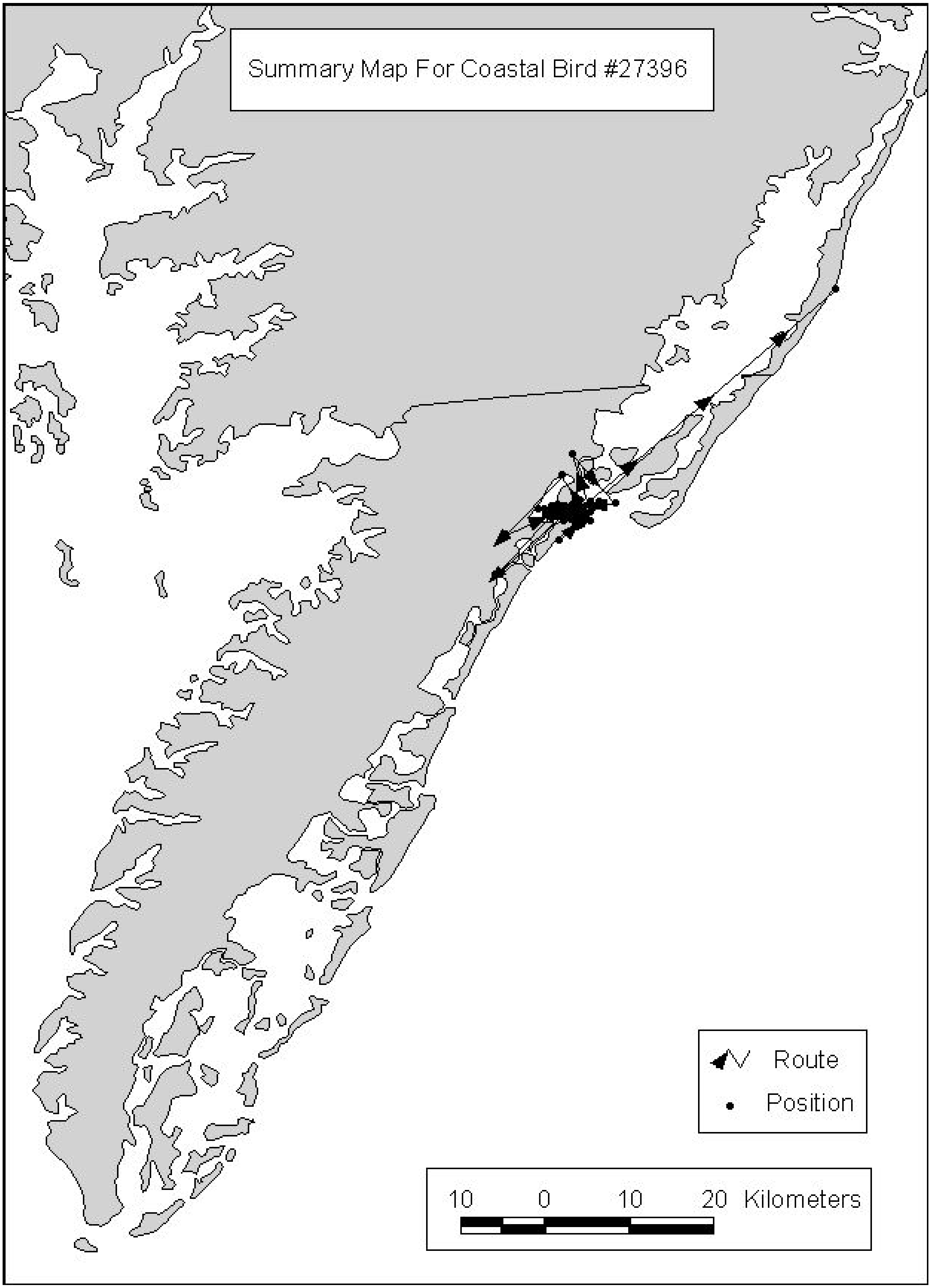
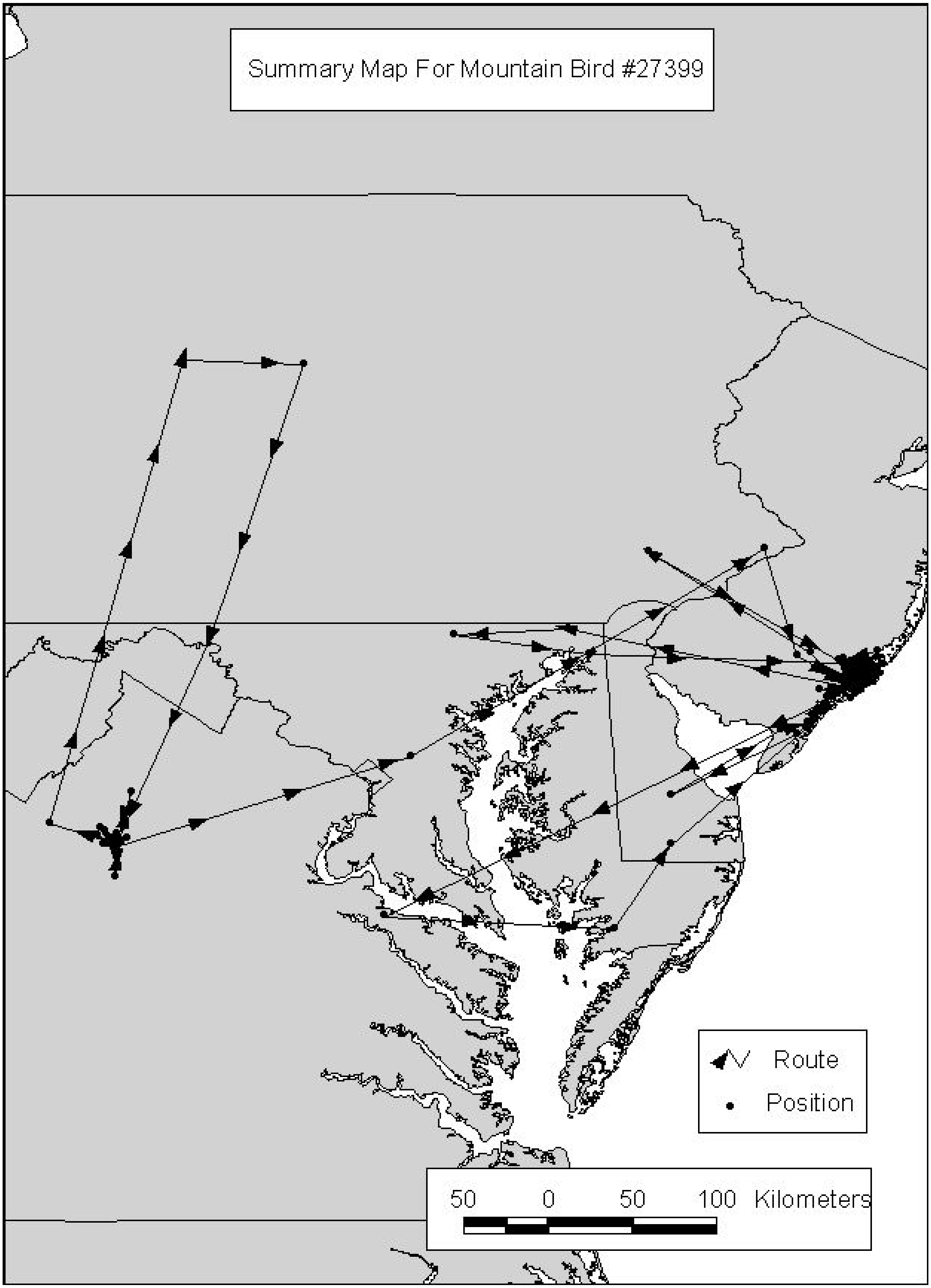
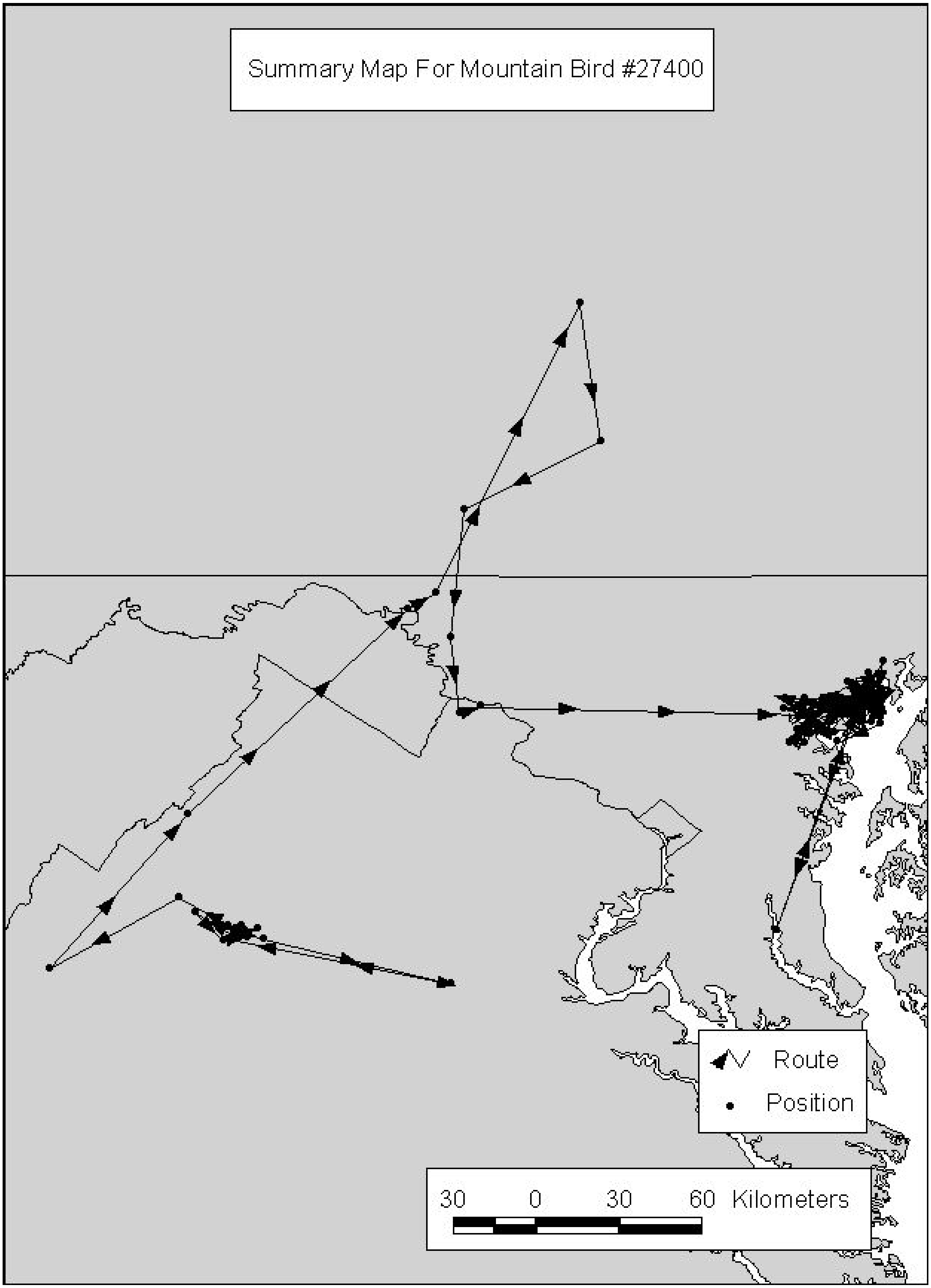
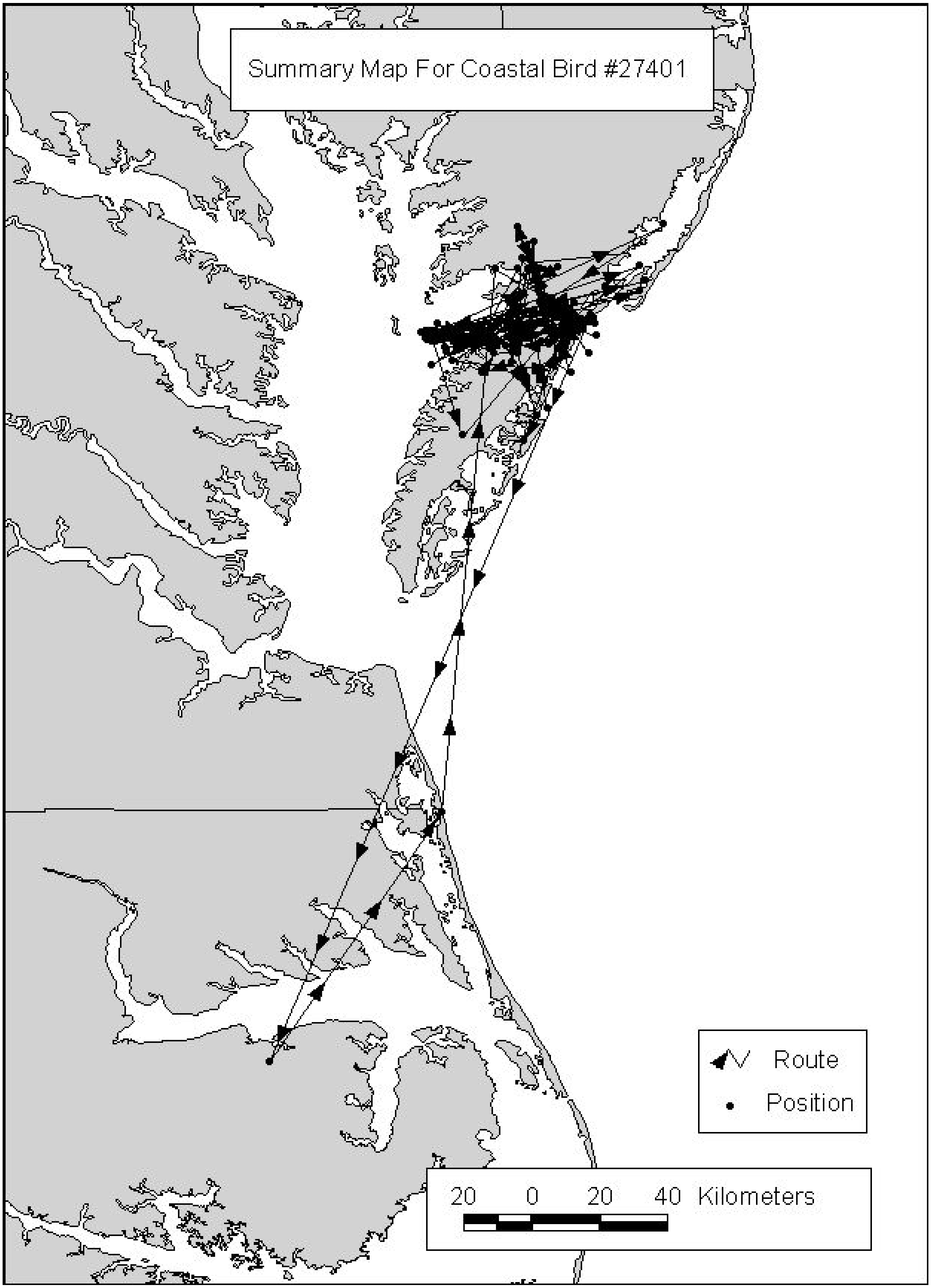

Summary Map For Coastal Bird #27396
Route
Position
10 0 10 20 Kilometers

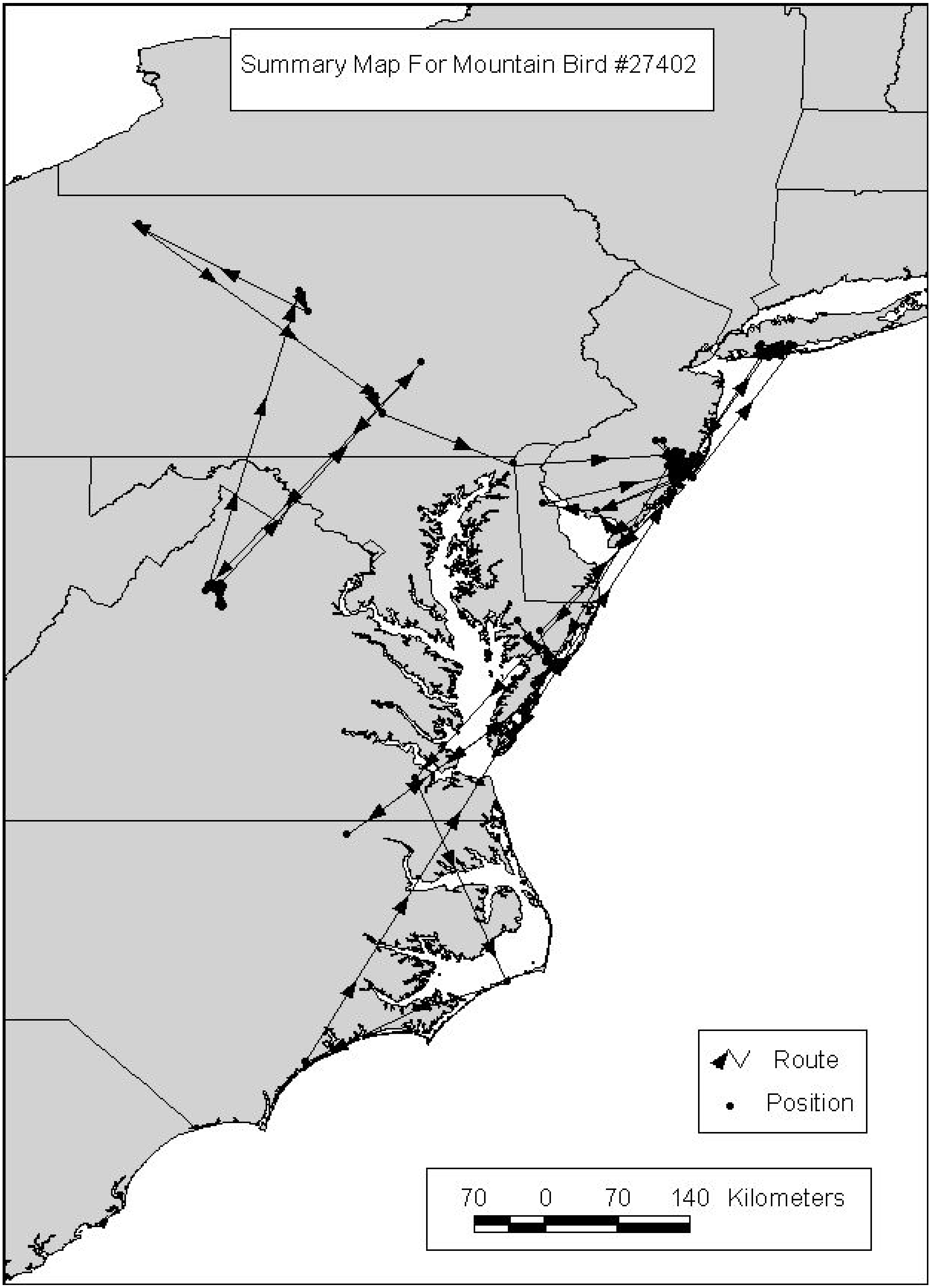

Summary Map For Mountain Bird #27399
Route
Position
50
0
50
100
Kilometers

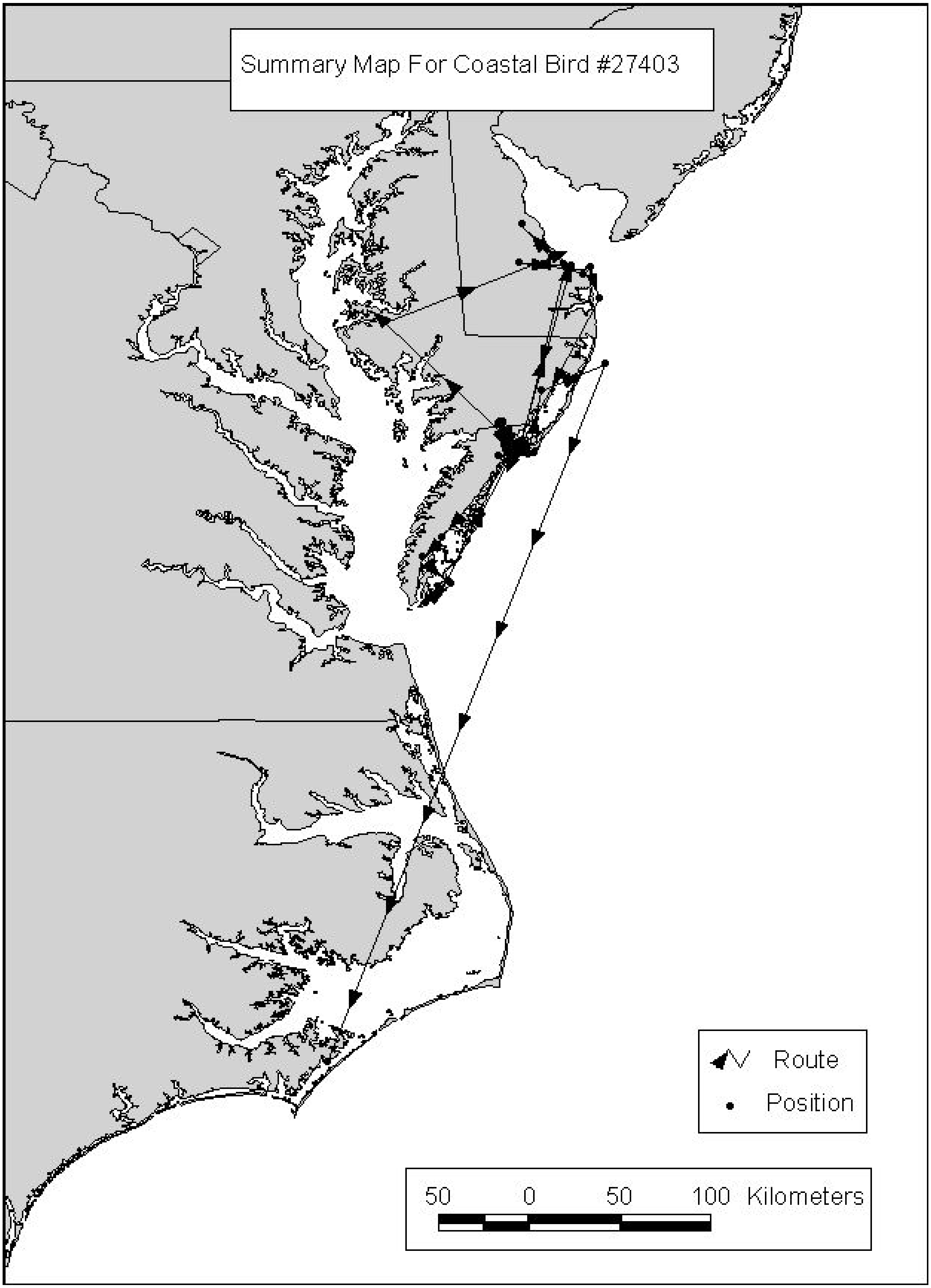


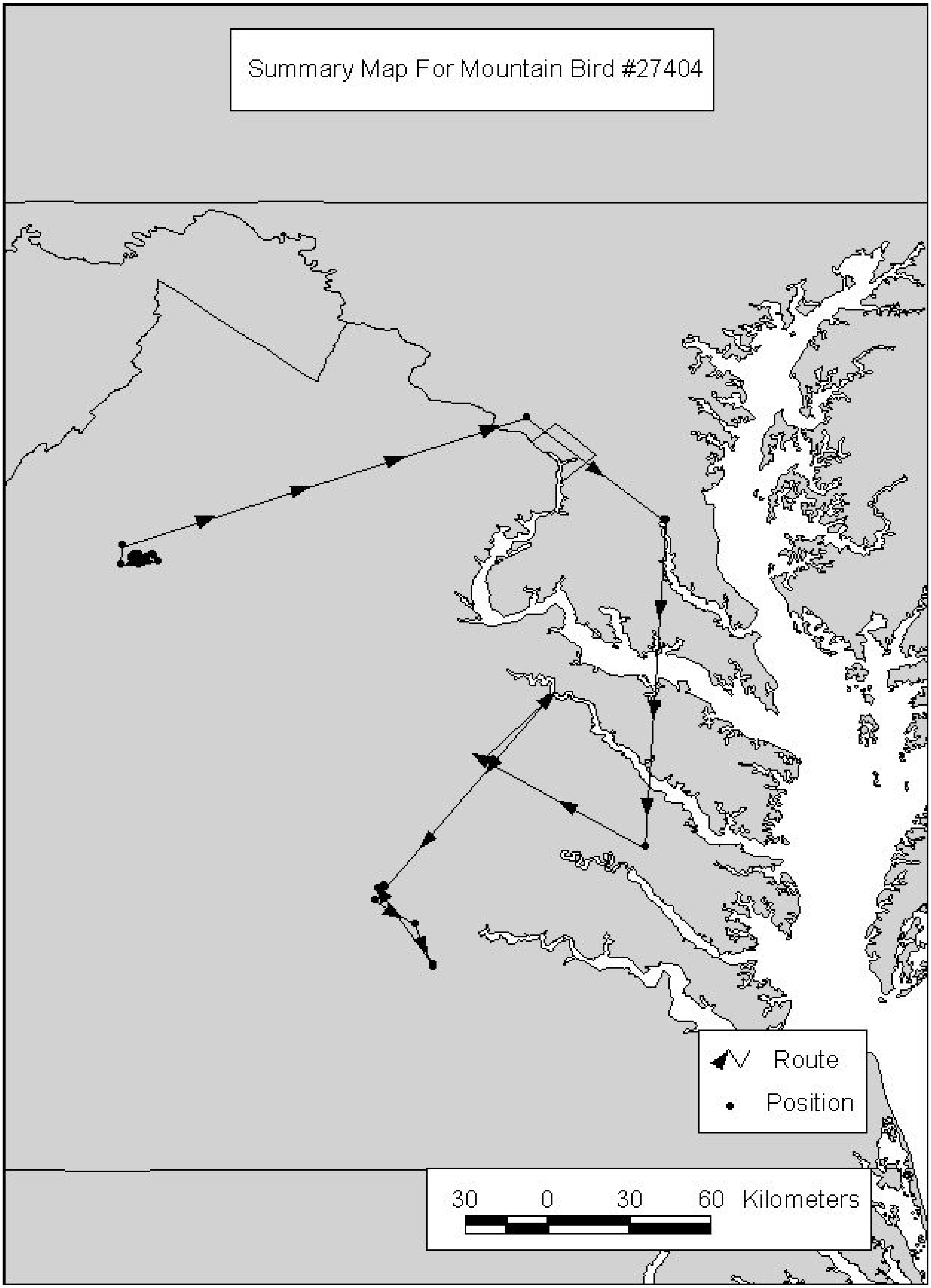
Summary Map For Mountain Bird #27400
Route
Position
30 0 30 60 Kilometers

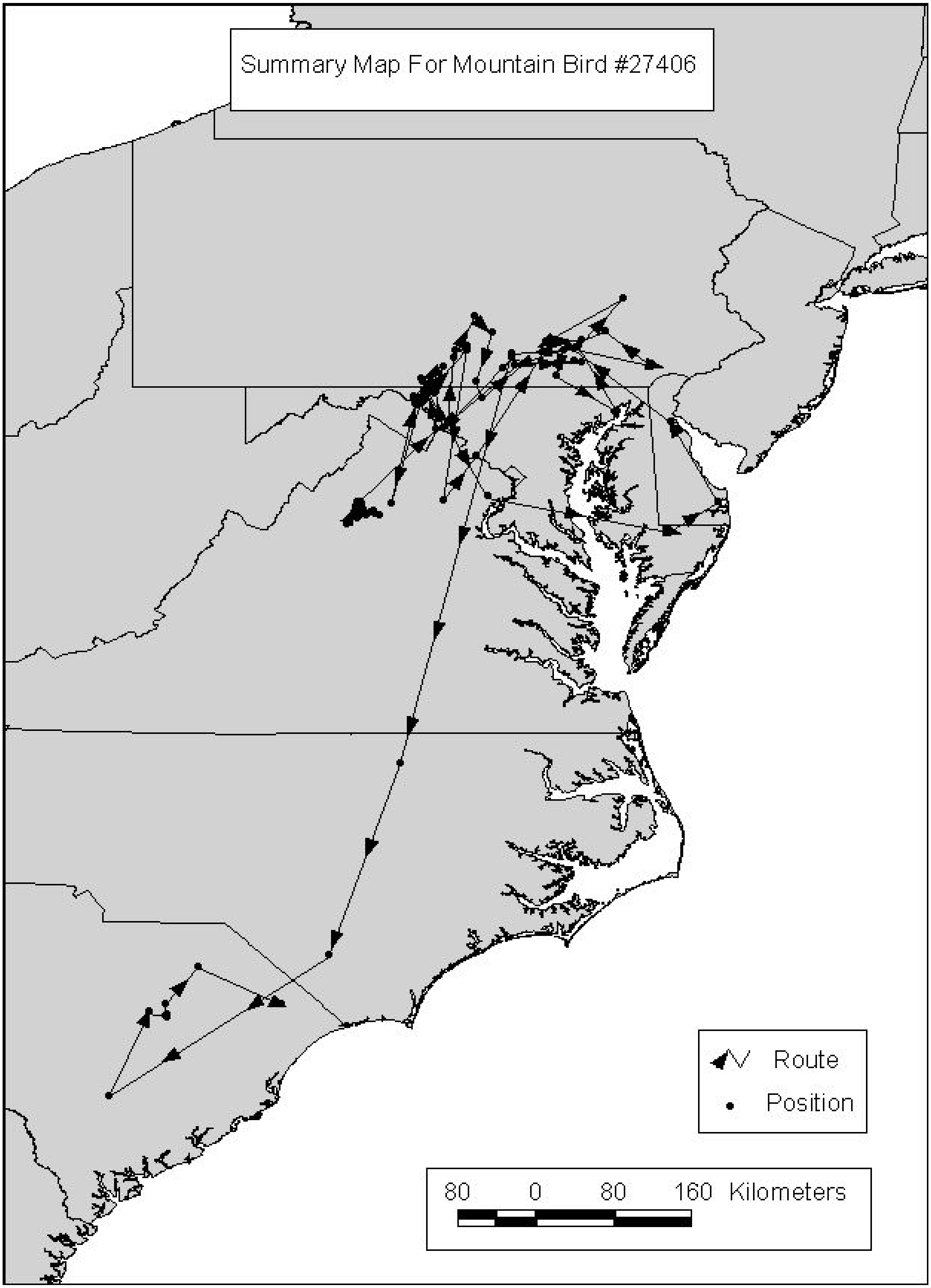


Summary Map For Coastal Bird #27401
Route
Position
20 0 20 40 Kilometers

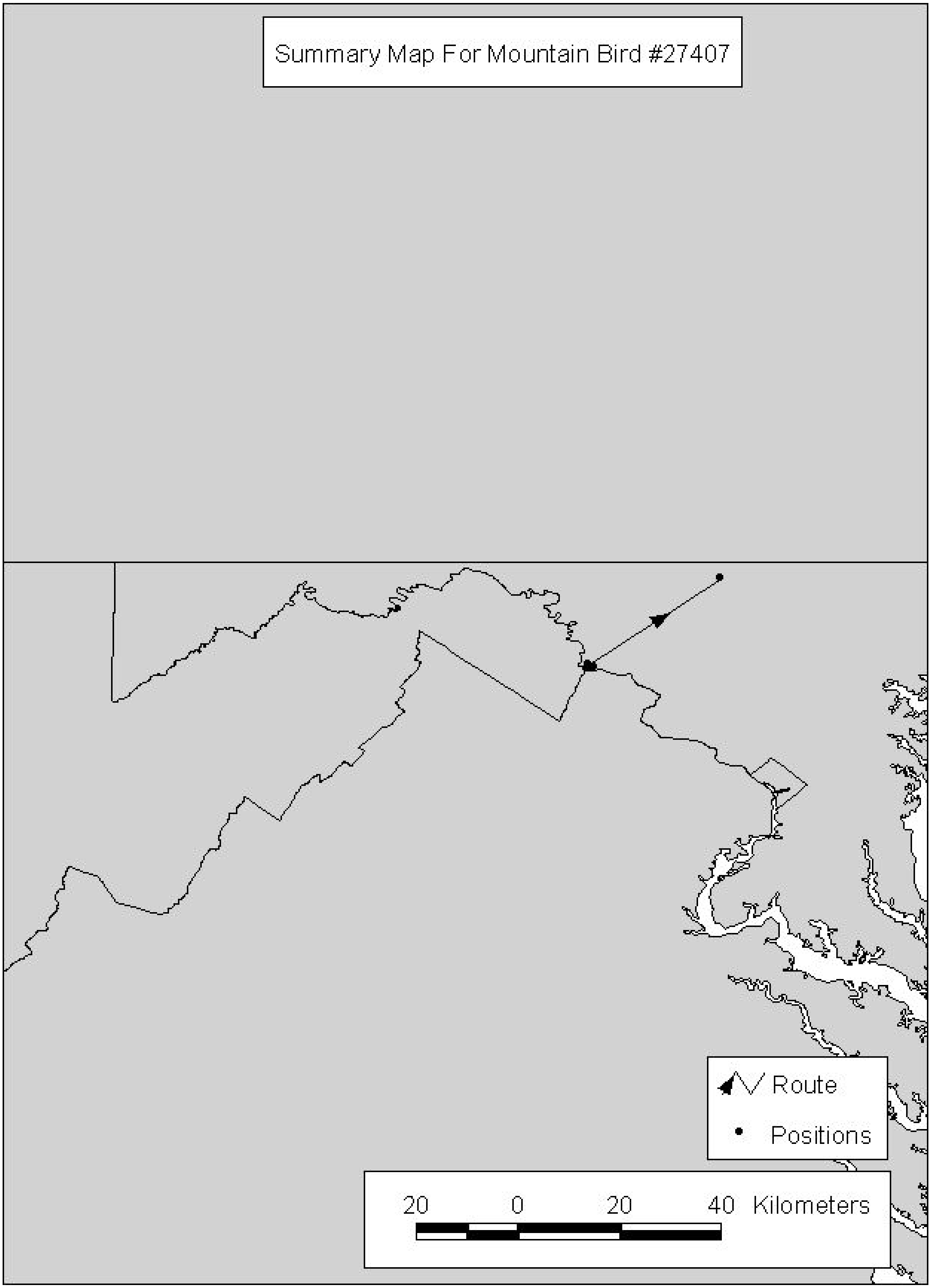

Summary Map For Mountain Bird #27402
Route
Position
70 0 70 140 Kilometers

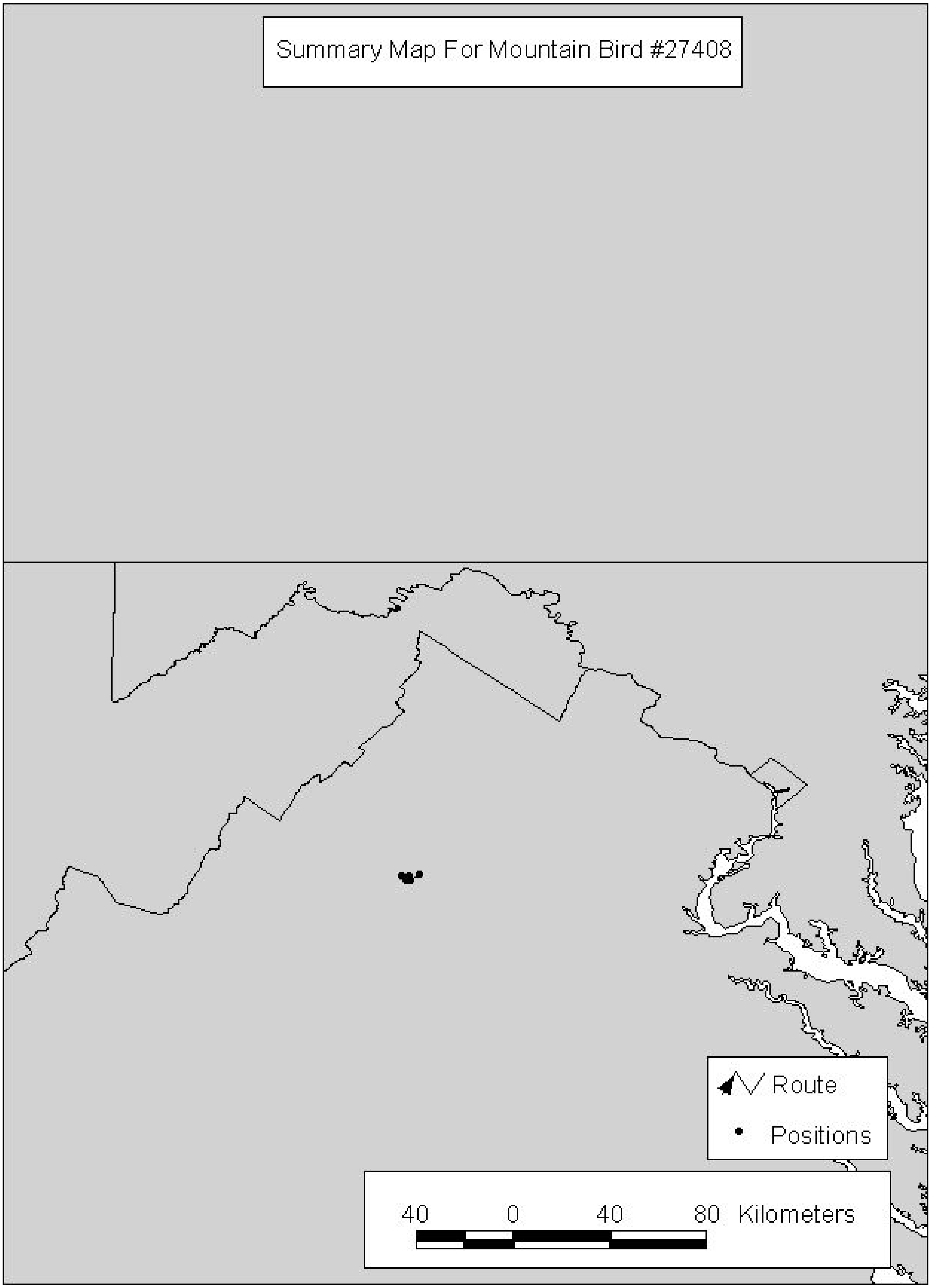

Summary Map For Coastal Bird #27403
Route
Position
50 0 50 100 Kilometers


Summary Map For Mountain Bird #27404
Route
Position
30 0 30 60 Kilometers

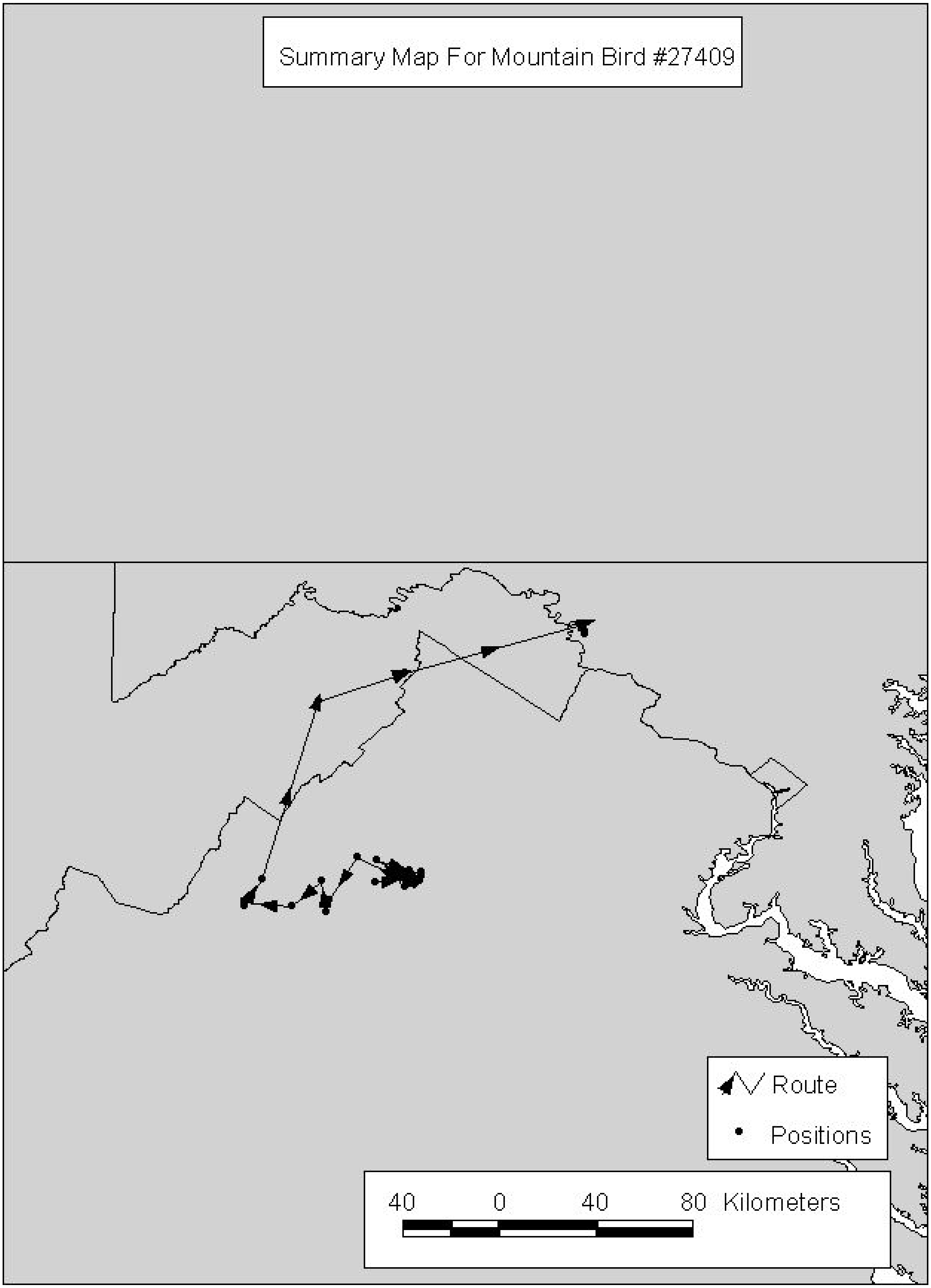


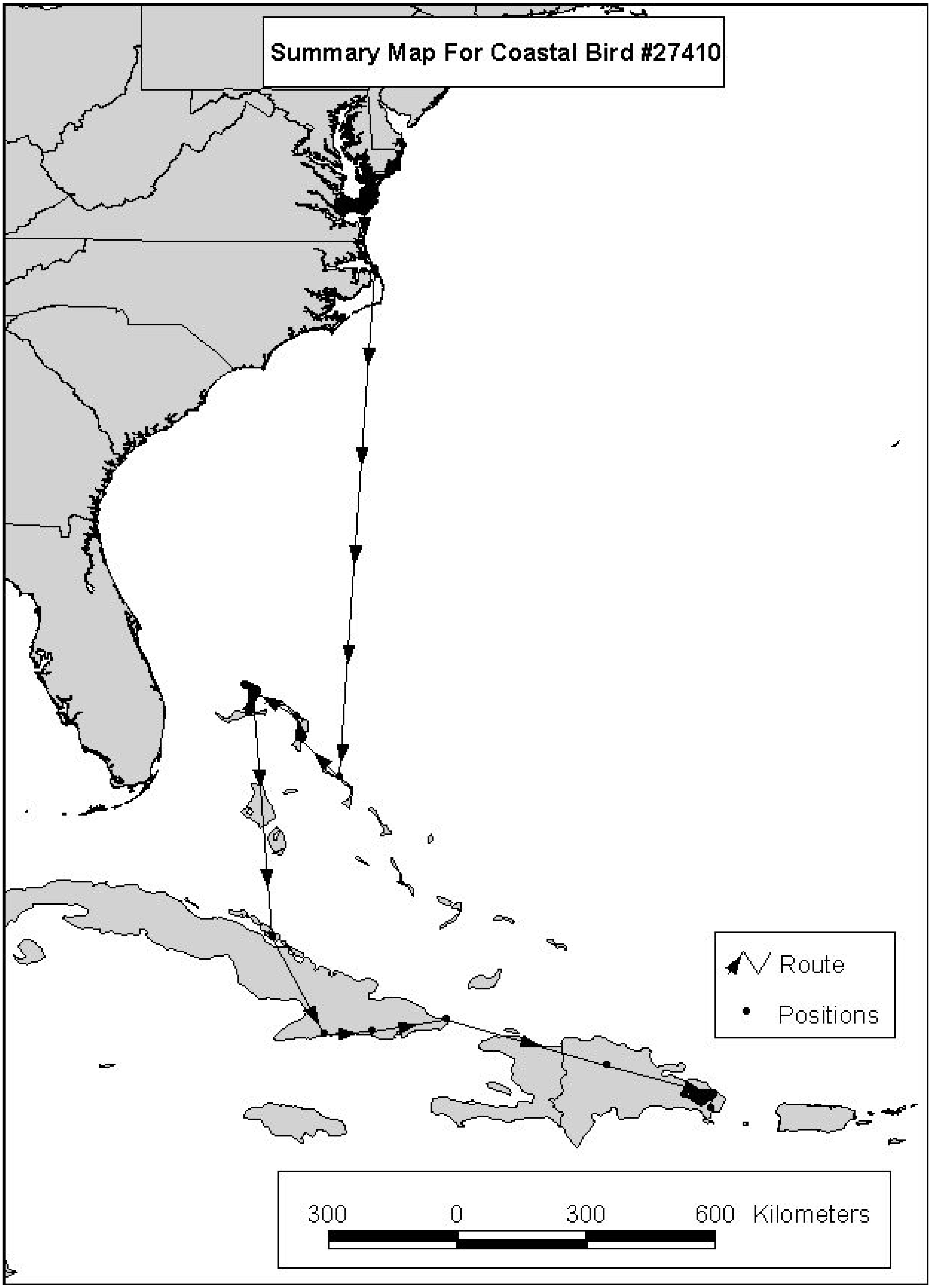
Summary Map For Mountain Bird #27406
Route
Position
80 0 80 160 Kilometers

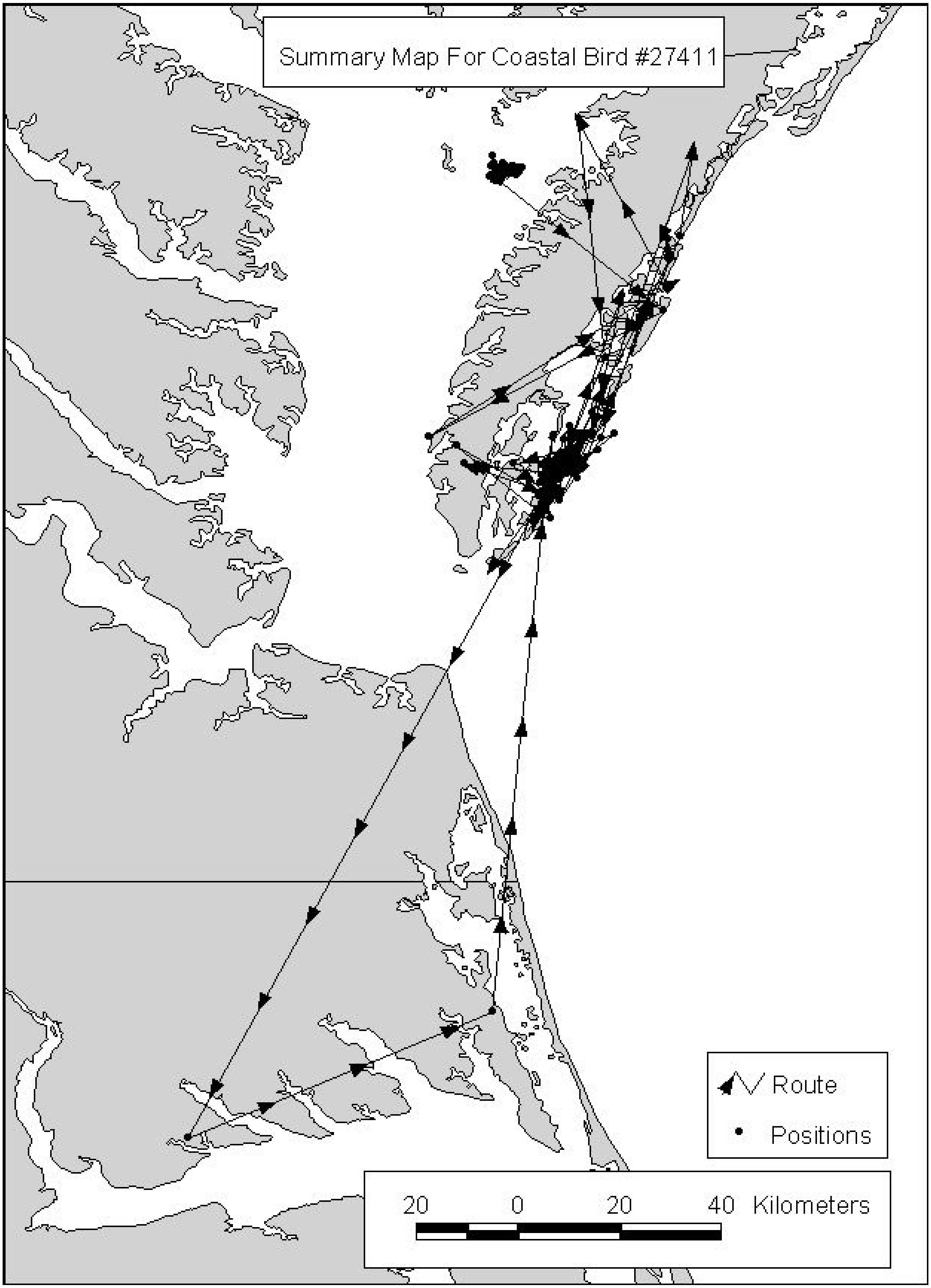

Summary Map For Mountain Bird #27407
Route
Positions
20 0 20 40 Kilometers



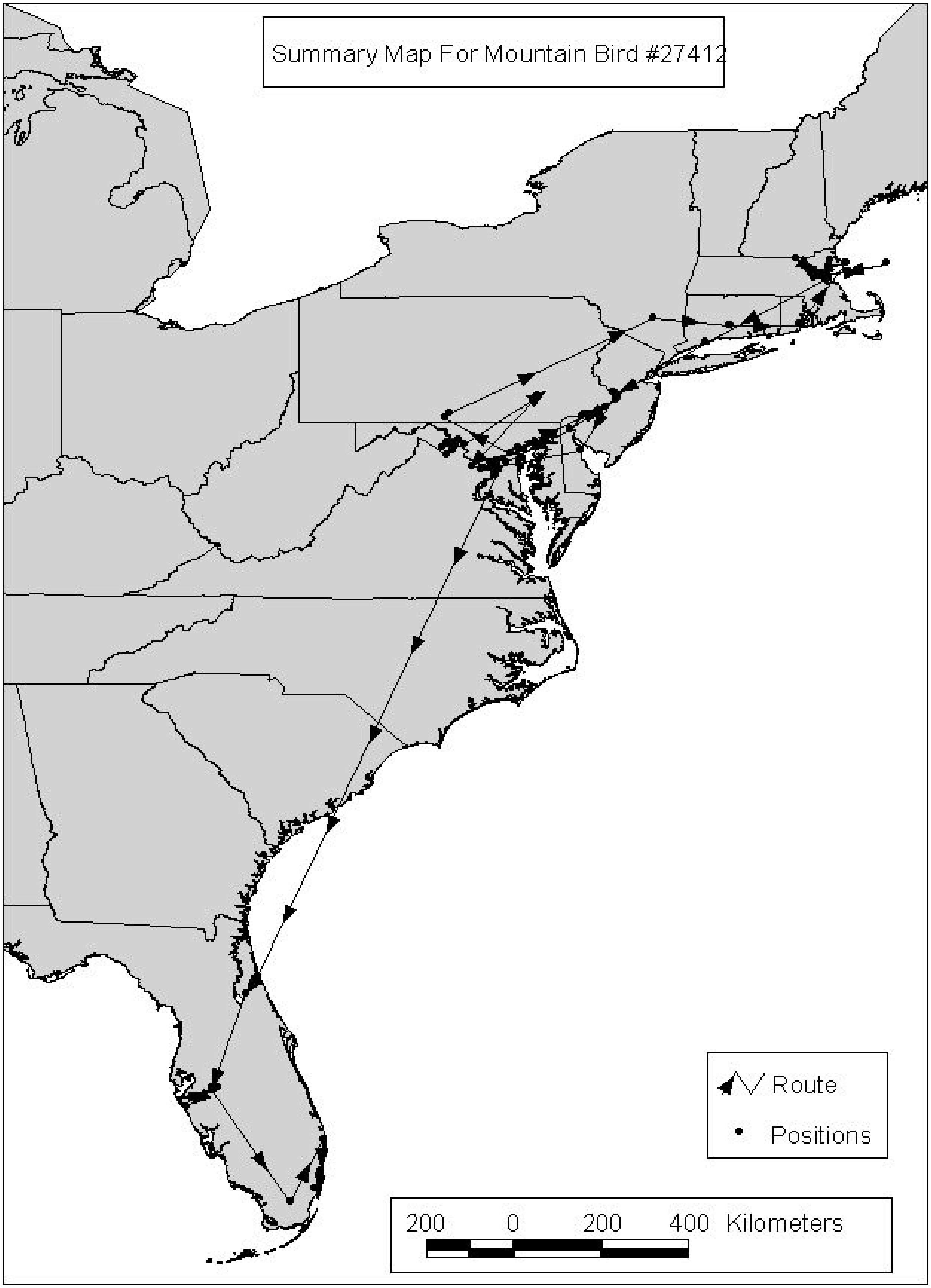
Summary Map For Mountain Bird #27408
Route
Positions
40
0
40
80
Kilometers


Summary Map For Mountain Bird #27409
Route
Positions
40 0 40 80 Kilometers


Summary Map For Coastal Bird #27410
Route
Positions
300 0 300 600 Kilometers



Summary Map For Coastal Bird #27411
Route
Positions
20 0 20 40 Kilometers


Summary Map For Mountain Bird #27412
Route
Positions
200 0 200 400 Kilometers