BALD EAGLE MOVEMENTS, DISTRIBUTION, and ABUNDANCE on the NORTHERN CHESAPEAKE BAY

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INTRODUCTION

The Chesapeake Bay is perhaps the most important unit of habitat for the endangered bald eagle (*Haliaeetus leucocephalus*) in eastern North America. It is inhabited throughout the year by a resident nesting population of more than 200 adult eagles (Cline 1984) and an unknown number of subadults. Additionally, it is used in summer by migrants from southern states (North Carolina to Florida) and in the winter by migrants from northern states (Pennsylvania to Maine).

The longest stretches of undeveloped shoreline in the northern Chesapeake Bay are within the Aberdeen Proving Ground (APG). An initial eagle survey on APG in early 1982 (Cline and Millsap 1982, Janis Chase, Contracting Officer's representative) documented substantial eagle use during winter. A second study in 1982-1983 (Millsap et al. 1983) further delineated concentration areas on APG by using shoreline surveys and by radio-tracking three bald eagles. While these studies suggested that APG included important bald eagle habitat, they did not provide any information about the importance of APG relative to other areas on the northern Chesapeake Bay. Moreover, the small sample of radioed birds and the restricted period of tracking in these studies could have resulted in overlooking important APG areas. The study reported here, conducted from October 1983 - June, 1985, was a continuation and expansion of this earlier work.

The primary objective of this study was to monitor bald eagle movements and to locate bald eagle intensive use areas on the northern Chesapeake Bay. An important goal was to determine how eagle use of APG compared with eagle use of the rest of the northern Bay, and thus to begin to understand the relative importance of APG habitat. Additionally, information on activity patterns, habitat use, foraging success, and the effect of human development on eagle distribution and abundance was obtained in the course of achieving the primary objective, and is included in this report.

STUDY AREA

The Northern Chesapeake Bay Study Area (NCSA) consisted of the Chesapeake Bay from the Bay Bridge at Annapolis to the Conowingo Dam on the Susquehanna River (Figs. 1 and 2). It included portions of the Susquehanna, Northeast, Elk, Bohemia, Sassafras, Bush, Gunpowder, and Chester rivers. Vegetation consisted of upland and lowland deciduous forests dominated by maples (*Acer* spp.), sweet gum (*Liquidambar styraciflua*), oaks (*Quercus* spp.), American sycamore (*Platanus occidentalis*), and American beech (*Fagus grandifolia*). Open marsh was dominated by cordgrass (*Spartina* spp.) and phragmites (*Phragmites communis*). Corn and hay were the predominant agricultural crops. Intensive farming occurred primarily on the eastern shore of the Bay.

On the western shore, the study area is heavily populated. Baltimore is the primary urban area. Extensive suburban development also exists along the Interstate 95 corridor from Baltimore to Northeast. The eastern shore consists of more discrete communities located on the major tributaries, including Elkton, Chesapeake City, Fredericktown, Georgetown, and Chestertown. Shoreline development is pervasive on the NCSA with the exception of the APG shoreline (Fig. 3).

METHODS

Trapping

We used a variety of trap types to catch bald eagles, including leghold traps, noose sets, rocket nets, and bow nets. These were baited with a variety of dead fish, birds, and mammals. Only leghold traps and noose fish were successful. These techniques are described in detail

below. When trapping on land, we usually set traps before daylight and started trapping at first light. Trapping from boats over water began at about sunrise. At least two people were present for all trapping to facilitate handling captured eagles.

Leghold traps

We used Victor Number 3 offset coil spring traps with one spring removed to reduce closing impact. Sets were similar to those described by Harmata (1984). The striking edge of the trap was padded with 0.5 cm rubber inner tube, wrapped with electrical tape and then wrapped again with friction tape. Four traps were connected with steel chain and the entire set was staked to the ground with a 30 cm tent stake. Traps were usually buried in the sand. Coarse gravel was removed and pans were covered with waxed paper to prevent interference with closure. We used 1-3 sets per trap site depending upon the size of the bait. We used a variety of dead fish, deer (*Odocoileus virginianus*), pigs, and rabbits (*Sylvilagus floridanus*) for bait with the leghold sets. Trap sites were on the Susquehanna River, the Bush River, and Romney Creek and were selected based on eagle use and accessibility. We constructed blinds near the trap site when trapping from shore. We did not conceal ourselves when trapping from boats but anchored at least 200 m from the traps.

Noose-fish

We used noose-fish sets similar to those used by Frenzel and Anthony (1982), Young (pers. commun.), and Jackman (pers. commun.). We used Jackman designed noose-fish (Fig. 4) after April 1984. This design allowed the fish to be pulled free if the nooses failed to ensnare the eagle's talons, thus "rewarding" the bird. Sets were anchored with 3.6-kg anchors attached with a shock cord to 18 kg-test monofilament line.

We removed the contents of the body cavity of white perch (*Morone americana*) or spot (*Leiostomus xanthurus*) and inserted styrofoam for floatation. Nooses were threaded through the anus, through the body cavity and styrofoam and out the mouth, and were attached to the

anchor line with an improved clinch knot. The body cavity was sewn shut. The nooses were then arranged on the fish and sewn down near the gills with 0.9-kg test monafilament line to keep the nooses arranged properly. These light weight ties pulled free when the eagles struck, allowing the nooses to close easily. Nooses were either flat on the water or stuck out of the water.

We used noose-fish sets primarily in protected coves on the Bush River and in Romney Creek. We usually put 2-3 noose-fish sets out during a trapping effort and rebaited sets when fish were taken. We also tried slowly motoring by the perched eagles and dropping the noose-fish on the opposite side of the boat, out of the bird's sight. Eagles caught in the nooses were retrieved with two 76-cm diameter fish landing nets.

Eagle Processing After Capture

After capture, eagles were processed at the trap sites or, in foul weather, at nearby shelter. Eagles were hooded and the feet wrapped with an ace bandage to prevent injury to the bird or personnel. Unbanded eagles were banded with size 9 U.S. Fish and Wildlife Service aluminum rivet bands. Wing cord and tail length were measured using a wing board and exposed culmen, culmen depth, anterior-posterior tarsus, lateral tarsus, and hallux were measured with vernier calipers (Baldwin et al. 1931). We weighed the bird on a 20-kg balance.

We took a blood sample (about 3-cc) from the brachial vein of either wing, 2-cc for a genetics study and 1-cc for lead analysis. We also took a feather tip sample (usually the fifth secondary) for heavy metal analysis.

We attached Telonics S2B5 9-month battery transmitters (50-g) ventrally on the central rectrices using Young's (1983) method. Two 6-mm holes were drilled in the left rectrix for attachment of the anterior and posterior ends of the transmitter. The anterior part of the radio was positioned as close to the rectrix follicle as possible. Vetafil sutures (0.6-mm) were used to

attach the radio and 0.4-mm sutures were used to attach the antenna to the shaft. All knots were surgeon's knots sealed with superglue. The sutures on the left rectrix ran through the drilled holes whereas the sutures on the right central rectrix were stitched around (not through) the right central rectrix.

Wildlife Materials LPB-2165-LD transmitters, (7-g, six weeks estimated life) were tied and glued ventrally onto a single central rectrix on ventral tail mounts.

We attached solar radios (Wildlife Materials) and one battery radio (Wildlife Materials) using backpack harnesses constructed of 0.64-cm teflon ribbon. The two anterior harness straps were placed over the shoulders; the two posterior straps ran behind the wings. The four straps were sewn together with silk thread at the sternum midpoint. The ventral connection was wrapped with electrical tape after trimming the excess harness material. Radios were positioned midway between the wings with the antenna trailing down the center of the back. Feathers potentially obscuring solar panels were trimmed. After radio attachment, we noted plumage characteristics, eye color, beak color, molt status, the presence of any unusual marks or scars, and the presence of ectoparasites.

Radio Telemetry

Eagles were tracked from the ground and the air using Telonics programmable scanning receivers and three-element Yagi antennae (ground) and two-element H-type antennae (air). Locations from ground tracking were determined from at least two bearings taken within a 15-minute time period from permanent stations. Bearings were taken using a hand-held antenna and a compass. When the eagle was in sight, we noted its location on U.S. Geological Survey 7.5 minute topographic maps.

We used radio-tracking equipment on fixed-wing aircraft to get visual locations of radio-tagged eagles after 1 September 1984. Locations were marked on 7.5 minute topographic

maps and perch type, activity, and habitat were recorded. This method was used to locate all eagles not on APG and those on APG when we were cleared to fly in APG's restricted airspace (Sundays).

Eagles on APG on weekdays were located via aerial triangulation. Three permanent stations were used on the eastern shore opposite APG. Bearings to radio-tagged eagles were read off the aircraft's heading indicator while circling each station. Bearings were calculated as the midpoint between where the peak signal first became audible and where it faded out. We attempted to obtain three bearings on each eagle within 15 minutes, but this was not always possible. Aerial tracking was conducted three times daily, three days per week, sampling morning, midday, and late afternoon time periods.

All-day ground tracking was conducted periodically from 28 February - 1 September 1984. All day tracking was conducted several days per week with different radio-tagged eagles selected for tracking during the week. Eagles were relocated every 30-45 minutes using homing/direct observation or, when this was not possible, using triangulation.

Telemetry data were processed using a revised version of TELEM (Koeln 1980). This program calculates locations of eagles from bearing data, home ranges from locations and distances moved between relocations. TELEM was also used in conjunction with a Tectronix 4662 plotter to plot eagle locations and movements on study area maps.

We tested the accuracy of ground and aerial telemetry systems by randomly placing 10 transmitters on APG and taking bearings from our regular stations. One observer experienced with the ground tracking took three ground bearings per test transmitter while three other observers took aerial bearings. We calculated the true bearing from the stations to each test transmitter using UTM coordinates and trigonometry. We also used the TELEM program (Koeln 1980) to calculate the fix position and compared this with the known position of each test transmitter.

Shoreline Surveys

Shoreline surveys were flown monthly on the northern part of the NCSA from fixed-wing aircraft (Cessna 150 and Cessna 172). All shoreline was flown from Carroll Island on the Gunpowder River north of Baltimore to Swan Point on the eastern shore (Fig. 5). This area was selected after several test surveys were flown because it economically covered most of the shoreline areas frequented by eagles. The 6-hour survey was broken into two sections (eastern and western shorelines) and flown consecutive days. The western shoreline, from Carroll Island to the Conowingo Dam, was flown only on Sundays because of restrictions in use of APG airspace. The survey route was flown with the observer on the shoreline side of the plane. Rivers, creeks, and inlets off the Bay were flown either in their entirety or up to the first bridge if a bridge existed. Surveys were flown at about 75 m above the ground and 75 m off the shore.

Both pilot and passenger acted as observers. The passenger recorded the location of all eagles observed on U.S. Geological Survey 7.5 minute topographic maps. We estimated age using plumage characteristics/age relationships described by Southern (1964) and Clark (1983). We classified the activity of all eagles observed (perched, flying, soaring, feeding, preening, observer flushed, roosting, at nest or other). We recorded the type of perch for perched birds and the general habitat occupied by the bird (bay, river, creek, marsh, wooded swamp, upland woods, forest opening, APG test range, pasture/field, pond and other).

We determined the shoreline length along the survey route by measuring the shoreline with dividers on 7.5 minute topographic maps. We also determined the land area of the NCSA by counting 100 ha grid cells on 7.5 minute topographic maps. We arbitrarily determined the limits of the NCSA as Interstate 95 and U.S. Route 2 on the western side, plus a 6 km strip up the Susquehanna to the Conowingo Dam. State Route 213 and U.S. Route 301 formed the eastern and southern borders. More than 95% of all of our radio-tagged eagle locations fell within this area.

Monitoring Movements off the NCSA -- Bay-wide Surveys

We flew bay-wide surveys monthly after 1 September 1984 to locate radio-tagged eagles that had left the NCSA. Each survey consisted of an approximately 3-hour flight down the eastern shore while we scanned all frequencies of our radio-tagged eagles. The 3-hour return trip was flown up the western shore covering parts or all of the James, York, Rappahannock, Potomac and Patuxent Rivers. We homed in on all eagle frequencies we picked up and got visual locations whenever possible.

Roost Counts

Roost counts were conducted incidental to radio-tracking and other work in the vicinity of roosts. Roost counts were done at the Octoraro roost near the Conowingo Dam, and at five roosts on APG (AA5, Heron Rookery, Abbey, Michaelsville, and Mosquito Creek) (Fig. 6). There is direct road access to all of the APG roosts.

Roost counts were done in two ways. When several roosts were counted during the same morning or evening, we drove slowly by each roost and noted the number and ages of all eagles present. When only one roost was counted during the period, the observer counted eagles leaving the roost in the morning, or counted eagles entering the roost in the evening. We also checked for radio-tagged eagles while doing roost counts.

Foraging Observations

We monitored foraging success incidental to our other work, especially during trapping. A foraging event was an instance in which an eagle struck at the water in an apparent effort to

catch fish. When eagles were observed foraging, we noted age of the bird from plumage characteristics and whether the foraging attempt was successful or unsuccessful.

Nesting Activity

We monitored nesting activity primarily during our aerial telemetry and survey flights. We flew by known nest sites from previous years during the nesting season to determine their status. A nest was assumed active if a bird was observed in incubating position. Active nests were periodically checked to determine success.

Human Development

In order to evaluate the relationship of human shoreline development patterns to the eagle distribution, we compared the eagle distribution from the 14 shoreline surveys (Fig. 7) with the distribution of developed sites (Fig. 3). We determined the distribution of developed sites by digitizing the site locations using the most recent U.S. Geological Survey 7.5 minute topographic maps. We only digitized sites within 200 m of the shoreline along the survey route. We field-checked the presence of these sites by air in June 1985 and revised the maps where necessary. We used the distances from random points to the nearest developed sites as a quantitative measure of the evenness of development distribution. We assumed that an even distribution would have smaller distances from random points on average than a more clumped distribution for areas with comparable development density. We also compared the distance from eagle locations to the nearest developed site with distances from random points to the nearest site. We also characterized all shoreline along the survey route as being either lightly, moderately or intensely developed by measuring the distance between developed sites on our

7.5 minute revised topographic maps. We defined lightly developed shoreline as that having > 500 m between developments, moderate had 250 to 500 m between developments and intensely developed shoreline had less than 250 m between developed sites.

RESULTS AND DISCUSSION

Eagles Trapped and Radio-tracked

We trapped and radio-tagged 10 bald eagles from 14 December 1983 - 28 March 1985. We also radio-tagged 2 nestlings, giving a total of 12 birds to radio-track (Table 1). We supplemented this sample by radio-tracking an additional 8 eagles which others radio-tagged as part of hacking programs in New York, New Jersey, and Pennsylvania (Table 2). We originally located these birds by periodically scanning through frequencies of radio-tagged birds hacked in adjacent states. All but one of these birds were hacked during summer, 1984 and located after we started aerial tracking in September, 1984.

Bald Eagle Distribution and Abundance

Distribution and abundance on the NCSA

We conducted 14 monthly aerial shoreline surveys, making 403 bald eagles sitings on the NCSA from 8 April 1984 - 23 June 1985 (Fig. 7). To identify differences in intensity of use, we subdivided the NCSA into five disinct areas: Edgewood Peninsula and the western shore to the south, Aberdeen Proving Ground (except the Edgewood area) and areas north to Havre de Grace, the Susquehanna River from Conowingo Dam to Havre de Grace, the Elk Neck area from Havre de Grace to the northern shoreline of the Sassafras River and the Remington Farms area - from the south shore of the Sassafras south to the Bay Bridge (Fig. 8). We used a chi-square analysis to compare the observed eagle distribution with the length of the survey

route in each area (Table 3). Eagles were found on Aberdeen much more frequently than expected based on the amount of shoreline on APG ($p < 0.001$). Eagles were found on the Elk Neck area much less frequently than expected. Eagles were found on Edgewood, Remington Farms, and the Susquehanna River in about the same proportion expected based on their shoreline mileage.

Numbers of eagles seen per survey ranged from a low of 10 (8 April 1984 survey) to a high of 48 (5 January 1985 survey) (Fig. 9). There appears to be two peak periods - late summer (July and August) and mid-winter (January). Numbers during the rest of the year appeared fairly constant.

We also radio-tracked eagles over the entire NCSA from 1 September 1984 - 1 July 1985, locating 14 different eagles, a total of 705 times (Table 4). We compared the observed distribution using chi-square analysis with the expected distribution if eagles were located in proportion to the land area of each major area (Table 5). Eagles were located on the Aberdeen area much more frequently than expected; were located on the Susquehanna about as often as expected, and were located on Edgewood, Elk Neck, and Remington Farms areas much less frequently than expected ($p < 0.001$). Similarly, when we compared eagle use with habitat availability on the basis of length of shoreline, APG received much more use than expected. The Susquehanna River was used about as expected based on available shoreline, while other areas were used much less frequently than expected.

Obvious radio-tagged eagle high use areas on the NCSA are APG, including the Edgewood Peninsula, the Susquehanna River near the Conowingo Dam, and the Sassafras River, Worton Point, and Remington Farms areas on the eastern shore (Figs. 10 and 11). The distribution of eagles from the shoreline surveys similarly showed very high use of APG, with minor concentrations on the Susquehanna, Edgewood, Sassafras River, and Worton Point areas (Fig. 7).

Distribution and abundance on Aberdeen Proving Ground

We located 9 different radio-tagged eagles 759 times on APG from 28 February 1984 - 1 September 1984 from the ground. We also located 11 different radio-tagged eagles 449 times on APG from 1 September 1984 - 1 July 1985 from the air. We used this sample of the eagle population to identify high use areas on APG. High use areas identified during ground tracking (28 February 1984 - 1 September 1984) were two key roosts (AA5 and Heron Rookery), Romney Creek including Abbey Roost, Spesutie Island, and the lower half of the Edgewood Peninsula (Figs. 12 and 13). Numbers of locations per km^2 ranged from none to a high of about 50 in the AA5 Roost area.

High use areas identified during aerial tracking (1 September 1984 - 1 July 1985) included the AA5 and Heron Rookery roosts, Romney Creek, and Mosquito Creek (Figs. 14 and 15). Additionally, aerial surveys showed substantial use of APG's Chesapeake Bay shoreline (Fig. 7).

Our data confirms the high use of the areas identified by Millsap et al. (1983), and additionally shows high use of Spesutie Island, Mosquito Creek, the Edgewood peninsula, and APG's Chesapeake Bay shoreline. Additionally, we observed use of three nests not reported by Millsap et al. (1983). There are several possible reasons that we discovered use areas not reported by Millsap et al. Our sampling was considerably more intensive (20 radio-equipped birds vs. 3 birds), and extensive (15 months vs. 6 months). The monthly air shoreline survey also covered much more shoreline than the previous surveys.

Another reason that our results showed use areas beyond those described by Millsap et al., is that eagle distribution is dynamic; although use of some areas (e.g. Romney Creek) tends to be stable from year to year, use of other areas changes over time, often for unknown reasons.

Distribution and abundance by season

The number of eagles seen on shoreline surveys varied seasonally (Fig. 9, Table 6). Peak surveys occurred during late summer (July-August 1984) and mid-winter (December 1984 -

January 1985). Spring and fall surveys, in contrast, were fairly constant at 20-30 eagles per survey.

The number of eagles per survey also varied by area seasonally (Table 6). Eagles were on Edgewood and Elk Neck most often in summer and winter. Eagles were almost totally absent from the Susquehanna in spring and summer, but increased to moderate numbers in late fall-early winter. Eagles were sighted on the Aberdeen and Remington Farms at fairly constant levels throughout the year.

The locations of radio-tagged eagles also varied seasonally (Table 7). Although individual eagles showed considerable variation, it appears that all areas were used most intensively (most locations) in winter. Use of all areas in spring was the lowest, apparently because a number of radio-tagged eagles moved off the study area. This effect might have been somewhat overestated, however, because some eagles may have molted their radios at this time. However, we only recovered 1 radio during the period (in February).

Distribution and abundance by day of week

We used the 679 locations of radio-tagged eagles to determine whether the distribution was dependent on the day of week we tracked. We found that there was not a strong relationship between use areas and day of the week (Table 8). Importantly, there was not a significant tendency for eagles to be found on Aberdeen and Edgewood more often on weekends than on weekdays.

Distribution and abundance by time of day

We also used the locations of radio-tagged eagles to evaluate distribution - time of day effects. Eagles selected different areas at different times of day ($p < 0.001$, Table 9). Eagles tended to be found on Edgewood more often in morning and midday periods than afternoon periods. Eagles were found on Aberdeen more frequently during afternoon periods. Eagles were

located on the Susquehanna consistently across time periods. Eagles were located on Remington Farms less often during midday periods.

Bald Eagle Distribution and Abundance -- Overview

Based on our results, the Aberdeen area has the largest eagle concentration of the entire NCSA. This concentration has occurred in densities far exceeding those expected if eagles were distributed in proportion to either land area or shoreline length. Both of these measures can be thought of as crude indices to the available habitat on NCSA.

Other concentration areas on the NCSA exist, but they are smaller and therefore support fewer eagles. Eagle use of the Susquehanna is a good example of this. Eagle densities below the Conowingo Dam, at times, are as high as on any stretch of APG shoreline. This high use area, however, only extends downriver a short distance. Other concentration areas include the Sassafras River, Worton Point, and the Remington Farms area.

Eagle use on Aberdeen appears to be centered around the communal roosts - AA5, Heron Rookery, Abbey, and Mosquito Creek (Figs. 12-15). Eagle use can be thought of as radiating out from these foci, although not in a uniform pattern. For example, eagle use from AA5, Heron Rookery, and Abbey seems to radiate toward Romney Creek, while eagles roosting in Mosquito Creek tend to move to Spesutie Island to forage. These patterns will be discussed further in the section on daily movements.

The NCSA eagle distribution is dynamic, changing with season and time of day. The precise causes of daily and seasonal rhythms are unknown. The two major peaks in eagle density coincide with the documented influx of southern migrants (Broley 1947) in summer and the influx of northern migrants in early winter. Although numbers observed during summer surveys were lower than the winter peak, we suspect actual densities may be comparable. Heavy canopy foliage during summer makes eagles perched in live trees difficult to see from the air during surveys.

Based on the timing of migration of eagles from southern and northern populations, we believe the eagles present during spring and fall are comprised mostly of Chesapeake Bay residents. Since fall and spring populations are about half as large as peak winter populations, migrants may comprise about half of the winter peak.

Eagle use of various NCSA areas seems to shift seasonally. This is most apparent on the Susquehanna with high use during fall and winter and low use in spring and summer. The reasons for this seasonality are not apparent. Additionally it is not clear whether the bulk of the birds wintering on the Susquehanna move there from other parts of the NCSA or whether they are northern migrants, or both. We located three radio-tagged eagles on the Susquehanna during fall 1984. One (eagle E613) was from an APG nest, another (eagle A734) was hacked in 1984 in New York and the third (eagle E451) was of unknown origin. We suspect the third eagle (E451) was of northern origin, however, because it stayed on the NCSA all winter and we lost radio contact with it in early spring.

We hypothesize that the concentration occurs in response to the consistently available food source from the Conowingo Dam and deteriorating feeding conditions elsewhere. We haven't monitored food resources and other conditions on the NCSA, and therefore cannot test this hypothesis.

We also noted seasonal use of certain areas of APG. Based on our radio-tagged eagles, Spesutie Island was used fairly heavily during summer 1984 but was used much less often the rest of the year.

We found no relationship between day of week (weekday vs. weekend) and eagle distribution. We originally suspected that eagles might be found on APG more often on weekends, especially Sundays, than on weekdays, because military activity in this area is low during this time, and human activities along the APG shoreline may be higher. The lack of a weekday affect suggests that the cyclic human activities described either do not affect eagle distribution or affect it on a different temporal or geographic scale than the ones on which we

measured it. Human activities must be monitored more closely in order to evaluate their true effect on eagle distribution.

Distribution shifts by time of day were documented although the causes of these shifts remain largely unknown. Some of these shifts are probably related to movements from roosting areas to foraging areas. Eagle use of Edgewood seems to fit this pattern. Eagles typically roosted on Aberdeen but foraged during morning and midday on the Edgewood shoreline. Because eagles seldom roosted on Edgewood, they were less likely to be found there during the late afternoon. Eagles may be found on Aberdeen more often in late afternoon because they roost there. These shifts in use by time of day can be more effectively interpreted from all-day tracking data and observations of what each individual is doing during these time of day periods.

Although we have identified a number of very important bald eagle concentration areas on the northern Chesapeake Bay, determination of why these areas are intensely used was beyond the scope of the present study. Yet, determination of why certain areas are important, and others are not, is necessary to the development of proactive eagle management. That is, if the factors underlying observed patterns of eagle distribution and abundance are not understood, it will be impossible for land managers, including the U.S. Army to effectively manage.

We hypothesize that there are at least four key factors that interact to determine distribution and abundance: vegetation, prey base, microclimate, and human activity. Additional study will be required to determine the relative importance of these factors and the nature of their interactions.

Bald Eagle Movements

Eagles moved about the NCSA and on and off the NCSA on almost a daily basis. Of 20 eagles radio-tracked on the NCSA, 10 were also located off the NCSA at least once (Fig. 16). Although there was much individual variation in eagle movements after leaving the NCSA (see Appendix A for individual moves), trends were apparent. Eagles tended to move off the study

area in a stepwise fashion. For example, we located eagle E451 moving stepwise from the NCSA down to Blackwater National Wildlife Refuge in the central part of the Chesapeake and back on two separate occasions (Figs. 24 and 25, Appendix A). The Blackwater area had the most relocations of radio-tagged eagles (8 of 22 locations), with the Potomac River second (5 of 22 locations). Eagles tended to move north and south on the Chesapeake, rather than east or west off the Chesapeake. Eagle E613 was an exception to this, moving to Delaware Bay once (Fig. 30, Appendix A). This north-south tendency, however, may be somewhat overstated because we did little searching for our birds in areas to the east or west. Our solar radios were audible at ranges exceeding 100 km on sunny days, hence an east-west bias might be minimal. For our battery-powered radios, this potential bias may be more relevant.

The period of time spent off the NCSA ranged from a minimum of 5 days to a maximum of the eagle never returning (see Appendix A: Figs. 24-34). When the eagle returned, the mean period absent was 22 days. This number reflects both the actual time gone plus the number of days back before we located it on a telemetry flight.

Apparently eagles move up and down the Chesapeake Bay with some regularity. Some of the eagles radio-tagged were clearly migrants into the area (eagle E552 from Maine; E842 from South Carolina). The unknown origin of unbanded birds makes interpretation of the nature of their movements more difficult. Eagles which we lost radio contact with during late summer and early fall (eagles E423, E641, E700) could either be southern migrants which moved back down the east coast or birds from other parts of the Chesapeake Bay which were not banded by the Chesapeake Bay banding team. We did not pick these birds up during Bay-wide searches, suggesting that these birds had indeed left the Chesapeake. Radio failure could also have accounted for lost contact with some of these birds although we had no indication this was occurring.

Movements by NCSA fledglings (eagles E544 and E613) could be attributed to post-fledging exploration. These birds regularly moved down the Bay. The pattern of

repeatedly returning to the NCSA, however, distinguished the movements of these birds from the others.

The final type of movement observed related to the single NCSA resident adult monitored. This bird, thought to be nesting on Aberdeen, never was observed off the NCSA. All of its movements, therefore, were within a small area, especially compared to the area covered by other birds.

In general, because eagles on the NCSA are from different populations (northern, Chesapeake resident and southern), the movement patterns are complex and difficult to interpret. Stimuli that make migrants move probably differs from the stimuli causing movements by Chesapeake residents. We suspect that non-breeding Chesapeake residents move whenever conditions drop below a threshold level of suitability. They may move until they find an area of the Chesapeake that surpasses this threshold. Migrants, in contrast, may leave the NCSA even when suitable conditions exist, because of an urge to return to natal areas. Finally, based on our observations, Chesapeake resident breeding birds appear to be strongly inclined to stay in their nesting territory year-round. This may be related to a need to defend nest sites.

Daily Activity Patterns

We radio-tracked 7 different eagles a total of 34 days on an all-day basis to determine daily activity patterns (Table 10 and Appendix B - Figs. 35-69). The starting points of all day tracking were either in a communal roost (AA5, Heron Rookery, Abbey, Mosquito Creek) or a location elsewhere on Aberdeen. If the eagle either was not roosting in a communal roost or had already left the roost by the time we started tracking, we used the first location as its starting point for analysis. The target end point of tracking was nightfall, although this was not always possible. We located these eagles 408 times on 34 days, averaging 12 locations per day, or about 1 location every hour. On 23 of 34 tracking days, we tracked the birds from roost to roost. The other 11 days either started after the bird left the roost or ended before it returned.

Most (20/34) tracking days started in the AA5 - Heron Rookery area (Appendix B: Figs. 35-69). Of these 20 days, birds were relocated on Romney Creek on 18 days (90%), on the Bush River on 5 days (25%), and on the Chesapeake Bay proper only on 2 days (10%). Of 7 tracking days starting in the Abbey Roost, birds were relocated on Romney Creek on 5 days and on the Bush River on 3 days. Six track days started in the Mosquito Creek-Spesutie Island area. All of these birds foraged on Spesutie Island. Eagle E544 was tracked all day on Edgewood. The locations for this fledgling started, ended, and centered around its nest location.

Based on the 23 days we tracked from roost to roost, eagles on average were located only 2.12 km from the roost (Table 11). The maximum distance an eagle was located from its roost was 5.60 km. The average maximum among the eagles we tracked was 4.59 km.

We also calculated daily convex polygon home ranges based on all day tracking (Table 10). The area of use ranged from 1.12 km^2 (eagle E544) to 16.57 km^2 (eagle E552).

In general, eagles foraged very close to roosts. We never observed birds roosting in Mosquito Creek and moving to Romney Creek to forage, or birds roosting in the AA5 or Heron Rookery Roosts and foraging on Spesutie Island. Furthermore, although all-day tracking was restricted to APG proper, we found no evidence that eagles roosting on APG moved to the eastern shore to forage. The 5-10 km distance from APG to the eastern shore may be outside the eagles' normal daily foraging range. The exception to this may be winter when eagles may move farther from the roost because food is more difficult to obtain. We observed eagles after ice-up in winter apparently roosting on APG and foraging over open water in the ship channel near the eastern shore.

This tendency to limit daily movements is consistent with the idea that eagles maximize their energy obtained/energy expended ratio, similar to data for other large avian scavengers. Black and turkey vultures typically forage within 15 km of their roost. In 270 days of all-day tracking in southcentral Pennsylvania, 95% of 4,400 relocations were within 15 km of the roost and 90% of relocations were within 10 km of the roost (Coleman 1985).

Seasonal and Total Home Ranges

We calculated seasonal home ranges for eagles on the NCSA based on the minimum convex polygon method. Home ranges for spring and summer 1984 represented tracking only in the Aberdeen-Edgewood areas (Table 10). Home ranges for fall, 1984 and winter and spring, 1985, represented tracking across the entire NCSA (Table 12). For this reason, seasonal home ranges for these two periods are not strictly comparable. We also plotted seasonal and total home ranges by eagle (Appendix C: Figs. 70-116) and composite home ranges for all eagles (Figs. 17 and 18).

It appears that, collectively, eagles use much of the Aberdeen-Edgewood area (Fig. 17). Most of this use runs parallel to the bay shoreline. Home ranges during spring, 1984 ranged from 42.65-km^2 to 66.33-km^2 (Table 10). Home ranges during summer, 1984 varied much more widely (16.65-km^2 to 705.29-km^2) although eagle E842's home range was inflated by several aerial locations off the Aberdeen-Edgewood area. With this exception, spring and summer, 1984 home ranges are comparable. Total home ranges during this period also were fairly comparable ranging from 20.75-km^2 to 75.92-km^2, excluding eagle E842.

Seasonal home ranges from 1 September 1984 - 1 July 1985 were more variable (Table 12, Appendix C: Figs. 70-116). Although we tracked over the entire NCSA during this period, some eagles rarely left the Aberdeen-Edgewood area. These birds, such as eagle E232, had relatively small seasonal and total home ranges. Other birds never left the area they originally were located in, such as eagle A734 on the Susquehanna, and also had very small home ranges.

Seasonal home ranges also varied with sample size. Eagles that were located many times had greater home ranges than those located only a few times. The correlation coefficient between sample size and seasonal home ranges for eagles tracked after 1 September 1984 was $r = 0.488$. Sample size, therefore accounts for about 24% of the variation in seasonal home ranges.

Total home ranges also are a crude measure of each eagles' activity. In general, total home ranges varied greatly (266.58-km^2 to 17809.75-km^2, Table 12). This difference is largely reflective of the number of times the individual moved off the NCSA, thereby greatly increasing its home range (Fig. 18).

The home range calculation has limited use for far-ranging raptors, such as bald eagles. When eagles are resident on an area for a period of time, such as some of our eagles were on either Aberdeen-Edgewood or the NCSA, it does provide a rough indication of area used. We emphasize that it is a rough measure because obviously the eagles did not use every point within the convex polygon. As the number of locations on the area increases, however, the calculated home range should stabilize at some point. We plotted home range versus sample size and found stabilization occurred at about 30 locations. This held as long as the eagle did not move to a completely new area. When the eagle did move, its new home range would again begin to converge after about 30 more locations. This pattern tended to be repeated throughout the year. Thus, home ranges may be most useful in studying habitat use during short periods of local residence.

Home range measures can also be used to distinguish between use by different ages of eagles. For example, eagle E522, an Aberdeen resident adult year-round, had a relatively small home range. Eagle E613, an Aberdeen fledgling, in contrast, spent much time off the NCSA and therefore had a very large home range.

Roost Use

We conducted 147 roost counts during the study period. We used 101 counts which started no later than 1-hour after sunrise or ended less than 1-hour before sunset as the basis for analysis of roost use. We used both morning and evening counts because they produced comparable results (Table 13, Fig. 19).

Eagles used the AA5 roost most frequently, regardless of season (Table 14). Use of this roost peaked during the winter at a mean count of 15.4 eagles. AA5 use was least during spring at a mean count of 3.8 eagles. Observed eagle use of Octoraro roost peaked during fall, Heron Rookery use peaked during winter and Abbey roost use was greatest during summer.

The seasonality of roost use can best be seen by looking at evening counts of AA5 (Fig. 20). We looked at AA5 for this purpose because it had the most counts. Use of AA5 peaked in January-February, 1984 at 20-25 eagles per count. Roost use dropped to none for one count during spring. Roost use during summer was intermediate, ranging from 1-16 eagles per count.

We also observed periodic roosting in several other areas of the NCSA. Radio-tagged eagles were located roosting on Octoraro Creek, about 5 km off the Susquehanna River (Fig. 21). Radio-tagged eagles also were located roosting on Deer Creek, about 5 km off the Susquehanna. We also observed eagles roosting on Mosquito Creek on APG, mainly during summer. Roost use on Mosquito Creek the rest of the year appears low.

We located one radio-tagged eagle roosting on the eastern shore. We did not locate any communal roosts on the eastern shore, although little effort was spent in this area. We suspect eagles found during the day on the eastern shore often roost there at night based on their absence from APG during roost checks.

We calculated the correlation coefficient for the shoreline survey counts versus the AA5 roost counts. We used the roost counts closest to the dates surveys were flown. Both morning and evening roost counts were used. There did not appear to be any relationship between AA5 roost use and the number of eagles seen on shoreline surveys ($r = -0.027$).

Analyses of roost use were hampered by infrequent sampling of roosts during fall, and infrequent sampling of the Heron Rookery and Abbey roosts during winter. Nevertheless, it appears that roost counts were greatest in winter and summer and least in spring. Winter and summer peaks may result primarily from the greater number of birds in the area at those times. Additionally, winter roost use may be high due to thermal advantages afforded by roost site. Stalmaster and Gessaman (1984) reported that coniferous roosts were warmer than deciduous

roosts during winter in Washington. Deciduous roosts, though, were warmer than foraging sites. There are few coniferous stands available in the NCSA, however, and eagles on the NCSA roost in deciduous trees. We do not know whether these sites are warmer during winter than other forested stands on the NCSA. The thermal characteristics, however, could explain roost preference. Additionally, location of foraging areas, and openness of the canopy may influence roost selection. Further studies will be required to determine the relative importance of each of these characteristics. The less frequent use of communal roosts during summer may result, in part, from a decreased need for thermal benefits during that time of year. In summer the primary selective factors may be tree height and openness of canopy that yield security and ease of use, and proximity to foraging areas.

Our roost counts and shoreline surveys appear to be poorly correlated. Sweeney and Fraser (1986) also found poor correlation in vulture roost counts and roadside surveys. They concluded that roost counts provided a better index to vulture population levels than roadside surveys. We believe shoreline surveys in our study, however, are more reliable than roost counts as indices to the eagle population. This largely results from the difficulty in conducting eagle roost counts on the NCSA and the relatively large number of roosts (five on APG alone) that are frequently used. In our study, roost counts are most useful as a means of evaluating roost dynamics.

Activity and Habitat Use

We noted the activity of 500 eagles observed during shoreline surveys (Table 15). Based on this sample, eagles spent most (70.8%) of their time perched. Eagles were observed flying (flapping flight and soaring) relatively infrequently (22.8%). About 6% of the eagles were observed at the nest site. Only 1 eagle was observed foraging.

Activity of radio-tagged eagles differed from activity of eagles observed on shoreline surveys ($p < 0.001$). Radio-tagged eagles were seen perched more often (74.6%) and in roosts

(4.6%) more often because surveys didn't cover all roosts. We also saw our radio-tagged eagles at nests only twice, largely because only one of these birds was of breeding age.

Habitat use by eagles seen on shoreline surveys also was different than habitat use by radio-tagged birds (Table 16, $p < 0.001$). Eagles on shoreline surveys were seen on shoreline habitat types (bay, river and creek) much more often (92% of the eagles seen) than radio-tagged eagles (59.5% of the eagles seen). Radio-tagged eagles also used wetlands and ponds fairly frequently (20.4% and 12.8% of locations, respectively).

Perch use by eagles seen on shoreline surveys was different from perch use by radio-tagged eagles (Table 17, $p < 0.001$). Survey eagles were seen most often in live deciduous trees (77.4% of all observations). Radio-tagged eagles also used live deciduous trees most often (60.7% of locations) but less than survey birds. They also were located in dead deciduous trees about twice as often as survey eagles (26.6% versus 12.5% of locations). Both types of eagles seldom perched on the ground, ice, manmade structures or in conifers.

Eagles on the NCSA spent most of their time perched. The tendency to be inactive has also been noted by Stalmaster and Gessaman (1984). Their wintering eagles in Washington, however, spent much more time perched (92.9%) than eagles on the NCSA. Stalmaster and Gessaman (1984) suggested that their eagles were less active than eagles from other studies conducted during less energy stressful (warmer) times of the year. It is also likely that our shoreline surveys underestimated the proportion of perched eagles because they are less obvious than birds in flight. Our radio-tagged eagles, however, also spent much less time perched than eagles in the Washington study. All day tracking of radio-tagged eagles would provide a much more reliable picture of activity budgets than aerial surveys or periodic relocations.

It is unclear whether NCSA eagles select habitat and perches in proportion to the availability of each perch and habitat type, or whether they show preferences. Even though eagles were seldom found in dead trees along creek shoreline, for example, they may actually be selecting for this habitat wherever it is found. Answering this question requires determining

the amount of each habitat type that is available. Preferences can then be determined by comparing actual use with habitat availability.

The difference between survey and radio-tagged eagles in activity, habitat use and perch use points out inherent biases in both samples of the eagle population. Survey eagles probably were observed flying more often because eagles in flight were more easily observed. Additionally, only shoreline habitats were covered during surveys, hence almost all observations were in bay, river or creek habitats. Perch use also would be restricted to those types found along the shoreline.

Radio-located eagles provide a better measure of activity, habitat use and perch use because there isn't nearly as great of an observability bias. The greatest potential bias, however, occurs if the radio-tagged eagles are not representative of the eagle population. This is most likely a problem when most of the sample comes from only a few radio-tagged eagles. As the proportion of radio-tagged eagles in the population increases, the potential for bias decreases.

Effects of Human Development

The overall development density is similar for all areas except Elk Neck, which had the greatest density at 6.08 houses per shoreline km (Table 18). Aberdeen, however, has the longest stretch of undeveloped shoreline which extends from Spesutie Island to the Bush River railroad bridge. Distances to houses from random points differed among areas ($p < 0.001$) consistent with the eagle distribution (Table 19). Aberdeen, the area with the greatest eagle numbers, had a high mean distance from random points to houses. Elk Neck, the area with the fewest eagles, had the smallest mean distance from random points to houses. Susquehanna and Remington Farms areas, intermediate in eagle numbers, also were intermediate in distances from random points to houses. Edgewood, somewhat an anomaly, had the greatest mean distance from random points to houses, yet only moderate eagle density.

Eagles selected areas farther from houses than random points for the whole study area ($p = 0.0008$, log transformed data). Based on pair-wise comparisons, Aberdeen and Elk Neck eagles selected areas significantly farther away from houses than random points were. ($p < 0.05$). These two areas accounted for 64% of all eagle locations.

Although eagles were found as close as 10 m from developed sites, 86.4% of the eagle locations were > 250 m from development. Based on this, we have classified shoreline on the NCSA as either intensely developed (houses within 250 m), moderately developed (houses between 250 m and 500 m apart) and lightly developed (houses > 500 m apart). On this basis, 45.1% of the NCSA shoreline is intensely developed, 12.9% is moderately developed and 42.0% lightly developed (Table 20). All areas except for the Susquehanna have about the same amount of lightly developed shoreline. Elk Neck has the most intensely developed shoreline.

We retested the comparison of the eagle shoreline distribution with shoreline length per area (Table 3), but this time using only the lightly developed shoreline and lightly-moderately developed shoreline combined. Both chi-square tests were still significant ($p < 0.001$) but the chi-square values were reduced ($\chi^2 = 270.06$ - lightly developed only vs. $\chi^2 = 310.05$ - lightly and moderately developed combined).

Eagles selected areas that were farther from human development than random points. On average, they selected areas 500-m farther away than our measure of what was available - the random points. This 500 m buffer is consistent with mean flush distances of 476 m for nesting eagles in Minnesota (Fraser et al. 1985), but much greater than mean flush distances of 196 m reported by Stalmaster and Newman (1978) for eagles wintering in western Washington.

We have documented a human development effect, but it appears that development alone cannot account for the patchiness of the eagle distribution. Even after dropping the developed shoreline from the analysis, significantly more eagles were located on Aberdeen than would be expected based on available undeveloped habitat. This suggests that factors in addition to levels of human disturbance affect observed eagle distribution.

We propose that eagles are not affected as much by the actual development as by human activity associated with that development. Although we have not tested this relationship, we believe measuring human activity directly would better demonstrate these effects. We made no attempt to classify human development sites as active or inactive. We suspect, however, that since some of the Aberdeen military sites are often unoccupied, it makes this area even more suitable for eagles than it would appear based solely on the number of buildings present. To date, we have made no attempt to quantify the effects of APG military activity on the eagle distribution. Concluding that the military activity either adversely or beneficially affects the eagle distribution, at this point, would be premature.

Foraging Success

We observed 68 foraging attempts by eagles over water (Table 21). Of the 68, 48 (70.6%) were successful. We also looked at foraging success by age class. Although sample sizes were small, there did not appear to be any differences in foraging success among age classes.

The foraging ecology of bald eagles on the NCSA is largely unknown. We have not documented what is being eaten by eagles and how this affects distributional patterns. When food is abundant, it may have little affect on eagle distribution on the NCSA. During periods of scarcity, however, such as winter, food availability may have a far greater affect on eagle distribution. We do know from casual observation while trapping and tracking that eagles often eat fish on the NCSA. We do not know how important mammalian and avian species are in the eagle's diet or what species of fish are used most often.

Age Structure of the Chesapeake Eagle Population

Of 402 eagles aged by plumage characteristics during shoreline surveys, 40.2% were adults, 6.8% were subadults and 53.0% were immatures (Table 22). Age structure differed seasonally

($p = 0.029$). Adults made up the greatest percentage of the population during winter (53.2%), compared with about half that in fall (25.0%).

The number of adults seen per survey ranged from a low of 3 during September, 1984, to a high of 25 in January 1985 (Fig. 22). The number of subadults ranged from none on several surveys to 7 on the 29 July 1984 survey. Immatures ranged from a low of 4 birds in April 1984 to a high of 22 in August 1984.

The seasonal trend in age distribution of eagles seen during roost counts was similar to the trend in age distribution from shoreline surveys, but the percentages differed (Table 23). Adults were seldom seen in roosts, making up only 16.9% of all roosting birds observed. Although the fall sample was limited, the age distribution was significantly different by season ($p = 0.0048$). Adults were seen more often than expected during winter, similar to results from the shoreline surveys. Subadults made up 8.5% of the population - similar to the percentages found in shoreline surveys. Immatures, in contrast, made up 74.6% of the roost count eagles, much greater than that observed during the shoreline surveys.

The age structure of the Chesapeake eagle population is dynamic, changing with recruitment into the population in spring, changing with age differential mortality and also changing as differentially aged migrants flood the bay in summer and winter. Because of its dynamic nature, interpretation of changes in the age structure is very difficult.

It appears that there is an influx of adults from northern populations in winter but not a comparable influx of adults in summer. Broley (1947) suggested the possibility of a northward migration of adult Florida bald eagles but had little evidence for this phenomenon. Based on our data, there does not appear to be an influx of southern adults in summer into the NCSA.

The influx of migrants also makes interpretation of the population dynamics of Chesapeake eagles difficult. Based on the increasing number of nesting pairs on the Bay (Cline 1984), we might conclude that the population is expanding. Taylor (1982) also concluded that the Chesapeake population has met or exceeded productivity levels needed for population maintenance since 1977. The large percentage of immature birds in the population is consistent

with this conclusion. We still know very little about eagle population dynamics, however, especially survival rates. Because of the intensive banding effort, however, recruitment into the population has been well documented (Cline 1984).

Nesting Activity on the Northern Chesapeake

We did not concentrate on documenting all nesting activity on the NCSA, largely because this was beyond the scope of the project and also is being done by others. We did collect some information on nesting incidental to our other activities. Most of these observations came from the Aberdeen area.

In 1984, we noted 2 successful nests on Aberdeen (Fig. 23). The nest on the Edgewood Peninsula produced two young, one of which we radio-tagged (eagle E544). The other nest site, on Little Romney Creek, produced one young, which we radio-tagged (eagle E613). The Edgewood nest had been active since 1978, whereas the Little Romney Creek nest was new in 1984 (Millsap et al. 1983).

In 1985, we found only 2 successful nests on Aberdeen (Fig. 23). The Delph Creek nest, originally used in 1980, produced 2 young. The Heron Rookery nest, new in 1985, produced 1 young. We suspect the pair that nested on Delph Creek in 1985 may have nested on Little Romney Creek in 1984. We aren't sure where or if the Heron Rookery pair nested previously but suspect they might have nested on Bridge Creek previously. The Edgewood nest, successful in 1983 (Cline 1983) and 1984, failed in 1985 from unknown causes. One addled egg also was found in a new Mosquito Creek nest in 1985.

We did not monitor nesting activity on the eastern shore in 1984. In 1985, we checked nests on the Sassafras River at Lloyd Creek (successful with 2 young), on Remington Farms (successful with 3 young), and at Swan Point (successful with 2 young).

The total productivity of the Aberdeen area has apparently increased in recent years. From 1977-1982, only 2 young were produced (Millsap et al. 1983). Since then, 2 were produced in 1983 (Cline 1983), and 3 in both 1984 and 1985.

The eagle production on the entire NCSA also appears to be increasing. In 1977, only 4 young were found by the banding project (Clark and Lincer 1977), whereas 13 young were banded in 1984 (Cline 1984). Some of the increase in number of young banded in recent years may be caused by an increasing data base on nesting activity and locations and increased nest surveys. It is likely, however, that the number of breeding pairs and their productivity is increasing. This increase is apt to continue until all potential breeding habitat on the Chesapeake is filled. When that occurs, recruitment into the population will likely level off.

Trap Success

We trapped for a total of 914.6 hours, and caught 10 different eagles plus 3 recaptures (Table 24). The double noose-fish caught the most eagles on a capture/trap hour basis, followed by the leghold set and then the single noose-fish. The leghold set was by far the most efficient on a strike/capture basis. The double noose-fish was about twice as efficient on a strike/capture basis as the single noose-fish. The double noose-fish also had far more strikes per hour trap time than the single noose-fish. Since we always trapped with at least two people, it cost at least 140 person-hours per trapped eagle.

Trapping eagles was the most labor intensive and time consuming task we conducted on the project. No one method was used with consistent success. It appears that eagles may be more susceptible to trapping at certain times of the year than others - our best success occurred in summer and early fall. This may be partly caused, however, by the very poor success during December 1983 - February 1984. We expended considerable trapping effort on the Susquehanna River during this period, when the area had few eagles and very difficult trapping conditions.

We had very little success at trapping eagles during winter. We expected eagles to be most trappable in winter when food probably is scarcest. We saw little indication that this was true. This result could be attributed to less eagle activity and foraging during winter - similar to the response to winter weather noted by Stalmaster and Gessaman (1984) in western Washington. We did, however, see the greatest numbers of eagles in the vicinity of the trap site during winter, although we did not see them actively foraging in this area because it was frozen.

The double noose-fish produced the greatest number of captures/hour of trapping, but this can be attributed, in part, to using only noose-fish sets during our best trapping months. It seems likely that the success rate at this time would have been higher if we had used leghold sets in addition to noose fish. The key to success with leghold traps was getting eagles to come down on the ground. Once on the ground, we caught a high percentage of the birds, as indicated by a high capture/strike ratio (Table 24). The noose-fish sets, in contrast, were very effective at getting strikes but poor at catching eagles that struck. Noose-fish also were rapidly destroyed by gulls on many occasions especially during October - Decembr. Gulls tended to forage earlier than eagles on the NCSA and often destroyed the noose-fish sets before the eagles arrived in the area. Noose-fish also were time consuming to prepare, requiring > 30 minutes/fish. In general radio-tagging nestlings is the most efficient means of radio-tagging an unbiased sample of the resident eagle population.

Telemetry Tests

We tested the accuracy of our aerial and ground telemetry locations. We tested the accuracy of the telemetry bearings taken at five aerial telemetry stations with three different observers and 10 randomly placed radio transmitters on the Aberdeen area (Table 25). We also tested the accuracy of bearings from 10 ground stations with 1 observer for the same 10 randomly placed radios (Table 26).

The mean aerial bearing error was 11.24 degrees. There were no significant differences between observers ($p = 0.81$) or stations ($p = 0.47$). The mean ground bearing error was significantly greater at 18.9 degrees ($p < 0.001$). We did not compare bearing error by ground station because of limited sample sizes but strongly suspect there are some great differences, as our limited data suggests.

We calculated the distance from the actual location of the test transmitters to the location determined from both ground and aerial telemetry (Table 27). The ground telemetry was successful in getting locations on only 4 of 10 transmitters. Mean fix error was 1.63 km. The aerial telemetry was successful in getting 26 of 30 possible locations, with a mean fix error of 3.50 km.

Our aerial telemetry provided more accurate bearings than our ground bearings on APG. This does not mean, however, that the aerial telemetry data provided locations closer to the actual location than the ground tracking. We found the opposite to be true, because aerial stations were much farther away from the test transmitters than ground stations were. In most cases, ground stations were located within 5 km of the transmitter. Aerial stations, in contrast, were never within 5 km of the transmitter and often were over 10 km away.

Although aerial telemetry provided poorer locations than ground telemetry, it was much more efficient at picking up all radio signals present on the study area. Both methods, however, provide information of equal value given the objectives of this study. We looked at eagle distribution at a macro scale and identified large concentration areas, such as APG, on this basis. Both telemetry methods were adequate for placing an eagle accurately in one of the five geographic areas of the NCSA. Aerial tracking had the additional advantage of covering the entire NCSA in an unbiased fashion to demonstrate relative use per area. Aerial tracking also allows us to get visual locations much more readily than ground tracking. For habitat analyses, this level of precision is of tantamount importance.

Distribution of Hacked Versus Wild Eagles

We compared the areas used by eight hacked eagles with that of seven wild eagles (Table 28). The hacked birds used the NCSA differently than the wild birds ($p < 0.001$). Wild birds tended to use Edgewood and Aberdeen more than expected and Remington Farms less than expected. Hacked birds, in contrast, used Edgewood and Aberdeen less often and the Susquehanna and Remington Farms more often than expected.

Although we tracked only 15 eagles for this analysis, the data strongly suggest that hacked eagles are not using the NCSA the same way that wild birds do.

It is not clear if this is a result of the hacking process, the origin of the birds, or an artifact of the sampling procedure. Wild trapped birds were all captured in the vicinity of APG. Thus, the sample may be biased toward birds that are, for one reason or another, likely to spend more time at APG than other Bay birds. It is therefore highly desirable to trap eagles throughout the NCSA, rather than just on APG. To date, our attempts to do so have been limited by the need to trap in the area with the greatest probability of success.

We are not sure what the presence of hacked eagles indicates for the survival of Chesapeake resident eagles. If hacked birds provide competition for scarce food in winter, the most likely period of environmental stress for Chesapeake eagles, survival is bound to decrease. If these hacked birds become established breeders in the release states, they may provide a positive contribution to our East Coast eagle population. If they do not use the same areas as Chesapeake eagles when wintering here, as our data would suggest, they would not provide competition for Chesapeake eagles and therefore would have no effect on wintering eagle survival.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Distribution and Abundance of Bald Eagles on the NCSA

Eagle abundance

It is clear that the NCSA provides important habitat for bald eagles. The peak count of 50 eagles certainly represents only a fraction of the birds using the NCSA. Because of migration and other movements, there is a substantial turnover of eagles on the NCSA. Thus, all the eagles present at any time are only a percentage of the total number of birds using the area.

The NCSA is used not only by Chesapeake Bay reared eagles, but also by eagles from most or all other eastern populations. In addition to wild eagles, our results indicate that the NCSA supports eagles released in restoration programs in a number of eastern states. Thus the NCSA appears to play a significant role in the survival of the bald eagle in the eastern United States.

Eagle distribution

Despite the apparent importance of the NCSA, eagles are not distributed evenly thoughout the area, but concentrate in relatively few areas. Suitable habitat appears to occur in relatively small parcels scattered throughout the NCSA except on Aberdeen Proving Ground. An important goal of eagle flyway management should be to maintain a chain of habitat patches along eagle migratory routes. Failure to maintain such a chain could interrupt migratory movements and/or alter the energy budgets of migrating bald eagles.

Our results suggest that freedom from human disturbance is one important attribute of use areas, but that other, undetermined factors may also be involved. Characteristics likely to be important to eagles are abundance and availability of food, roosting habitat with good access and favorable thermal characteristics (Stalmaster and Gessamen 1984), and suitable perches.

The presence of these habitat components is not enough, however. They must be juxtaposed so that eagles can make use of each component without excessive energy expenditures.

The importance of Aberdeen Proving Ground

APG clearly contains the most important bald eagle habitat on the northern Chesapeake Bay. In this study, the Proving Ground consistently received more eagle use than any other area on the NCSA, and much more use per unit of habitat. Events on APG that affect bald eagles are likely to have significant ramifications for the Chesapeake Bay bald eagle population, and quite possibly for other eastern populations as well.

Management Recommendations

The importance of APG to eagles and the limited access available to traditional eagle managers suggests a special Army role and responsibility in eagle conservation and management on APG. We strongly recommend that the Army develop a specific eagle management plan which will formalize their management strategy for this endangered species on APG. This plan should delimit eagle management areas based on our results and those of Millsap et al. 1983 and outline management approaches for three different types of areas - foraging, roosting and nesting.

Eagle management areas

During this study, the Romney Creek area and Bush River area were primary foraging sites. We also have documented frequent daytime use of Spesutie Island, Mosquito Creek, the Edgewood Peninsula shoreline and the APG-Chesapeake Bay shoreline. All of these areas should be included as foraging management areas.

Four roosting areas - AA5, Heron Rookery, Abbey Road, and Mosquito Creek were used frequently. The Michaelsville roost should also be considered for roost management. Although

use of Michaelsville during our study was infrequent, we have observed heavy use in the past during severe winters.

Several new nest sites have been documented during our study. These sites should be added to the list of nest sites identified for management by Millsap et al. 1983.

Eagle management approach

Foraging Areas

We believe the goal of foraging area management should be to provide eagles a disturbance-free shoreline zone in which they can forage and loaf during daylight hours. We recommend a buffer zone be established along these shoreline areas to provide this environment. Stalmaster (1981) recommended a 250-300 m zone around perches and feeding areas. We concur with this recommended zone width and recommend it be strictly enforced when siting new activities on APG. Ongoing activities within this zone should also be monitored to determine the extent of their impact on eagles. Changes in vegetative habitat within this zone should not be pursued until more is known about eagle habitat characteristics on APG.

Roosting Areas

We believe the goal of roost management on APG should be maintenance of existing roosts in a disturbance-free environment. Attempts at creation of new roosts at this time would be premature until roost characteristics on APG are better defined. Based on results from experimental disturbance studies (Stalmaster and Newman 1978, Knight and Knight 1984, Fraser et al. 1985), we believe a buffer zone of 300 m around roosts would prevent disturbance to most roosting eagles. We note, however, that eagle susceptability to disturbance may vary geographically and recommend site specific studies of the impact of disturbance on APG. Human activity in these roost areas should be prohibited except those absolutely necessary. Necessary human activity within roost management zones should be scheduled for midday periods. Vehicle taffic through roosts with road access should be prohibited whenever feasible.

Any human-induced changes in vegetative habitat within the roost management zones should be prohibited until we better understand the definitive roost characteristics.

Nesting Areas

Nest management on APG should follow the approach used in other eagle populations (e.g., Mathisen et al. 1977, Fraser 1983 and Grier et al. 1983). We find these recommendations generally sound and strongly urge they be implemented on APG. Based on Fraser's (1985) results, however, we recommend extending Millsap's et al. (1983) secondary buffer zone to 500 m.

The recommended buffer zone sizes are based on small samples from other populations. Inter-population variation in response to human intrusions seems likely. Thus, we suggest that studies be conducted to determine the impact of human activities for the Chesapeake Bay population. These studies would necessarily include experimental disturbances and determination of flushing distances (Stalmaster and Newman 1978, Fraser et al. 1985). Such studies would facilitate site specific management and provide an index to the sensitivity of the Chesapeake Bay population.

Preventing mortality

The bald eagle's life history strategy (delayed reproduction, small clutch size) makes this species particularly sensitive to changes in mortality rates. Thus it is imperative that eagle managers make every effort to eliminate needless human induced mortality. Small mammal trapping with open ground sets baited with carrion should be prohibited in eagle use areas and protective regulations should be enforced on APG.

Surveys

It is imperative that the efficacy of the APG eagle management program be continually evaluated. Additionally, the dynamic nature of eagle use areas mandates frequent surveys to

ensure that newly inhabited areas are discovered soon after use begins. Thus, careful surveys of age specific population size and reproductive performance should be conducted seasonally.

We recommend weekly flights during egglaying to estimate nest occupancy and activity, one or two flights after hatch to estimate hatching success, and one or two flights in the week prior to the beginning of nest departure, to count the young. To design an efficient shoreline survey, a detailed understanding is required of the forces driving changes in abundance of shoreline eagles. Until such information is available, the monthly surveys associated with ongoing research will suffice to keep track of gross changes in shoreline eagles.

Understanding eagle ecology

The reasons that bald eagles favor APG are, at best, poorly understood. Our results suggest that freedom from human disturbance is an important factor, but not the only factor. Effective long term management programs require improved understanding of bald eagle requirements. Such an understanding will enable land managers to accurately predict the effects of man-derived impacts on bald eagle populations. This understanding will only be achieved by implementing a large scale study of bald eagle ecology, which includes studies of eagles at a number of important concentration areas such as APG, Blackwater and Caldeon, and which also includes studies of less favorable areas.

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LITERATURE CITED

Baldwin, P. S., H. C. Olberhoeser and L. G. Worley. 1931. Measurement of birds. Scientific publications of the Cleveland Museum of Natural History, Volume II, Cleveland, OH. 198 pp.

Broley, C. L. 1947. Migration and nesting of Florida bald eagles. Wilson Bull. 59(1): 3-20.

Clark, W. S. 1983. The field identification of North American eagles. American Birds 37(5): 822-826.

_____ and J. L. Lincer. 1977. Chesapeake Bay bald eagle banding project report. Raptor Information Center, National Wildlife Federation, Washington, D.C. 21 pp.

Cline, K. W. 1983. Chesapeake Bay bald eagle banding project report. Raptor Information Center, National Wildlife Federation, Washington, D.C. 46 pp.

_____. 1984. Chesapeake Bay bald eagle banding project report. Raptor Information Center, National Wildlife Federation, Washington, D.C. 36 pp.

_____ and B.A. Millsap. 1982. Winter bald eagle studies on Aberdeen Proving Ground. Report prepared for U.S. Dept. of the Army, Aberdeen Proving Ground, MD. 29 pp.

Coleman, J. S. 1985. Home range, habitat use, behavior and morphology of the Gettysburg Vultures. M.S. Thesis, VPI and SU, Blacksburg, VA. 105 pp.

Fraser, J. D. 1983. The impact of human activities on bald eagle populations - a review. pp. 68 -84 in Gerrard, J. M. and T. N. Ingram, eds. The bald eagle in Canada. White Horse Plains Publishers. Headingly, Manitoba.

_____, L. D. Frenzel, and J. E. Mathisen. 1985. The impact of human activities on breeding bald eagles in north-central Minnesota. J. Wildl. Manage. 49(3): 585-592.

Frenzel, R. W. and R. G. Anthony. 1982. A method for live-capturing bald eagles and osprey over open water. U.S. Dept. Interior, Fish and Wildl. Service Research Inform. Bull. 82-13.

Grier, J. W., J. B. Elder, F. J. Gramlich, N. F. Green, J. V. Kussman, J. E. Mathisen and J. Mattsson. 1983. Northern States bald eagle recovery plan. U. S. Dept. Interior, Fish and Wildl. Service Reference Service, Denver, CO. 147 pp.

Harmata, A. R. 1984. Bald eagles in the San Luis Valley, Colorado: their winter ecology and spring migration. Ph.D. Thesis, Montana State Univ., Boseman, MT. 222 pp.

Knight, R. L. and S. K. Knight. 1984. Responses of wintering bald eagles to boating activity. J. Wildl. Manage. 48(3):999-1004.

Koeln, G. T. 1980. A computer system for analyzing radio telemetry data. Unpubl. rep., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA. 10 pp.

Mathisen, J. E., D. J. Sorenson, L. D. Frenzel, and T. C. Dunston. 1977. Management strategy for bald eagles. Trans. N. Amer. Wildl. Conf. 42: 86-92.

Millsap, B. A., K. W. Cline and M. J. Gilroy. 1983. Distribution and movements of bald eagles on Aberdeen Proving Ground, MD. Report prepared for U.S. Dept. of the Army, Aberdeen Proving Ground, MD. 71 pp.

Southern, W. E. 1964. Additional observations on winter bald eagle populations: including remarks on biotelemetry techniques and immature plumages. Wilson Bull. 76(2): 121-137.

Stalmaster, M. V. 1981. Management strategies for wintering bald eagles in the Pacific Northwest. Pp. 49-67 in R. L. Knight, G. T. Allen, M. V. Stalmaster, and C. W. Servheen, eds. Proc. Washington bald eagle symp. 14-15 June, Seattle, WA.

_____, M. V. and J. A. Gessaman. Ecological energetics and foraging behavior of overwintering bald eagles. Ecological Monographs 54(4): 407-428.

_____ and J. R. Newman. 1978. Behavioral responses of bald eagles to human activity. J. Wildl. Manage. 42(3): 506-513.

Sweeney, T. M. and J. D. Fraser. 1986. Vulture roost dynamics and monitoring techniques in southwest Virginia. Wildl. Soc. Bull. 14: 49-54.

Taylor, G. J. 1982. The status of the bald eagle in the Chesapeake Bay. pp. 143-147 in Proceedings of the Bald Eagle Conference on "Bald Eagle Restoration." Aug. 13-15, 1982, Rochester, NY.

Young, L. S. 1983. Movements of bald eagles associated with autumn concentrations in Glacier National Park. M.S. Thesis, Univ. Montana, Missoula, MT. 102. pp.

Table 1: Band number, origin, period tracked, number of locations, age at capture and weight at capture of radio-tagged bald eagles on the Northern Chesapeake Study Area.

Eagle	Band No.	Where Banded	lst Date Tracked	Last Date Tracked	No. Locations	Age at[6] Capture	Wt. at Capture(g)
E232	629-15556	APG[1]	11-25-84	03-24-85	80	juv	4470
E423	629-15552	APG[1]	05-19-84	06-14-84	117	imm	----
E451	629-15555	APG[1]	10-04-84	04-02-85	99	sub	3624
E496	629-15030	CCMD[2]	09-19-84	04-10-85	8	imm	4166
E522	629-00099	BWNWR[3]	04-19-84	03-24-85	210	ad	3383
E544	629-15238	APG[1]	06-03-84	03-17-85	91	juv	----
E552	629-12233	Maine	02-28-84	03-27-84	41	juv	----
E573	629-15086	TNMD[4]	11-20-84	11-27-84	6	juv	3987
E613	629-15240	APG[1]	06-03-84	06-26-85	124	juv	----
E641	629-15554	APG[1]	06-22-84	09-03-84	212	imm	3225
E700	629-15553	APG[1]	06-01-84	06-24-84	82	sub	2852
E842	629-02848	SC[5]	07-19-84	08-26-84	146	sub	3350

[1]APG = Aberdeen Proving Ground, MD.
[2]CCMD = Charles County, MD.
[3]BWNWR = Blackwater National Wildlife Refuge, MD.
[4]TNMD = Tilghman Neck, MD.
[5]SC = South Carolina.
[6]Age at capture determined from plumage, if unbanded at capture, or from original banding date, if banded as a nestling.
Ad = adult, sub = subadult, imm = immature and juv = juvenile.

Table 2: Period tracked, number of locations and age for radio-tagged bald eagles located on the Northern Chesapeake Study Area. All eagles shown here came from hacking programs.

Eagle	Origin	1st Date Tracked	Last Date Tracked	No. Locations	Age at First Location
A451	New Jersey	12-04-84	02-20-85	34	fledgling
A477	New Jersey	12-04-84	02-07-85	36	fledgling
A635	New York	12-17-84	12-31-84	11	fledgling
A734	New York	10-14-84	01-02-85	57	fledgling
A801	New Jersey	12-21-84	12-31-84	6	fledgling
A842	New Jersey	12-04-84	03-28-85	69	fledgling
B292	New Jersey	12-19-84	03-05-85	43	fledgling
B414	Pennsylvania	03-11-84	03-27-84	3	fledgling

Table 3: Locations of bald eagles seen on aerial shoreline surveys on the Northern Chesapeake Study Area from 8 Apr 1984 - 23 Jun 1985 compared to kilometers of shoreline on the survey route*.

	Area										
	Edgewood		Aberdeen**		Susquehanna		Elk Neck		Remington Farms		Total
	N	%	N	%	N	%	N	%	N	%	N
Eagles	53	18.2	212	52.6	25	6.2	33	8.9	80	19.9	403
Shoreline (km)	95.8	13.2	91.8	17.4	36.6	7.0	169.1	32.1	132.9	25.3	526.2

*Chi-square analysis was used to compare the distribution of eagles with the distribution of shoreline miles. $\chi^2 = 369.7$, df = 4, $p < 0.001$.

Table 4: Locations of radio-tagged bald eagles on the Northern Chesapeake Study Area from 1 Sep 1984 - 1 Jul 1985.

Eagle	Number and Percent of Locations by Area										Total
	Edgewood		Aberdeen		Susquehanna River		Elk Neck		Remington Farms		
	N	%	N	%	N	%	N	%	N	%	
E232*	19	23.7	61	76.2	0	0	0	0	0	0	80
E451*	8	8.25	49	50.5	1	1.0	11	11.3	28	28.9	97
E496*	0	0	2	100	0	0	0	0	0	0	2
E522*	29	22.0	99	75.0	0	0	1	0.8	3	2.3	132
E544*	3	5.4	38	67.9	0	0	8	14.3	7	12.5	56
E573*	0	0	5	83.3	0	0	0	0	1	16.7	6
E613*	14	17.7	48	60.8	1	1.3	4	5.1	12	15.2	79
A451**	2	6.1	6	18.2	0	0	1	3.0	24	72.7	33
A477**	1	2.9	5	14.3	0	0	0	0	29	82.9	35
A635**	0	0	0	0	0	0	0	0	11	100	11
A734**	0	0	0	0	57	100	0	0	0	0	57
A801**	0	0	0	0	0	0	0	0	6	100	6
A842**	2	2.9	31	45.6	0	0	1	1.5	34	50.0	68
B292**	4	9.3	23	53.5	0	0	0	0	16	37.2	43
Total	82	11.6	367	52.1	59	8.4	26	3.7	171	24.2	705

*Eagles trapped at Aberdeen Proving Gound (APG).

**Eagles from hacking programs in Pennsylvania, New York and New Jersey.

Table 5: Area (km^2) and shoreline miles (km) of the major geographical units on the Northern Chesapeake Study Area, and radio-tagged eagle locations in each area.*

	Area		Shoreline Miles		Eagles	
Unit	km^2	%	km	%	N	%
Edgewood	600	24.3	536.5	37.4	82	11.6
Aberdeen	261	10.6	91.8	6.4	367	52.1
Susquehanna River	161	6.5	36.6	2.6	59	8.4
Elk Neck	420	17.0	169.1	11.8	26	3.7
Remington Farms	1028	41.6	600.9	41.8	171	24.2
Total	2470	100.0	1434.9	100.0	705	100.0

*Chi-square analysis was used to compare the eagle distribution per unit with the land area per unit and shoreline mileage per unit. χ^2area = 1317.89, df = 4, $p < 0.001$, χ^2 shoreline = 2602.90, df = 4, $p < 0.001$.

Table 6: Mean number of bald eagles seen per aerial shoreline survey by season on the Northern Chesapeake Study Area from 8 Apr 1984 - 23 Jun 1985.

Season	Number of Surveys	Area					
		Edgewood	Aberdeen	Susquehanna	Elk Neck	Remington Farms	Total
Mar-May	3	1.3	15.0	1.0	0.7	4.3	22.3
Jun-Aug	6	5.2	12.3	0.3	3.0	7.0	27.8
Sep-Nov	2	2.0	15.0	5.0	1.5	4.5	28.0
Dec-Feb	3	4.7	21.0	3.3	3.3	5.3	37.7
Total	14	3.8	15.1	1.8	2.4	5.7	28.8

Table 7: Locations of radio-tagged bald eagles on the Northern Chesapeake Study Area from 1 Sep 1984 - 31 May 1985 by season.

	Area														
	Edgewood			Aberdeen*			Susquehanna			Elk Neck			Remington Farms		
Eagle	F	W	S	F	W	S	F	W	S	F	W	S	F	W	S
E232	2	15	2	4	48	9	0	0	0	0	0	0	0	0	0
E451	8	0	0	20	23	6	1	0	0	0	11	0	14	10	4
E522	16	12	1	50	44	5	0	0	0	0	0	1	2	1	0
E544	2	1	0	4	25	8	0	0	0	1	7	0	0	7	0
E613	11	1	2	25	13	7	1	0	0	3	1	0	8	1	2
A451	*	2	*	*	6	*	*	0	*	*	1	*	*	24	*
A477	*	1	*	*	5	*	*	0	*	*	0	*	*	29	*
A734	0	0	*	0	0	*	37	20	*	0	0	*	0	0	*
A842	*	0	2	*	21	10	*	0	0	*	1	0	*	32	2
B292	*	4	0	*	20	3	*	0	0	*	0	0	*	16	0
Total	39	36	7	103	205	48	39	20	0	4	21	1	24	120	8

* Eagle was not located on the study area during this period.

F = Sep - Nov 1984, W = Dec 1984 - Feb 1985, S = Mar - May 1985.

Table 8: Locations of all radio-tagged bald eagles on the Northern Chesapeake Study Area from 1 Sep 1984 - 1 Jul 1985 by weekday (Mon. - Fri.) versus weekend (Sat. - Sun.)*.

	Area										
	Edgewood		Aberdeen		Susquehanna		Elk Neck		Remington Farms		Total
	N	%	N	%	N	%	N	%	N	%	N
Weekday	55	12.0	232	50.8	41	9.0	19	4.2	110	24.1	457
Weekend	27	12.2	127	57.2	18	8.1	7	3.2	43	19.4	222
Total	82		359		59		26		153		679

*Chi-square analysis was used to compare eagle distribution by area on weekdays versus weekends. $\chi^2 = 3.162$, df = 4, $p > 0.50$.

Table 9: Locations of all radio-tagged bald eagles on the Northern Chesapeake Study Area from 1 Sep 1984 - 1 Jul 1985 by time of day.*

Time* of Day	Edgewood		Aberdeen		Susquehanna		Elk Neck		Remington Farms		Total
	N	%	N	%	N	%	N	%	N	%	N
AM	39	14.4	131	48.5	19	7.0	13	4.8	68	25.2	270
Noon	30	17.0	86	48.9	21	11.9	6	3.4	33	18.8	176
PM	13	5.6	142	60.9	19	8.2	7	3.0	52	22.3	233
Total	82		359		59		26		153		679

*Time of day categories are: AM = less than 4 hours after sunrise, noon = 4-8 hours after sunrise and PM = greater than 8 hours after sunrise.

**$\chi^2 = 23.48$, df = 8, $p < 0.001$.

Table 10: Mean daily activity areas and seasonal and total convex polygon home ranges for radio-tagged bald eagles tracked on Aberdeen Proving Ground from 28 Feb 1984 - 1 Sep 1984.

	Mean Daily Activity Area		Seasonal Home Ranges				Total Home Range		
			Mar-May	June-Aug					
Eagle	No. Days	Mean N/Day	Area (km²)	N	Area (km²)	N	Area(km²)	N	Area(km²)
E423	10	10.5	9.68	70	66.33	47	16.65	117	72.06
E522	3	16.7	14.84	72	42.65	5	*	77	40.75
E544	1	9.0	1.12	--	--	33	47.41	33	47.41
E552	2	10.5	16.57	38	61.60	--	--	41	62.00
E613	0	0	0	--	--	40	75.92	40	75.92
E641	11	13.6	4.19	--	--	210	71.55	213	71.55
E700	5	13.2	1.53	--	--	82	20.75	82	20.75
E842**	2	13.5	1.31	--	--	147	705.29	147	705.29
Total	34	12.0	6.82						

-- Eagle was not located on the study area during this period.

* Home range was not calculated because of limited sample size.

** Seasonal and total home ranges include some aerial locations off Aberdeen Proving Ground.

Table 11: Mean and maximum distances (km) radio-tagged bald eagles were located from roost per day on the Northern Chesapeake Study Area from all-day tracking data collected 16 Mar 1984 - 12 Aug 1984.

Eagle	No. days tracked	Mean no. locations	Mean distance from roost	Maximum distance from roost
E423	6	8.5	2.51	5.54
E522	3	17.0	1.82	5.60
E552	1	9.0	2.21	4.40
E641	7	14.0	2.58	5.11
E700	5	12.2	1.23	2.64
E842	1	7.0	2.64	4.23
Total	23	12.0	2.12	4.59

Table 12: Seasonal convex polygon home ranges for radio-tagged bald eagles tracked on the Northern Chesapeake Study Area and total convex polygon home ranges for bald eagles tracked on the entire Chesapeake Bay from 1 Sep 1984 - 1 Jul 1985.

	Seasonal Home Ranges						Total Home Range	
	Sep-Nov		Dec-Feb		Mar-May			
Eagle	N	Area (km^2)	N	Area (km^2)	N	Area (km^2)	N	Area (km^2)
E232	6	17.99	61	266.58	11	96.25	80	266.58
E451	43	621.78	44	873.01	10	513.57	99	4112.36
E522	68	430.12	57	320.93	7	41.45	132	725.93
E544	7	88.07	41	864.58	8	25.21	57	3054.68
E613	48	630.89	16	143.89	11	542.78	89	17809.75
A451	--	--	33	715.96	--	--	34	2475.71
A477	--	--	35	449.84	--	--	36	1851.45
A734	37	58.18	20	26.62	--	--	57	62.89
A842	--	--	54	341.70	14	87.24	69	928.66
B292	--	--	40	421.12	*	*	43	421.12

-- Eagle was not found on the study area during this period.

* Home range was not calculated because of limited sample sizes.

Table 13: Mean number of bald eagles per morning roost count versus evening roost count by roost on the Northern Chesapeake Study Area from 13 Nov 1983 - 1 Jul 1985. N = number of roost counts, $\bar{x}$ = mean number of eagles per count.*

	Roost									
	AA5		Heron Rookery		Michaelsville		Abbey Road		Total	
	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$
Morning	14	4.5	4	2.5	1	0.0	4	3.5	23	3.8
Evening	14	5.5	4	2.3	1	1.0	4	2.3	23	4.2

* AM and PM counts for each roost were conducted on the same day.

Table 14: Mean number of bald eagles per roost count per roost by season on the Northern Chesapeake Study Area 13 Nov 1983 - 1 Jul 1985. N = number of roost counts; $\bar{x}$ = mean number of eagles per count.

	Roost											
	Octoraro		AA5		Heron Rookery		Michaelsville		Abbey Road		Total	
Season	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$
Fall	2	6.0	*	*	*	*	*	*	*	*	2	6.0
Winter	9	1.8	7	15.4	2	6.5	1	0.0	1	0.0	20	6.9
Spring	*	*	19	3.8	6	2.3	*	*	8	0.9	32	2.9
Summer	*	*	26	7.9	4	2.8	*	*	16	4.9	46	6.4
Total	11	2.6	52	7.4	12	3.2	1	0.0	25	3.4	100	5.4

* No roost counts conducted for this roost during this season.

Table 15: Activity of bald eagles seen on aerial shoreline surveys from 9 Jan 1984 - 23 Jun 1985 and activity of radio-tagged eagles located from Sep 1 1984 - 1 Jul 1985 on the Northern Chesapeake Study Area.

	Activity												
	Perched		Flying		Soaring		Foraging		Roost		Nest		Total
	N	%	N	%	N	%	N	%	N	%	N	%	N
Shoreline Surveys	354	70.8	109	21.8	5	1.0	1	0.2	0	0.0	31	6.2	500
Radio Locations	241	74.6	54	16.7	7	2.2	4	1.2	15	4.6	2	0.6	323

*Chi-square analysis was used to compare eagle activity on shoreline surveys with activity of radio-tagged eagles.

$\chi^2 = 46.73$, df = 5, $p < 0.001$.

Table 16: General habitat classes of eagles seen on shoreline surveys from 9 Jan 1984 - 23 Jun 1985 and eagles visually located via radio telemetry from 1 Sep 1984 - 1 Jul 1985 on the Northern Chesapeake Study Area.*

	Habitat Class														
	Bay		River		Creek		Wetland		Forest		Field		Pond		Total
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N
Shoreline Surveys	216	43.5	143	28.8	98	19.7	11	2.2	22	4.4	7	1.4	0	0.0	497
Radio Locations	55	14.9	92	25.0	72	19.6	75	20.4	13	3.5	14	3.8	47	12.8	368

* Chi square analysis was used to compare habitat use by eagles during shoreline surveys versus radio-located eagles. $\chi^2 = 195.07$, df = 6, $p < 0.001$.

Table 17: Perch type used by eagles seen on shoreline surveys from 9 Jan 1984 - 23 Jun 1985 versus eagles visually located via radio telemetry from 1 Sep 1984 - 1 Jul 1985 in the Northern Chesapeake Study Area.*

	Perch Type												
	Conifer		Live Deciduous		Dead Decidous		Ground		Manmade		Ice		Total
	N	%	N	%	N	%	N	%	N	%	N	%	
Shoreline Surveys	7	2.7	199	77.4	32	12.5	15	5.8	0	0.0	4	1.6	257
Radio Locations	1	0.4	148	60.7	65	26.6	12	4.9	4	1.6	14	5.7	244

* Chi-square analysis was used to compare perch use by eagles from shoreline surveys versus radio-located eagles. $\chi^2 = 32.796$, df = 5, $p < 0.001$.

Table 18: Human development (houses per km shoreline) by area on the Northern Chesapeake Study Area*.

Area					
Edgewood	Aberdeen	Susquehanna	Elk Neck	Remington Farms	Total
4.55	4.45	3.31	6.08	2.76	4.14

*Houses within 200 m of the shoreline were counted off the most recent U.S.G.S. topographic maps that we updated by aerial survey in June 1985.

Table 19: Mean distances in meters from bald eagles seen on aerial shoreline surveys and from random points to the nearest human development on the Northern Chesapeake Study Area from 9 Jan 1984 - 23 Jun 1985.*

	Area											
	Edgewood		Aberdeen**		Susquehanna		Elk Neck**		Remington Farms		Total	
	N	Distance	N	Distance	N	Distance	N	Distance	N	Distance	N	Distance
Bald eagles	76	1028	303	1678	26	652	38	667	87	610	530	1287
Random points	73	1213	71	1142	31	627	100	393	74	508	349	762

* Differences between distances from eagles versus random points were compared by area using 2-way analysis of variance with correction made for unequal cell sample sizes. F area = 26.00, p = 0.0001, F eagle/random = 3.25, p = 0.07, F interaction = 3.29, p = 0.01. Distances were also log transformed to correct for unequal variances and a 2-way analysis of variance was rerun. F area = 18.84, p = 0.0001, F eagle/random = 11.42, p = 0.0008, F int. = 3.62, p = 0.006. Friedman's test was also conducted on 25 randomly selected eagle locations and 25 randomly selected points per area. F eagle/random = 3.63, p = 0.06.

** Distances to eagles significantly different from distances to random points, based on pair-wise comparison using Friedman's test, $p < 0.05$.

Table 20: Miles of intensely, moderately and lightly developed shoreline by area along the survey route on the Northern Chesapeake Study Area.*

Development	Area											
	Edgewood		Aberdeen		Susquehanna		Elk Neck		Remington		Total	
Class	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)
Intense	36.0	37.6	37.8	41.2	12.8	35.0	106.1	62.7	44.1	33.2	236.8	45.0
Moderate	10.1	10.5	9.4	10.2	7.4	20.2	20.0	11.8	21.2	16.0	68.1	12.9
Light	49.7	51.9	44.6	48.6	16.4	44.8	43.0	25.5	67.6	50.8	221.3	42.1
Total	95.8	100	91.8	100	36.6	100	169.1	100	132.9	100	526.2	

*Intensely developed = houses < 250 m apart.
Moderately developed = 250 m < houses < 500 m apart.
Lightly developed = houses > 500 m apart.

Table 21: Foraging success of bald eagles by age class on the Northern Chesapeake Study Area.

	Age Class						Total	
	Adult		Subadult		Immature			
Forage attempt	N	%	N	%	N	%	N	%
Successful	7	63.6	4	80.0	37	71.1	48	70.6
Unsuccessful	4	36.4	1	20.0	15	28.9	20	29.4
Total	11	100	5	100	52	100	68	100.0

Table 22: Age distribution of bald eagles seen on aerial shoreline surveys by season of the year on the Northern Chesapeake from 8 1984 - 23 Jun 1985.*

Season	# of Surveys	Age Class						Total
		Adult		Sub-Adult		Immature		
		N/Survey	%	N/Survey	%	N/Survey	%	N/Survey
Mar-May	3	9.3	42.4	1.0	4.6	11.7	53.0	22.0
Jun-Aug	6	10.0	35.9	2.3	8.4	15.5	55.7	27.8
Sep-Nov	2	7.0	25.0	2.5	8.9	18.5	66.1	28.0
Dec-Feb	3	19.3	51.8	1.7	4.5	15.3	43.7	37.3
Total	14	11.4	39.8	1.9	6.7	15.3	53.2	28.7

* Chi-square analysis was conducted on the frequency table to compare age class by season.
$\chi^2 = 14.053$, df = 6, p = 0.029.

Table 23: Age distribution of bald eagles seen during roost counts by season of the year on the Northern Chesapeake Study Area from 13 Nov 1983 - 1 Jul 1985.*

Season	# of Counts	Age Class						Total
		Adult		Sub-adult		Immature		
		N/Count	%	N/Count	%	N/Count	%	N/Count
Mar-May	60	0.35	15.4	0.05	2.2	1.87	82.4	2.27
Jun-Aug	51	0.73	15.1	0.49	10.2	3.59	74.7	4.80
Sep-Nov	2	0.0	0.0	0.0	0.0	5.50	100	5.50
Dec-Feb	35	1.06	21.8	0.57	11.8	3.23	66.5	4.86
Total	148	0.64	16.9	0.32	8.5	2.83	74.6	3.80

* Chi-square analysis was conducted on the frequency table to compare age class by season.
$\chi^2 = 18.826$, df = 6, p = 0.0048.

Table 24: Trap statistics by trap type for trapping bald eagles on the Northern Chesapeake Study Area from 14 Dec 1983 - 27 Mar 1985.*

Trap statistic	Trap type: Leghold-fish	Single noose-fish	Double noose-fish	Other***	TOTAL
Total hrs.	290.6	276.1	123.0	67.6	914.6
Set hrs.	330.0	428.8	145.9	64.3	969.0
Mean start time**	-0.27	0.10	0.30	-0.07	0.04
Mean end time**	3.06	1.59	2.00	2.88	2.33
Mean trap time	3.33	1.49	1.30	2.95	2.29
No. strikes	14	63	34	1	112
No. captures	5	4	4	0	13
Strikes/capture	2.8	15.8	8.5	-	8.6
Total hrs./capture	58.1	69.0	30.8	-	70.4
Set hrs./capture	66.0	107.2	36.5	-	74.5

* Trap statistics compiled here represent trapping only in the morning. Afternoon and evening trapping accounted for only 3% of the total set hours and yielded no captures.

** Time is measured in hours after sunrise.

*** Other trap types used include leghold traps around various bird and mammal carcasses and noose-ducks.

Table 25: Mean bearing error (degrees) by observer for the aerial telemetry stations used on the Northern Chesapeake Study Area.*

Station	N	Observer						Total	
		#1		#2		#3			
		Error	N	Error	N	Error		N	Error
E001	7	13.3	7	17.7	6	10.5		20	14.0
E002	7	12.5	9	11.6	5	9.5		21	11.4
E003	9	14.6	7	8.9	9	11.1		25	11.8
E004	10	10.1	9	7.3	8	11.5		27	9.6
E006	-	-	8	8.6	9	10.6		17	9.6
Total	33	12.5	40	10.7	37	10.8		110	11.24

* 2-way analysis of variance was conducted on the data. F observer = 0.21; p = 0.81; F station = 0.90; p = 0.47; & F interaction = 0.69; p = 0.68.

Table 26: Mean bearing error (degrees) by observer #4 for some of the ground telemetry stations used on the Northern Chesapeake Study Area.

Station	N	Error
A101	1	16.3
A104	1	46.3
A108	1	35.0
A127	1	20.3
A128	1	0.9
A129	2	15.5
A132	1	19.1
A217	3	20.1
A234	4	24.0
A238	4	8.4
Total	19	18.9

Table 27: Distance (km) from actual location of test transmitter to the location determined by telemetry by observer on the Northern Chesapeake Study Area.

Transmitter	Observer #1	#2	#3	#4	Mean Distance
032	*	16.81	0.64	*	8.73
082	1.31	4.74	1.63	*	2.56
112	1.15	3.58	3.95	*	2.89
272	1.41	3.29	3.12	*	2.61
292	1.99	*	*	*	1.99
331	2.05	0.67	2.70	1.71	1.78
351	4.39	5.59	8.74	0.94	4.92
412	3.34	*	2.71	1.07	2.37
592	2.13	0.58	4.40	2.79	2.48
622	4.12	4.93	1.01	*	3.35
Mean Distance	2.43	5.02	3.21	1.63	3.25

* Observer either could not get a signal or else fix was not possible given the bearings taken.

Table 28: Number and % of locations of hacked versus wild bald eagles on the Northern Chesapeake Study Area from 1 Sep 1984 - 1 Jul 1985*.

	Area										
	Edgewood		Aberdeen		Susquehanna		Elk Neck		Remington Farms		Total
	N	%	N	%	N	%	N	%	N	%	N
Wild	73	16.2	302	66.8	2	0.4	24	5.3	51	11.3	452
Hacked	9	3.6	65	25.7	57	22.5	2	0.8	120	47.4	253
Total	82	11.6	367	52.1	59		26	3.7	171	24.2	705

*Hacked birds includes eagles A451, A477, A635, A734, A801, A842, B292. Wild birds include eagles E232, E451, E496, E522, E544, E573 and E613.

Chi-square analysis was used to compare the distribution of wild versus hacked eagles by area. $\chi^2 = 266.99$, df = 4, $p < 0.001$.

FIGURES

Figure 1. Map of the Chesapeake Bay highlighting the Northern Chesapeake Study Area.

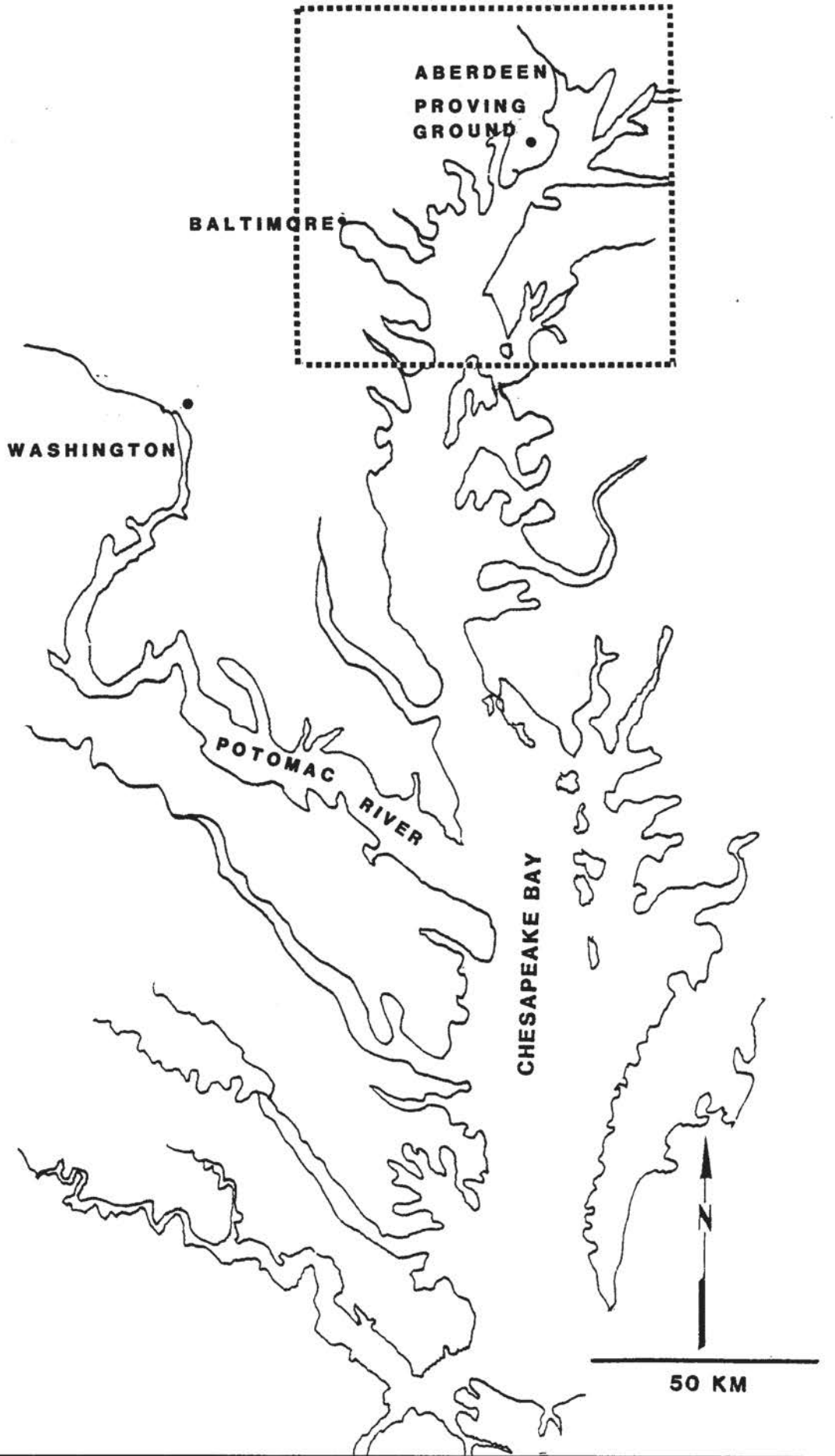


Figure 2. Map of the Northern Chesapeake Study Area.

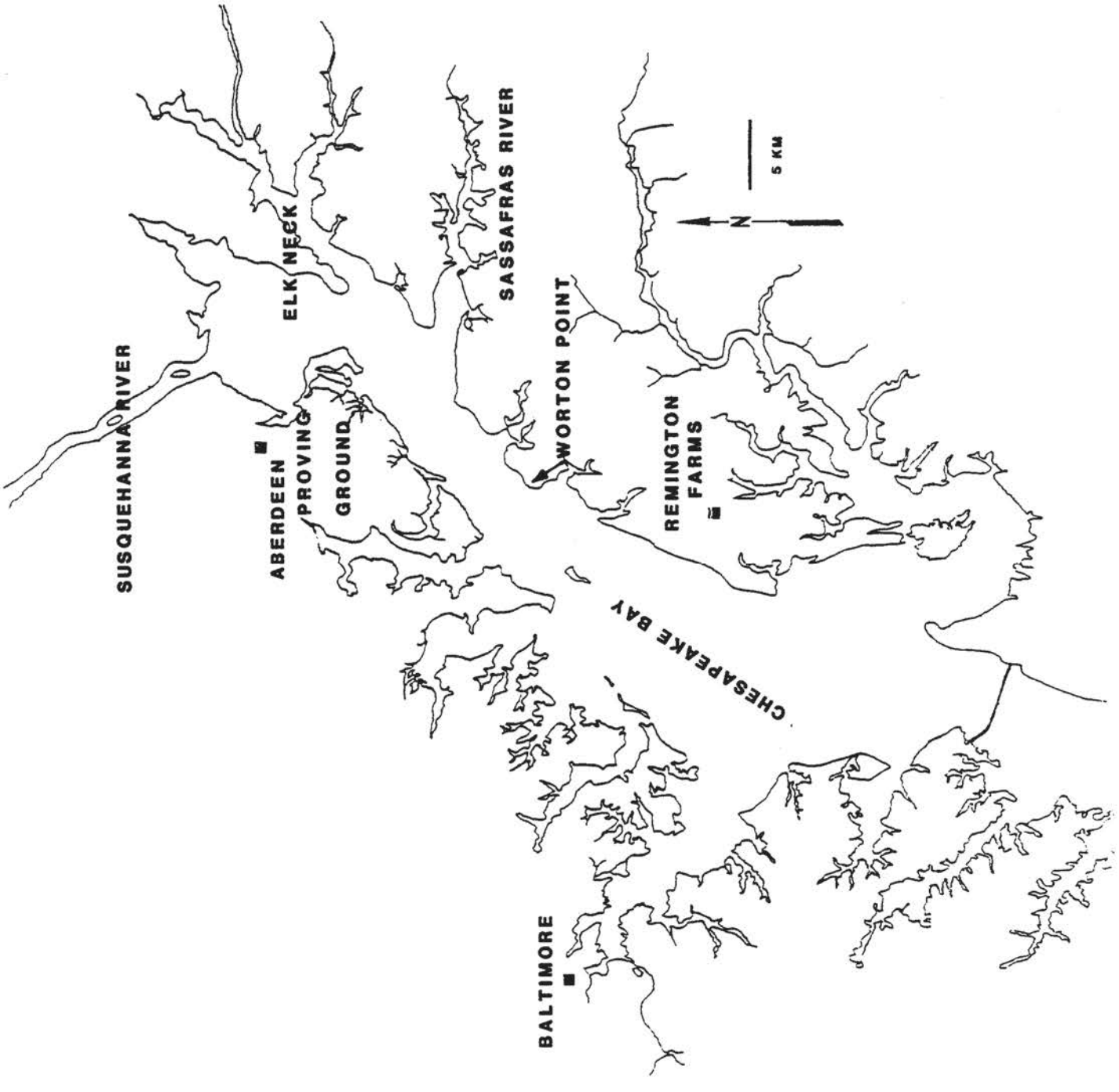


Figure 3. Shoreline development along the shoreline survey route on the Northern Chesapeake Study Area. Development on Aberdeen Proving Ground includes houses and military installations. Development elsewhere consists primarily of houses.

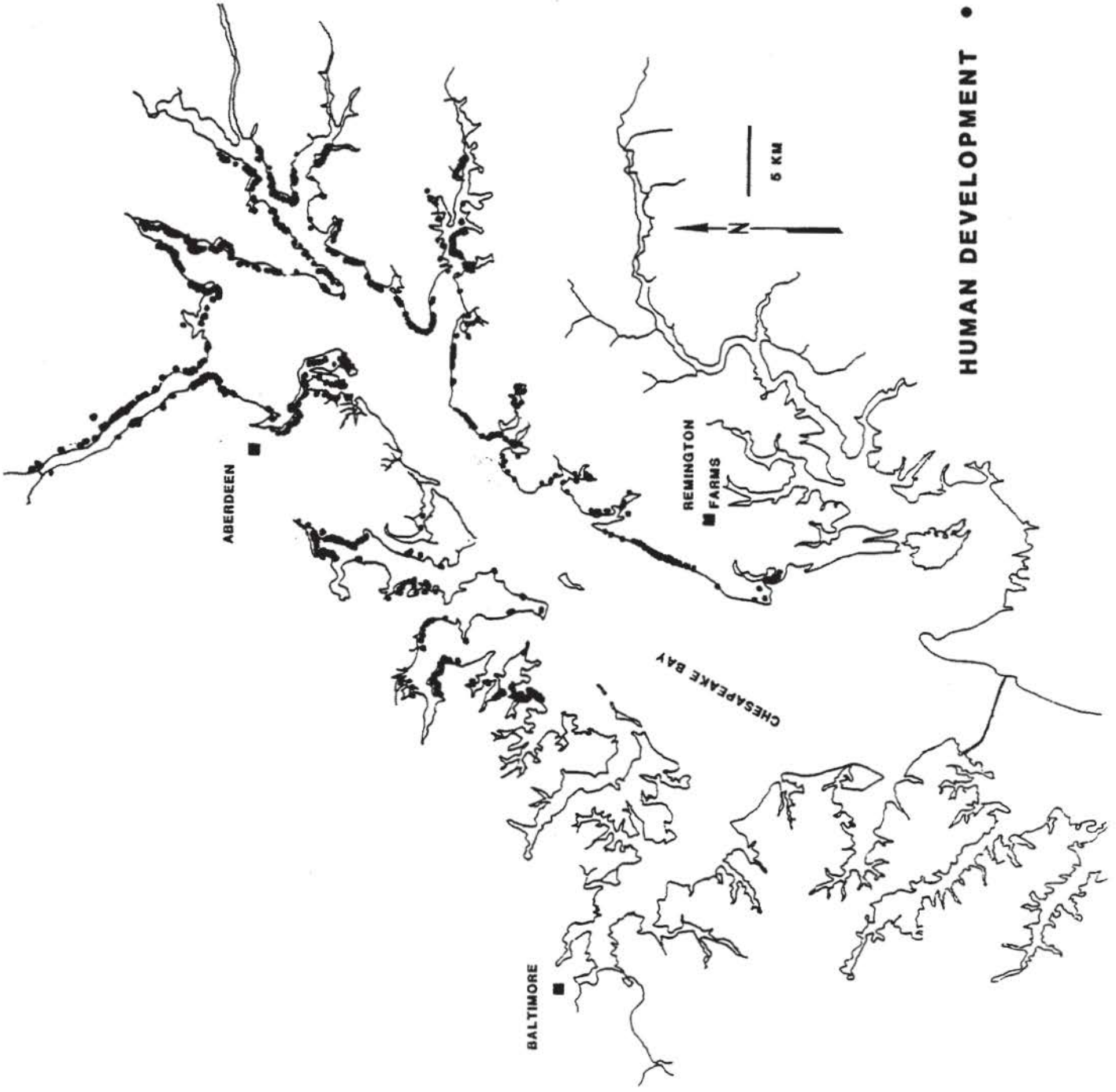


Figure 4. Design of the noose-fish set used to trap bald eagles over open water as demonstrated by Jackman (pers. commun.).

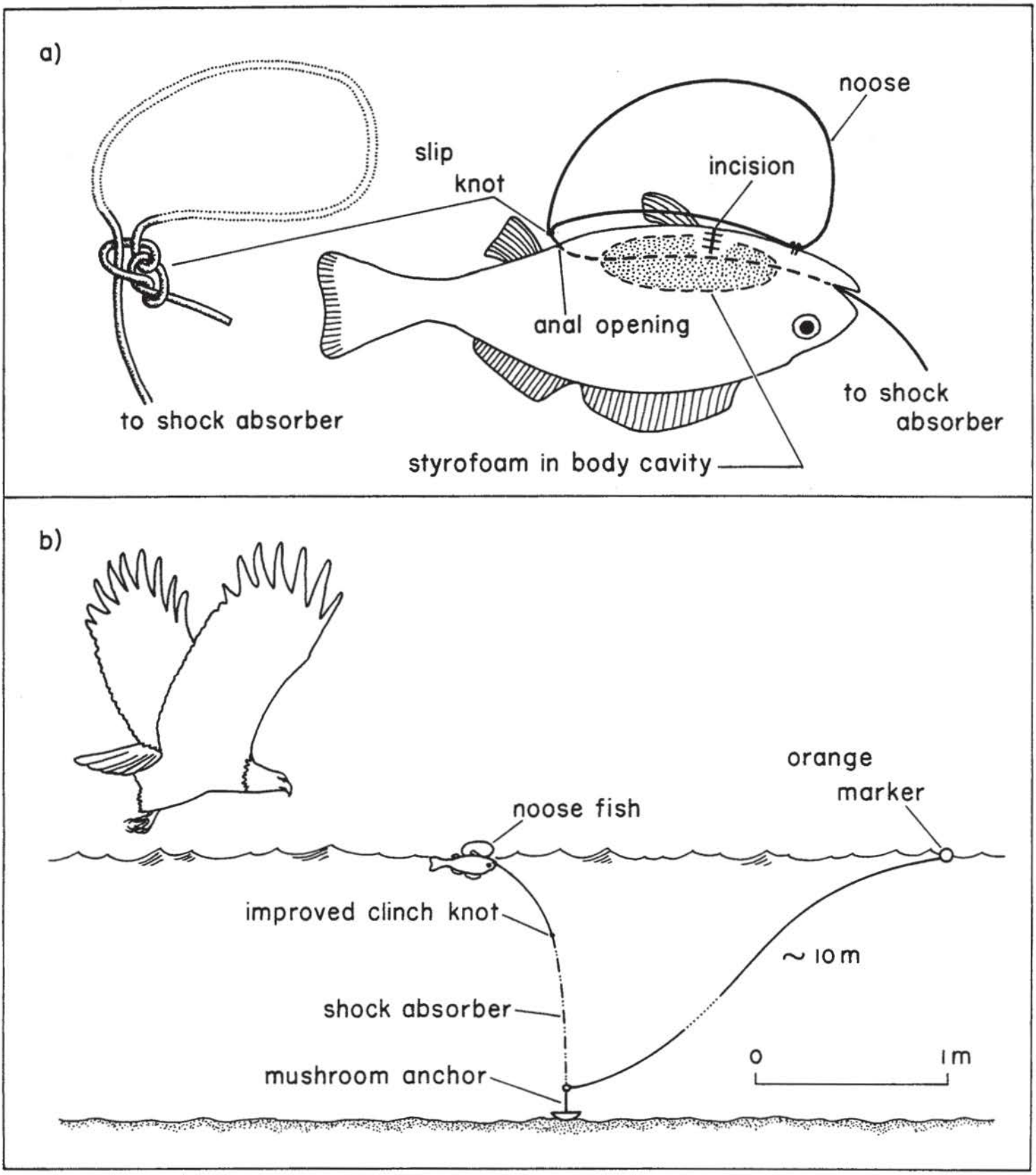


Figure 5. Map of the Northern Chesapeake Study Area showing the shoreline survey route.

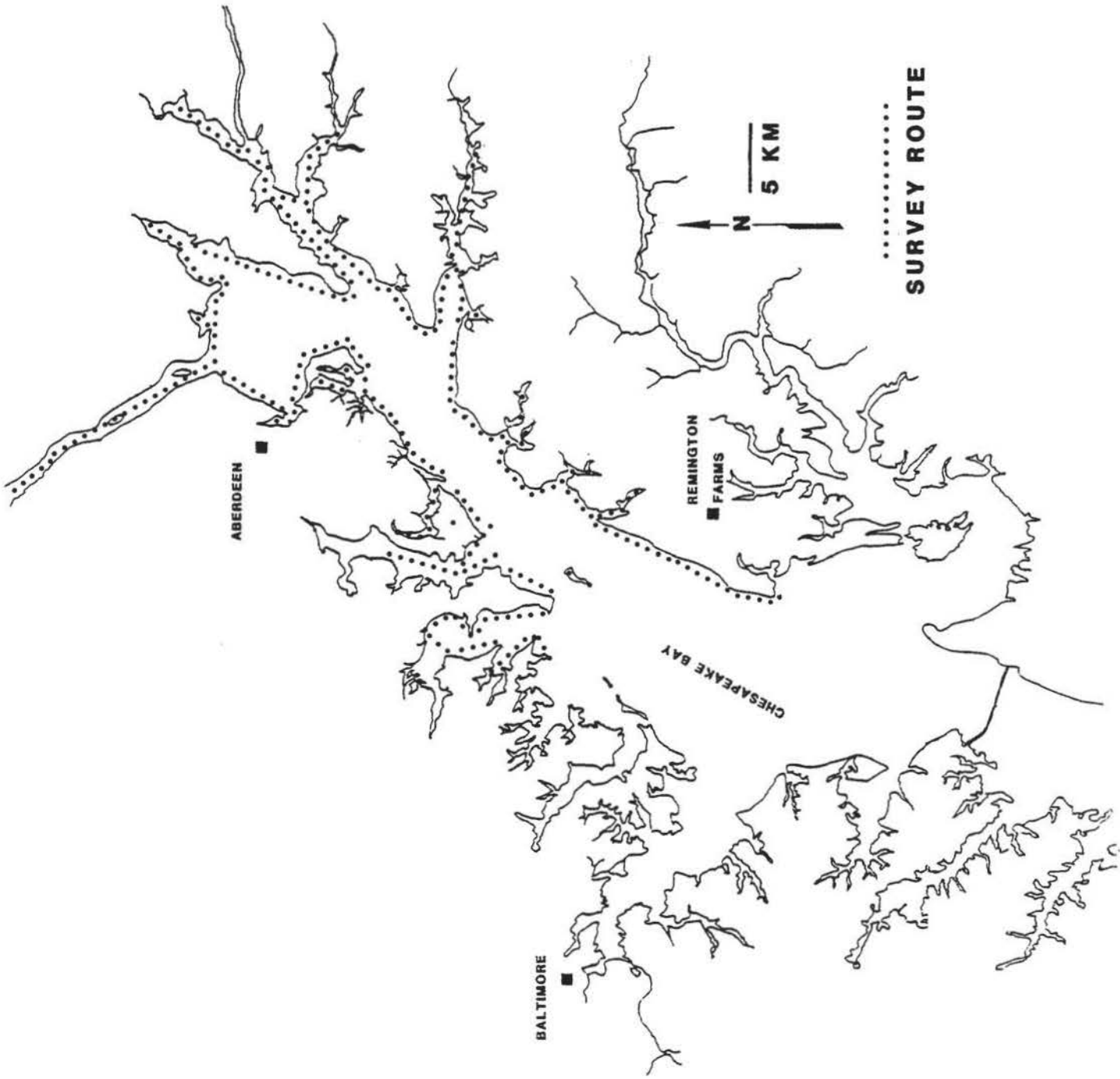


Figure 6. Locations of bald eagle communal roosts on Aberdeen Proving Ground.

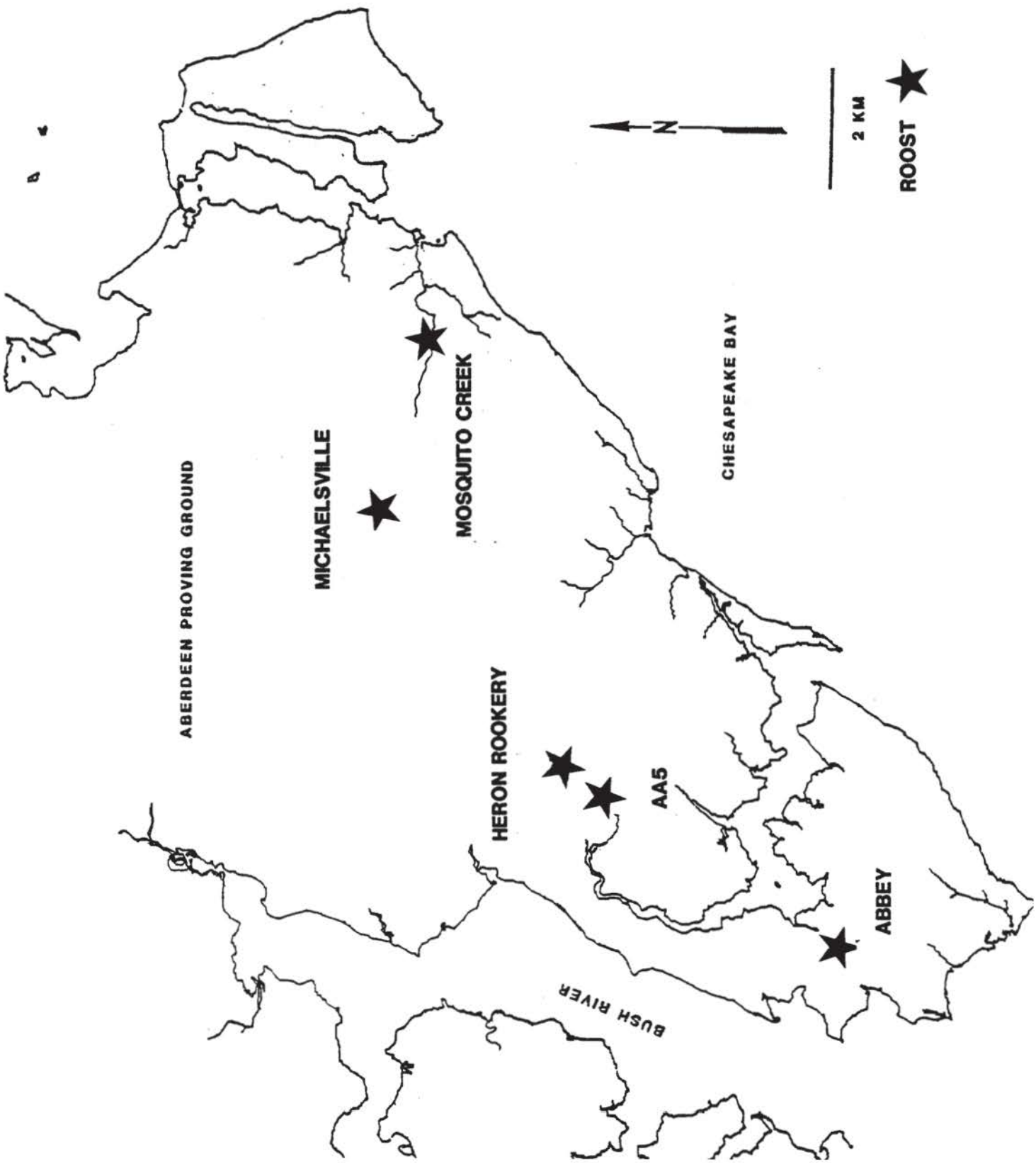


Figure 7. Distribution of bald eagles on the Northern Chesapeake Study Area based on aerial shoreline surveys from 8 Apr 1984 - 23 Jun 1985.

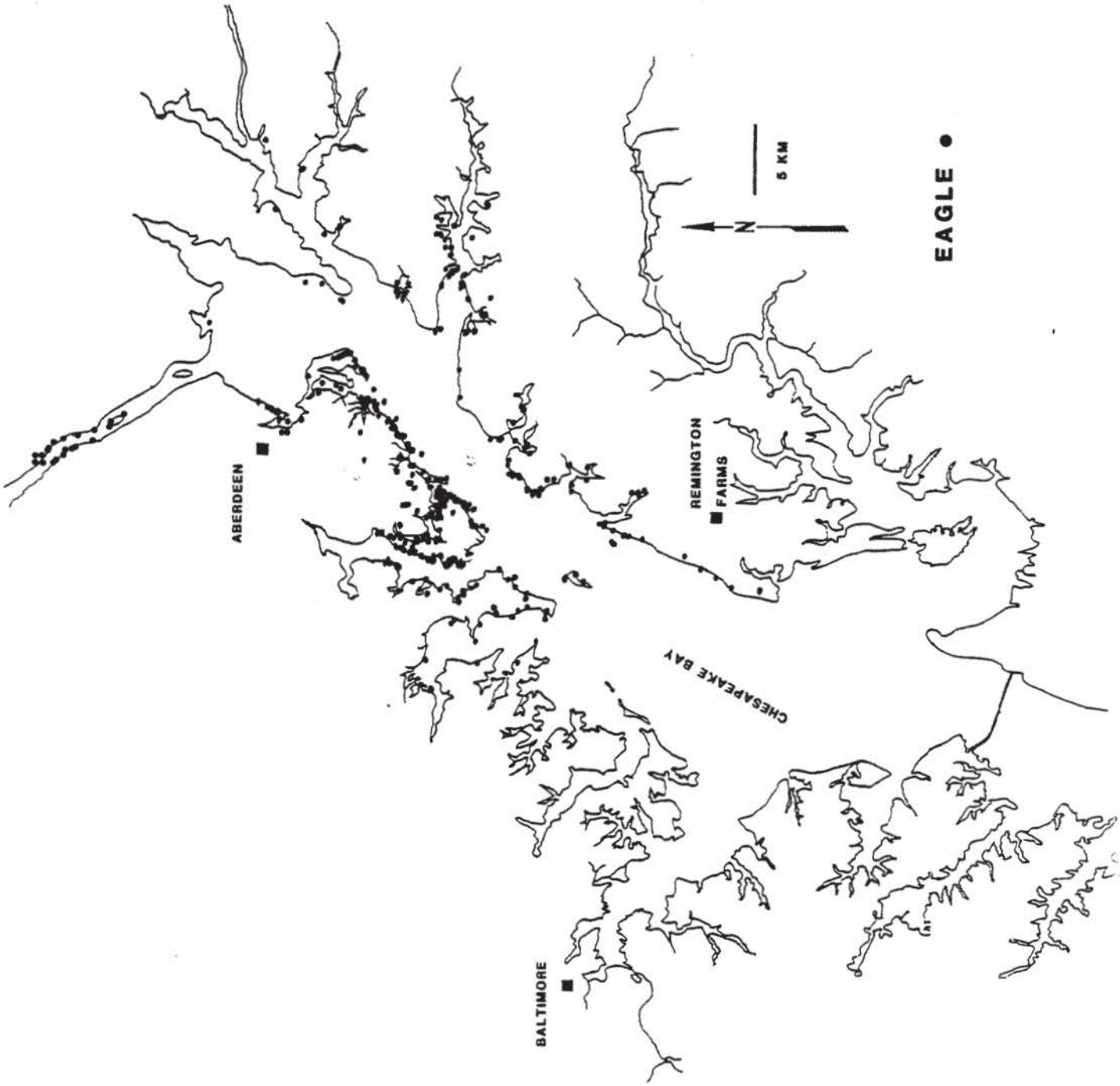


Figure 8. Major sub-study areas on the Northern Chesapeake Study Area used to analyze bald eagle distribution.

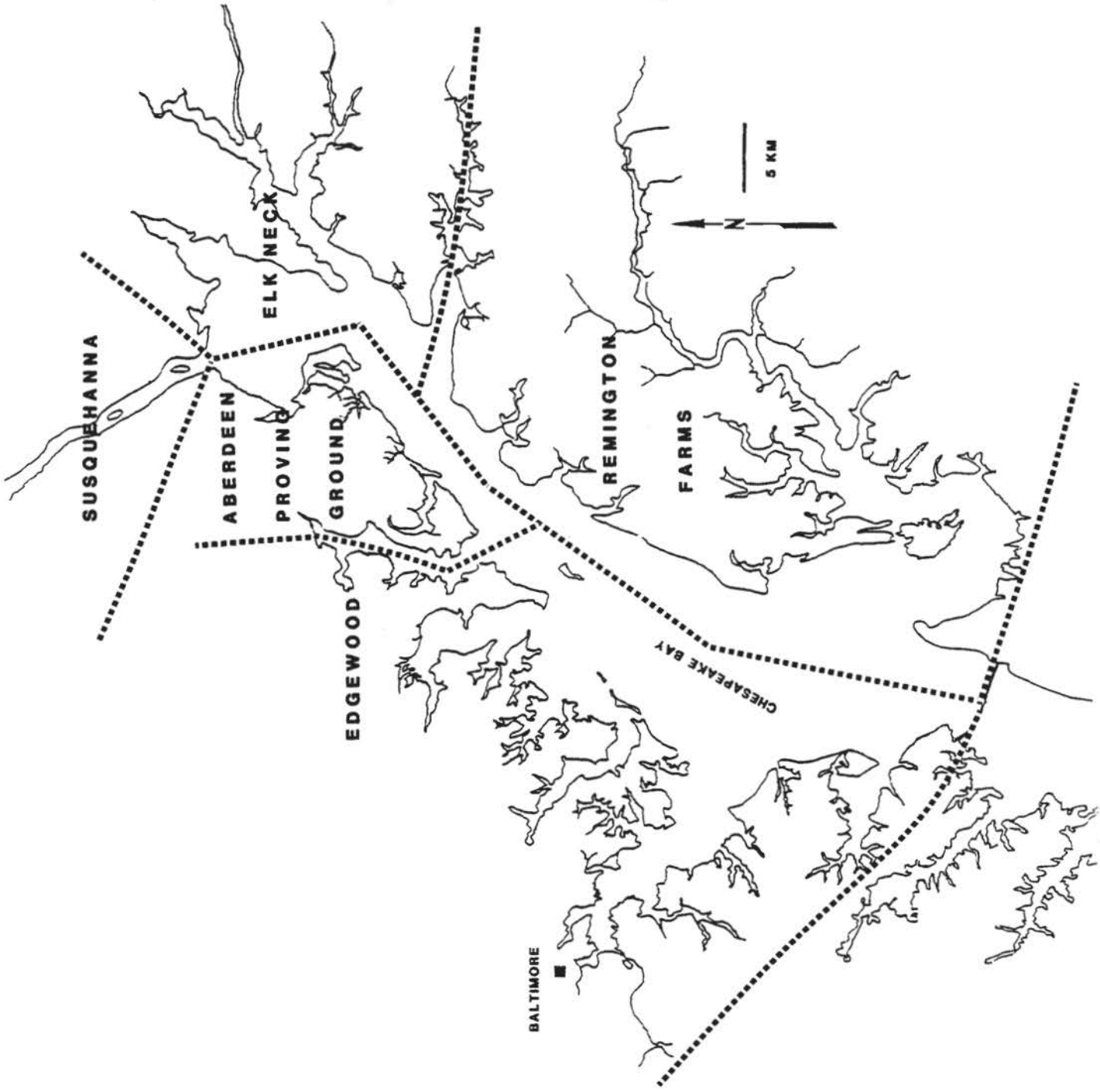


Figure 9. Numbers and general locations of bald eagles seen during aerial shoreline surveys of the Northern Chesapeake Study Area from 8 Apr 1984 - 23 Jun 1985.

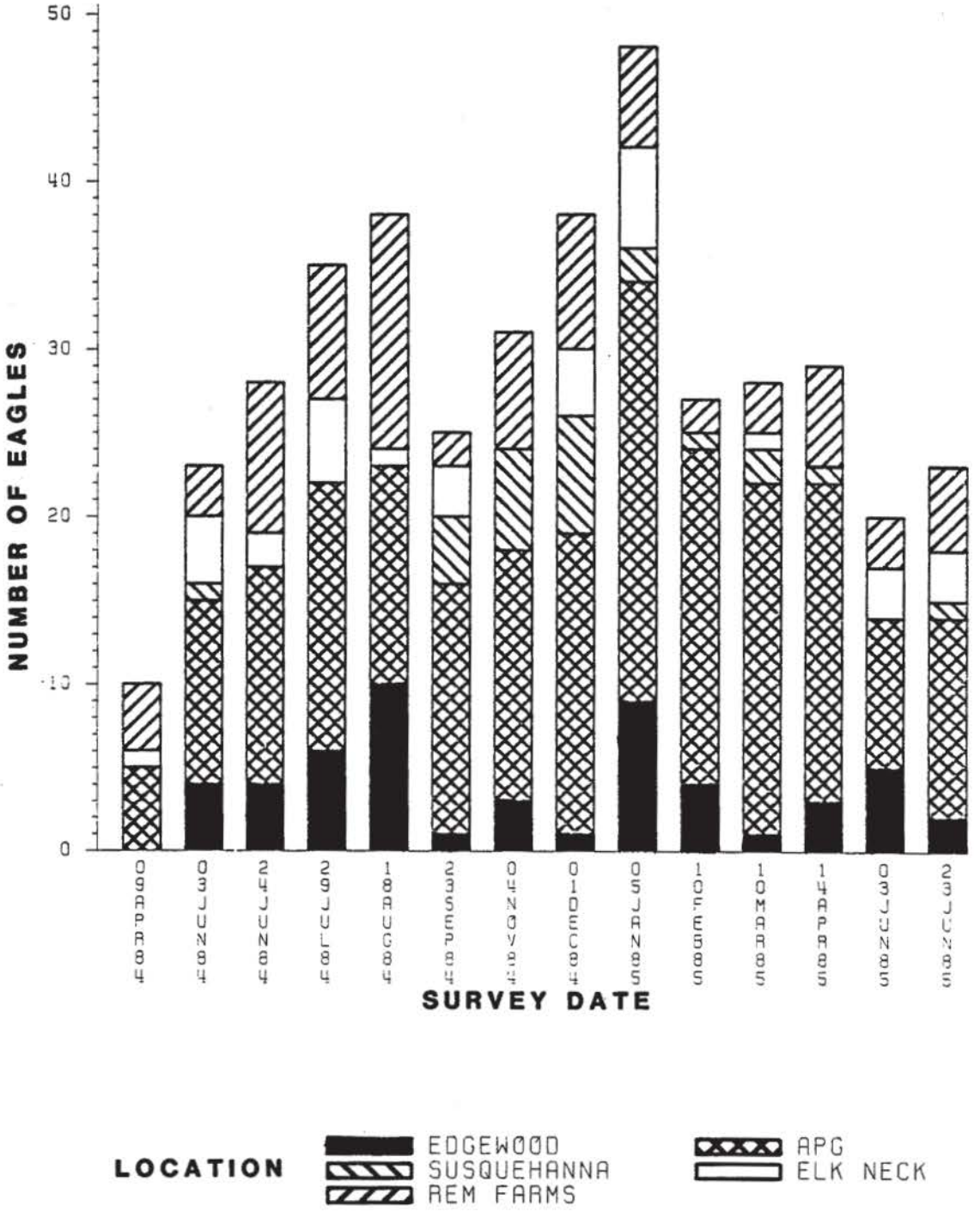


Figure 10. Locations of radio-tagged bald eagles on the NCSA 1 Sep 1984 - 1 Jul 1985.

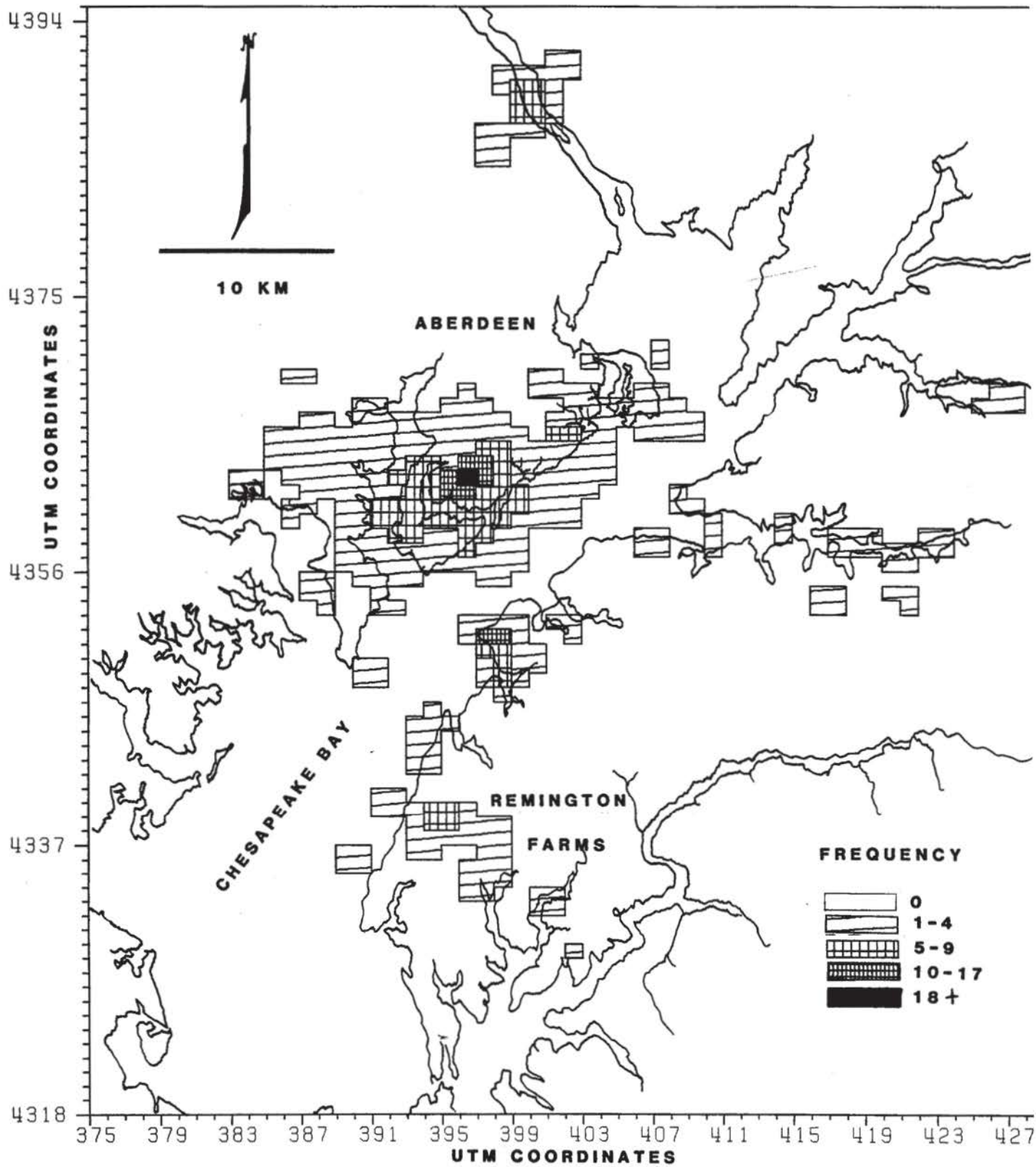


Figure 11. Locations of all radio-tagged bald eagles on the Northern Chesapeake Study Area from 1 Sep 1984 - 1 Jul 1985 highlighting concentration areas.

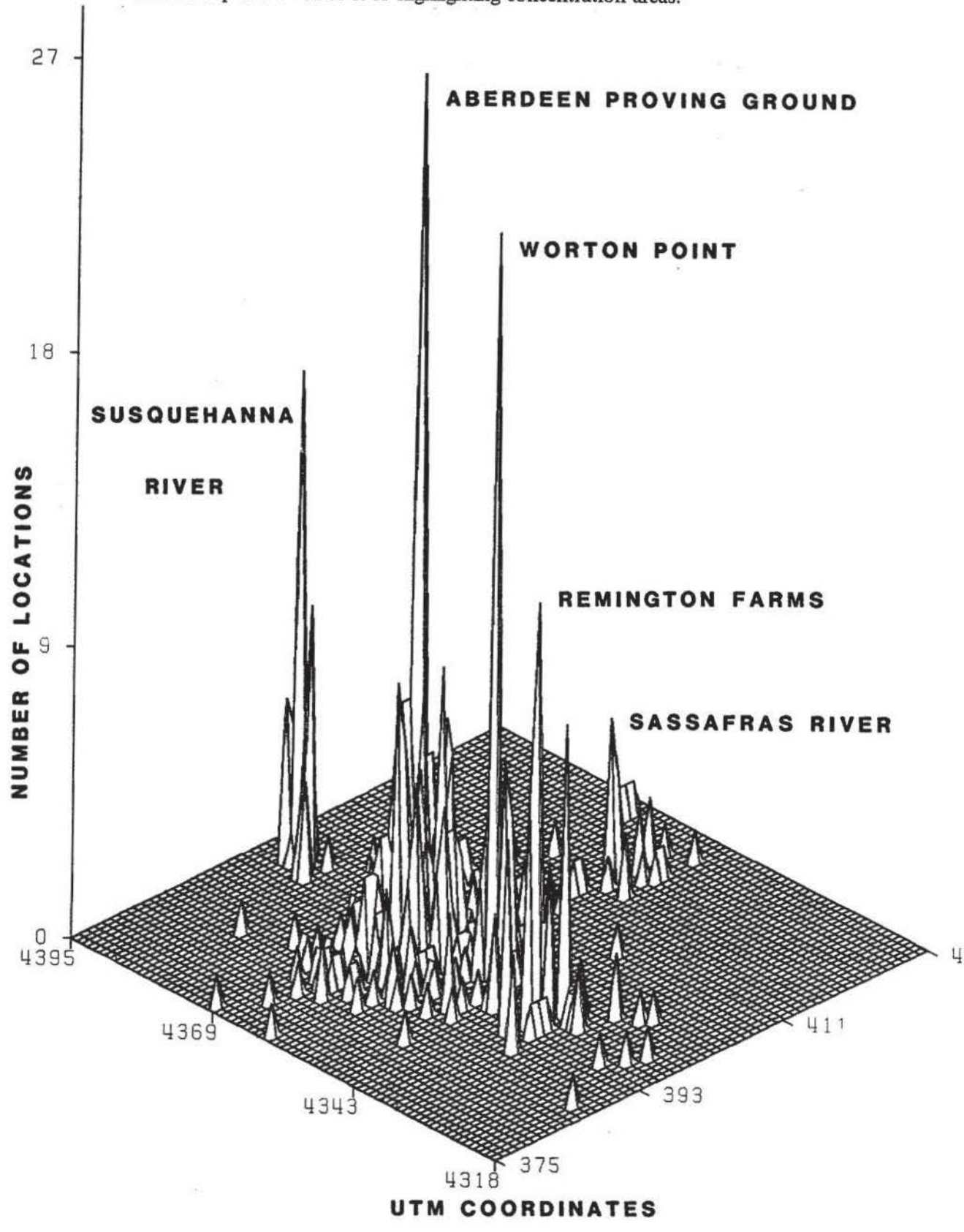


Figure 12. Locations of radio-tagged bald eagles tracked from the ground on Aberdeen Proving Ground from 28 Feb - 1 Sep 1984.

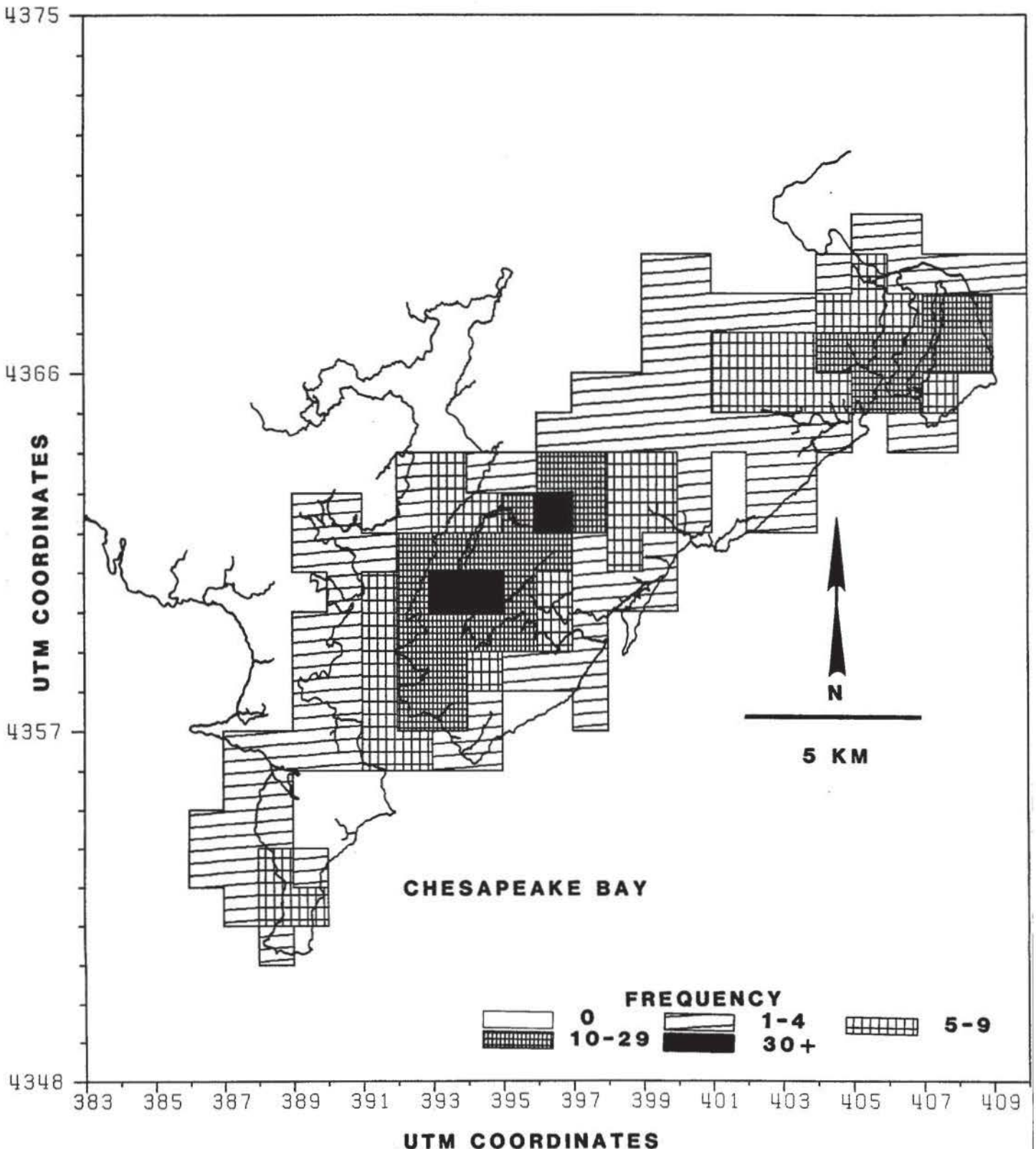


Figure 13. Locations of radio-tagged bald eagles tracked on Aberdeen Proving Ground from 28 Feb - 1 Sep 1984 highlighting concentration areas.

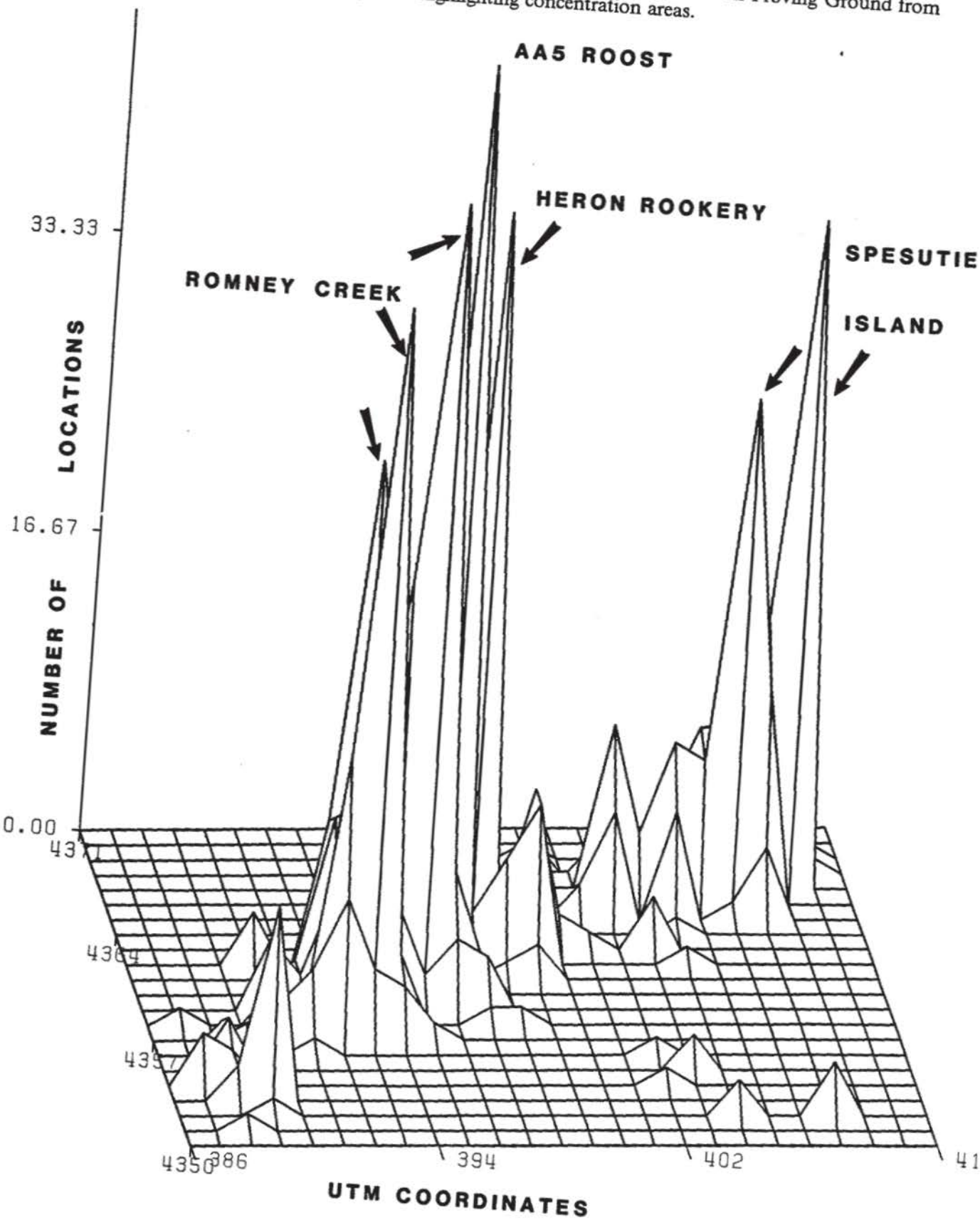


Figure 14. Locations of radio-tagged bald eagles from aerial tracking on Aberdeen Proving Ground from 1 Sep 1984 - 1 Jul 1985.

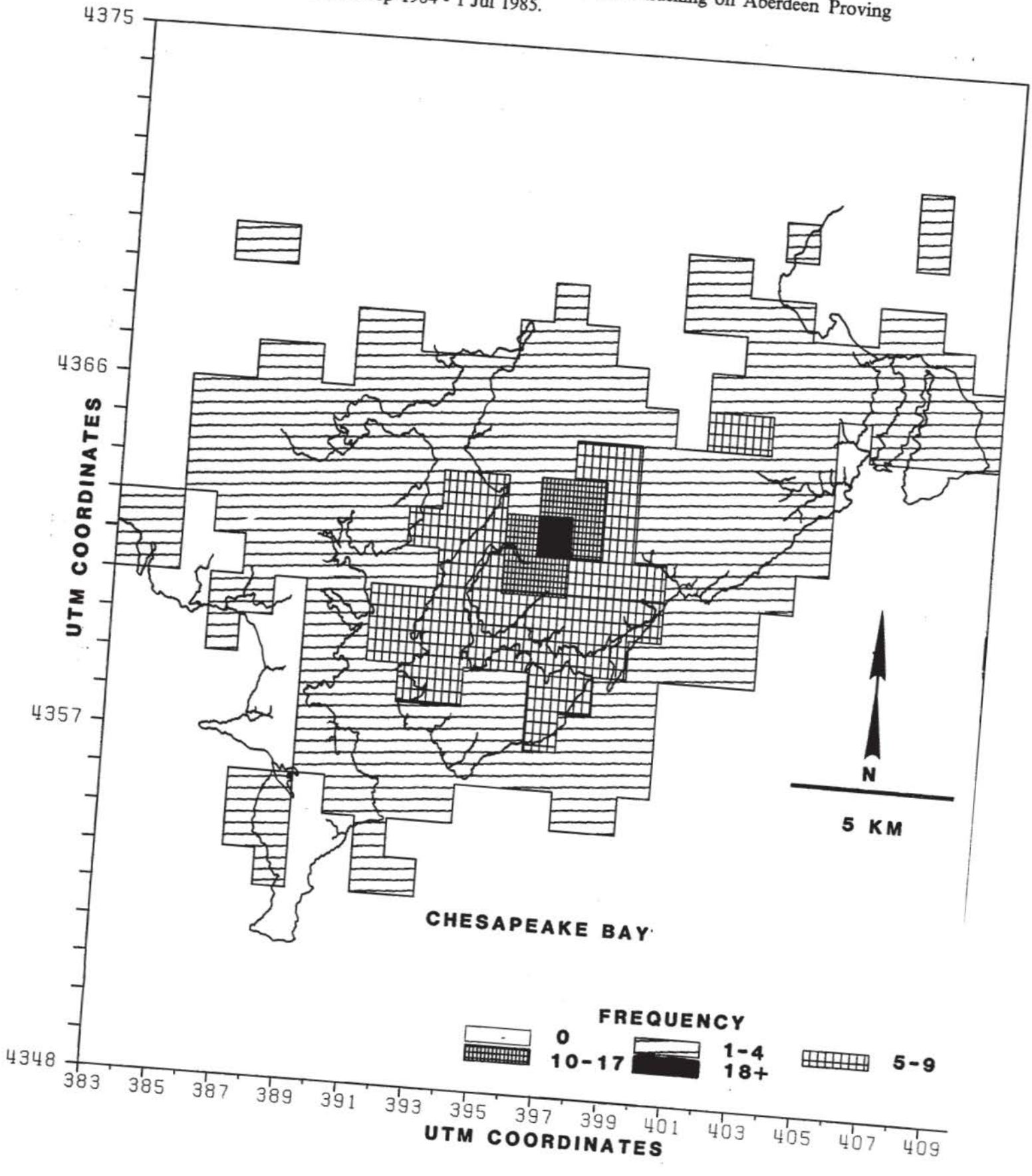


Figure 15. Locations of radio-tagged bald eagles from aerial tracking on Aberdeen Proving Ground from 1 Sep 1984 - 1 Jul 1985 highlighting concentration areas.

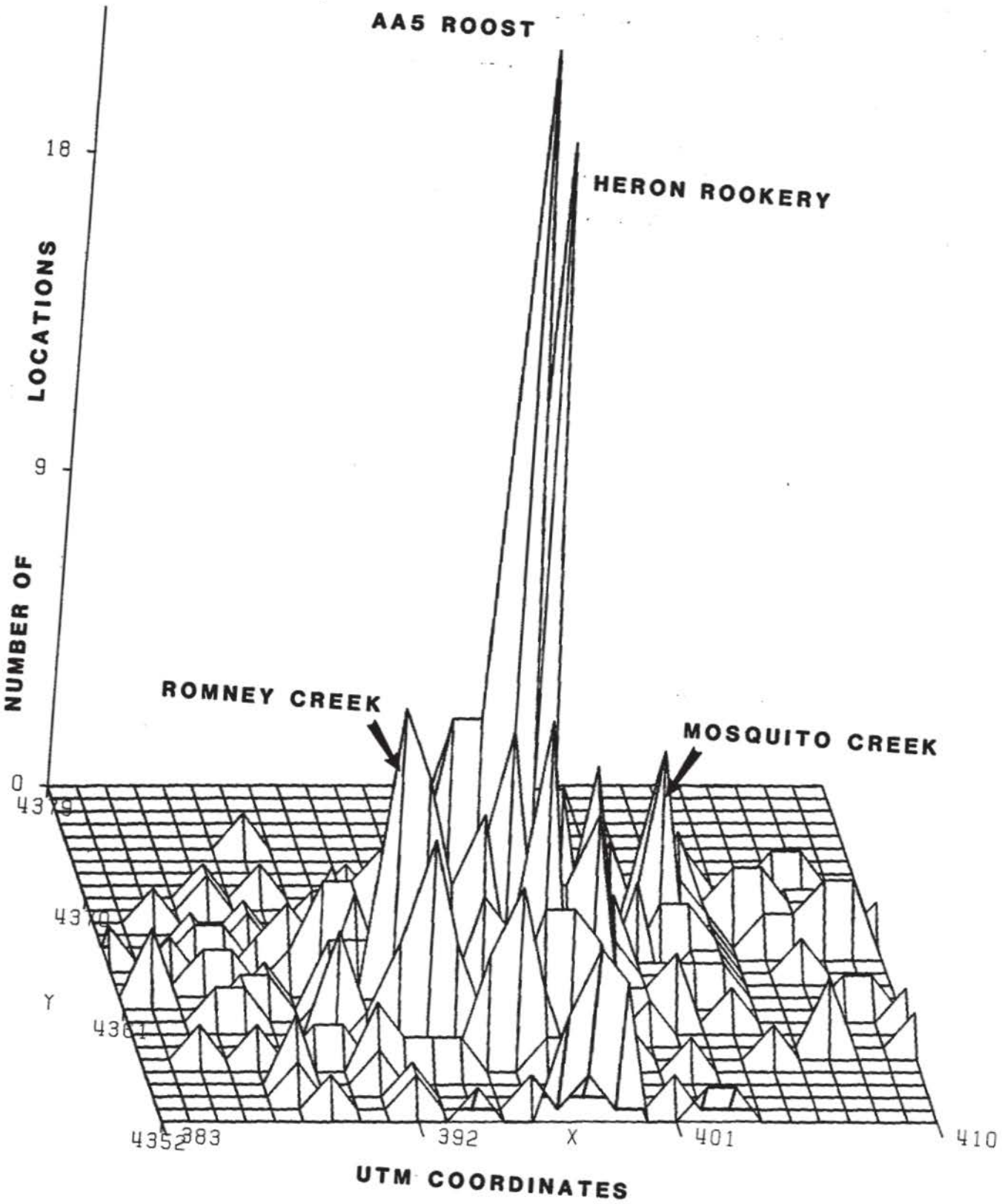


Figure 16. Locations of radio-tagged bald eagles off the Northern Chesapeake Study Area from 1 Sep 1984 - 1 Jul 1985.

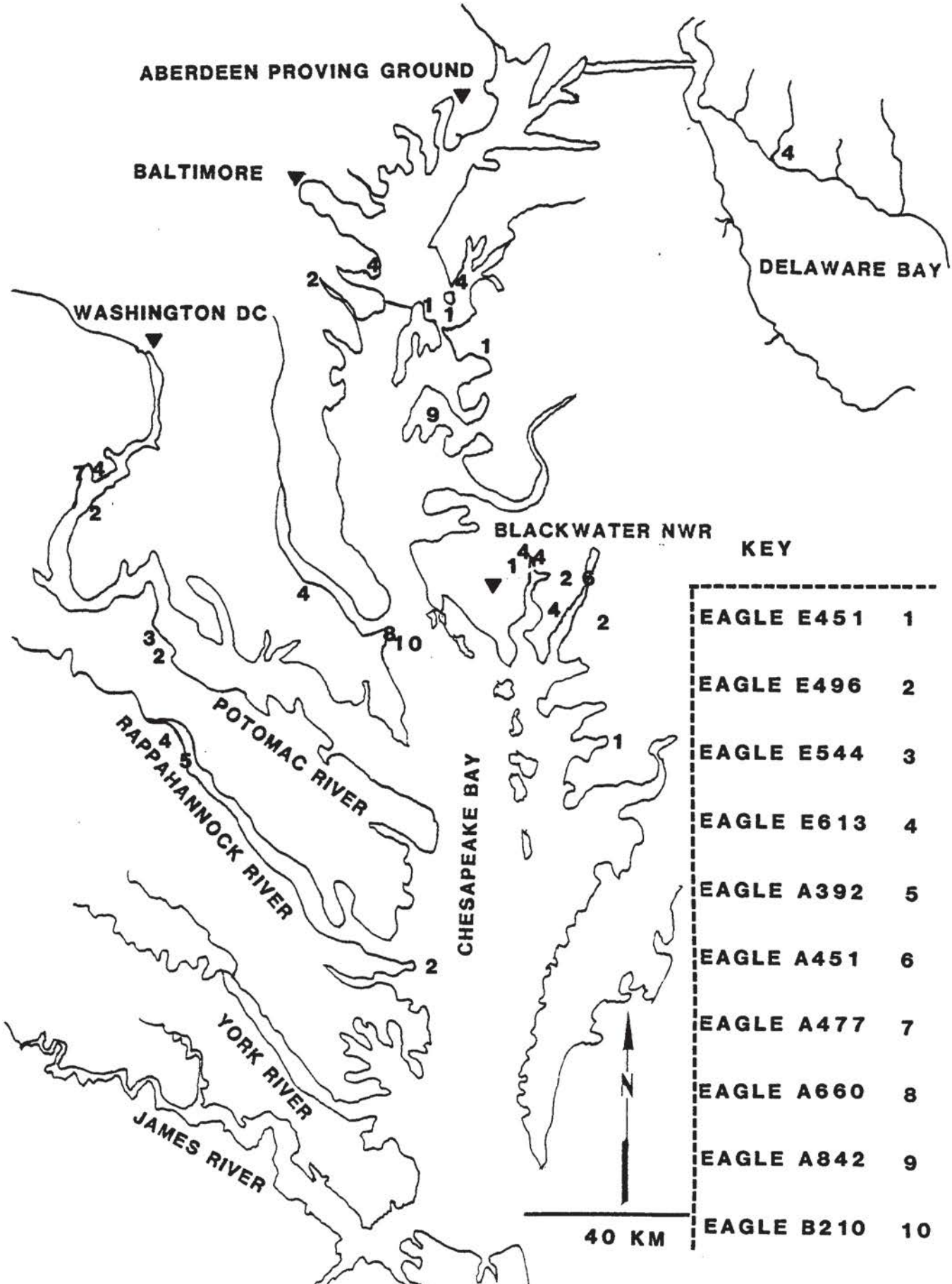


Figure 17. Home ranges of all eagles tracked on the Aberdeen-Edgewood area from 28 Feb 1984 - 1 Sep 1984.

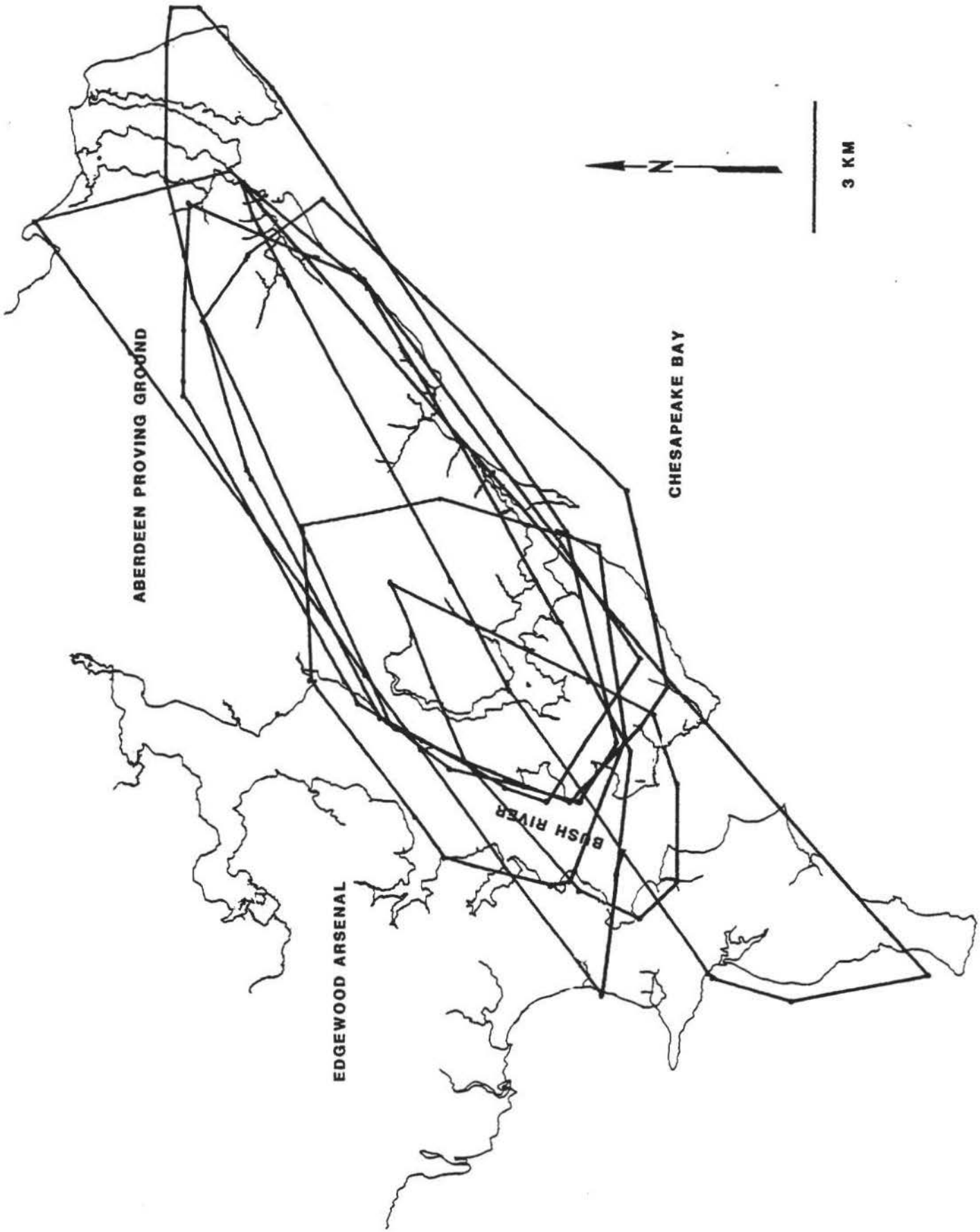


Figure 18. Home ranges of all eagles tracked on the Chesapeake Bay from 1 Sep 1984 - 1 Jul 1985.

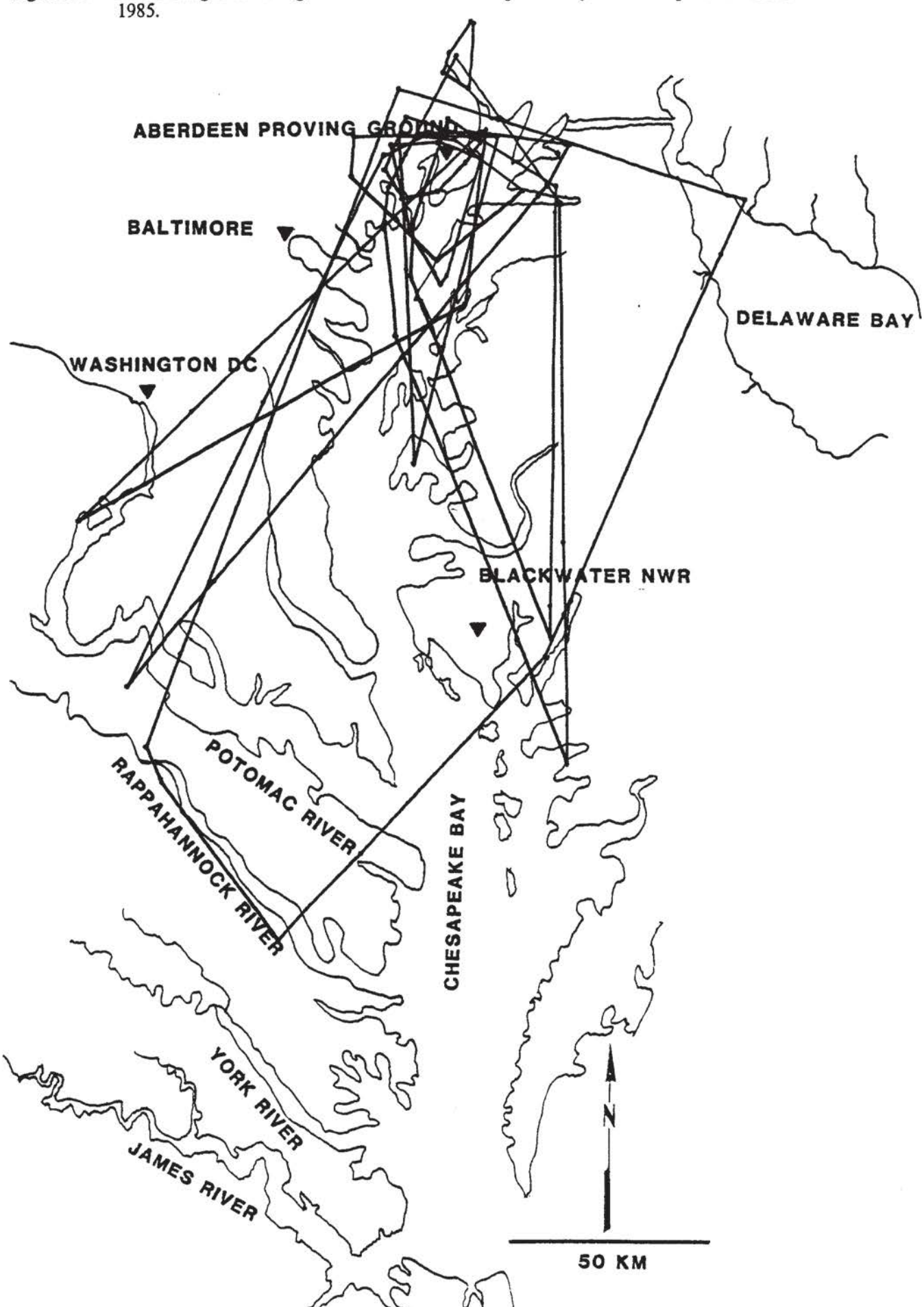


Figure 19. Mean number of eagles seen during morning versus evening roost counts by roost on Aberdeen Proving Ground.

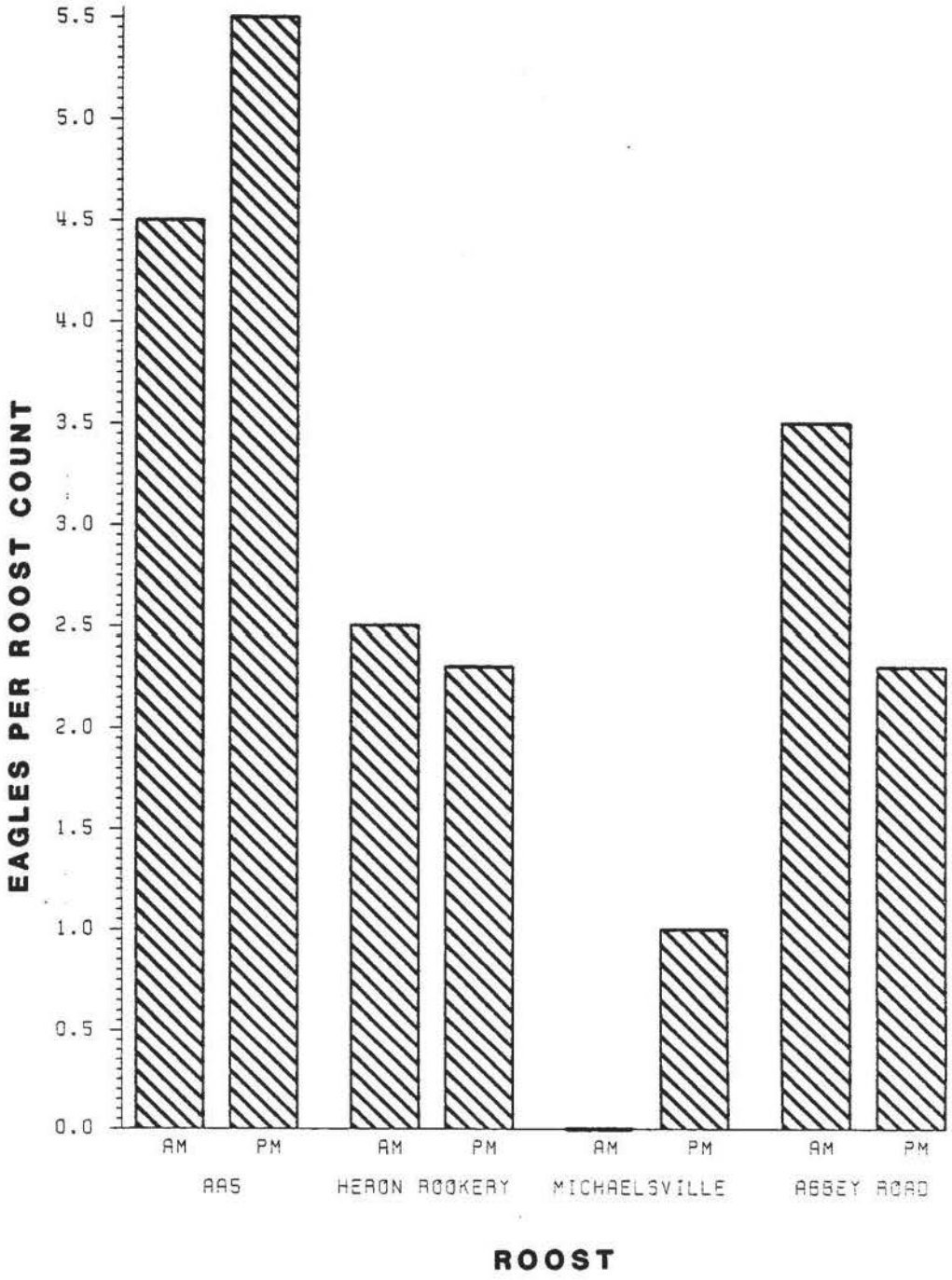


Figure 20. Numbers and ages of eagles observed in AA5 Roost on Aberdeen Proving Ground per evening roost count from 3 Feb 1984 - 30 May 1985.

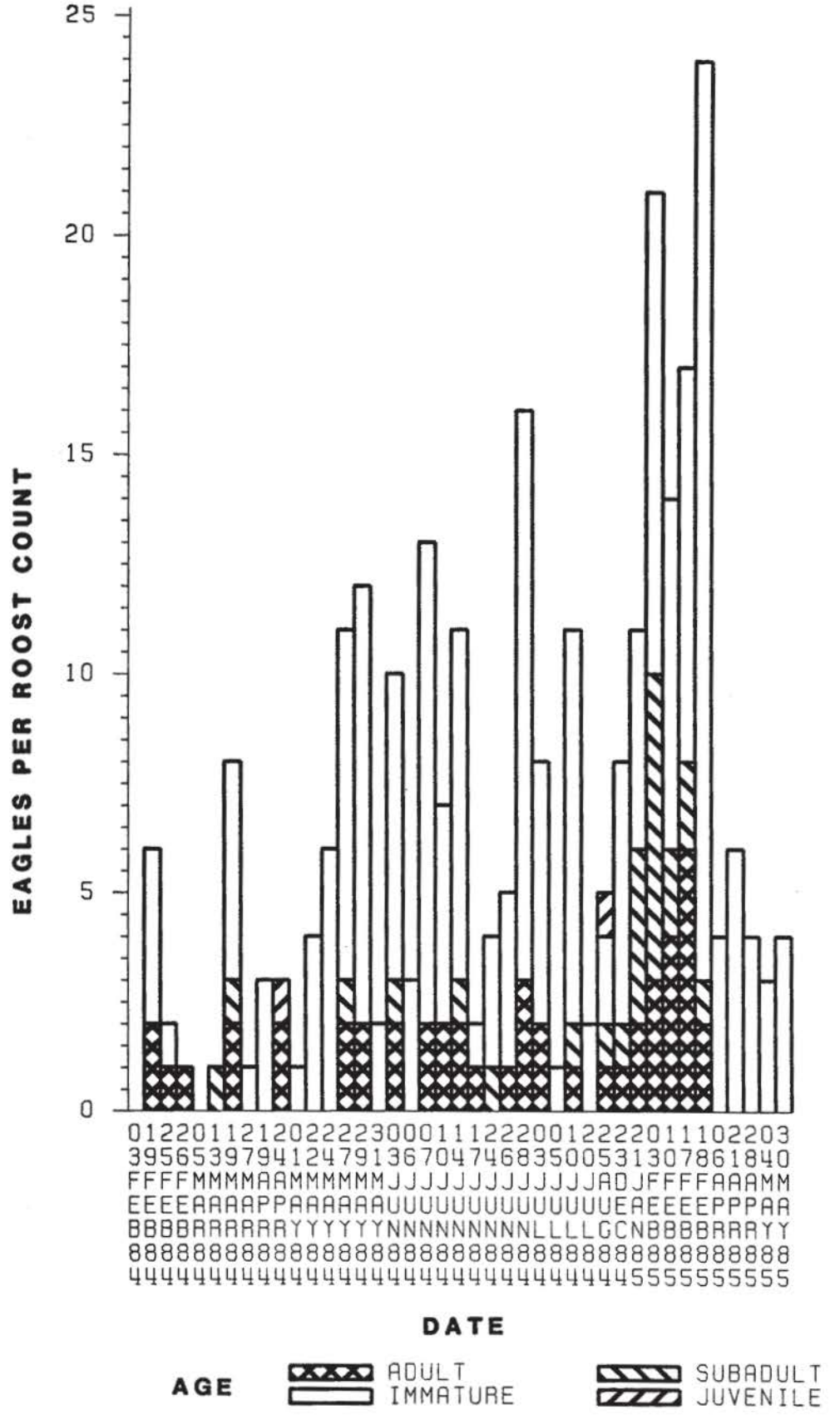


Figure 21. Bald eagle communal roosts located on the Susquehanna River.

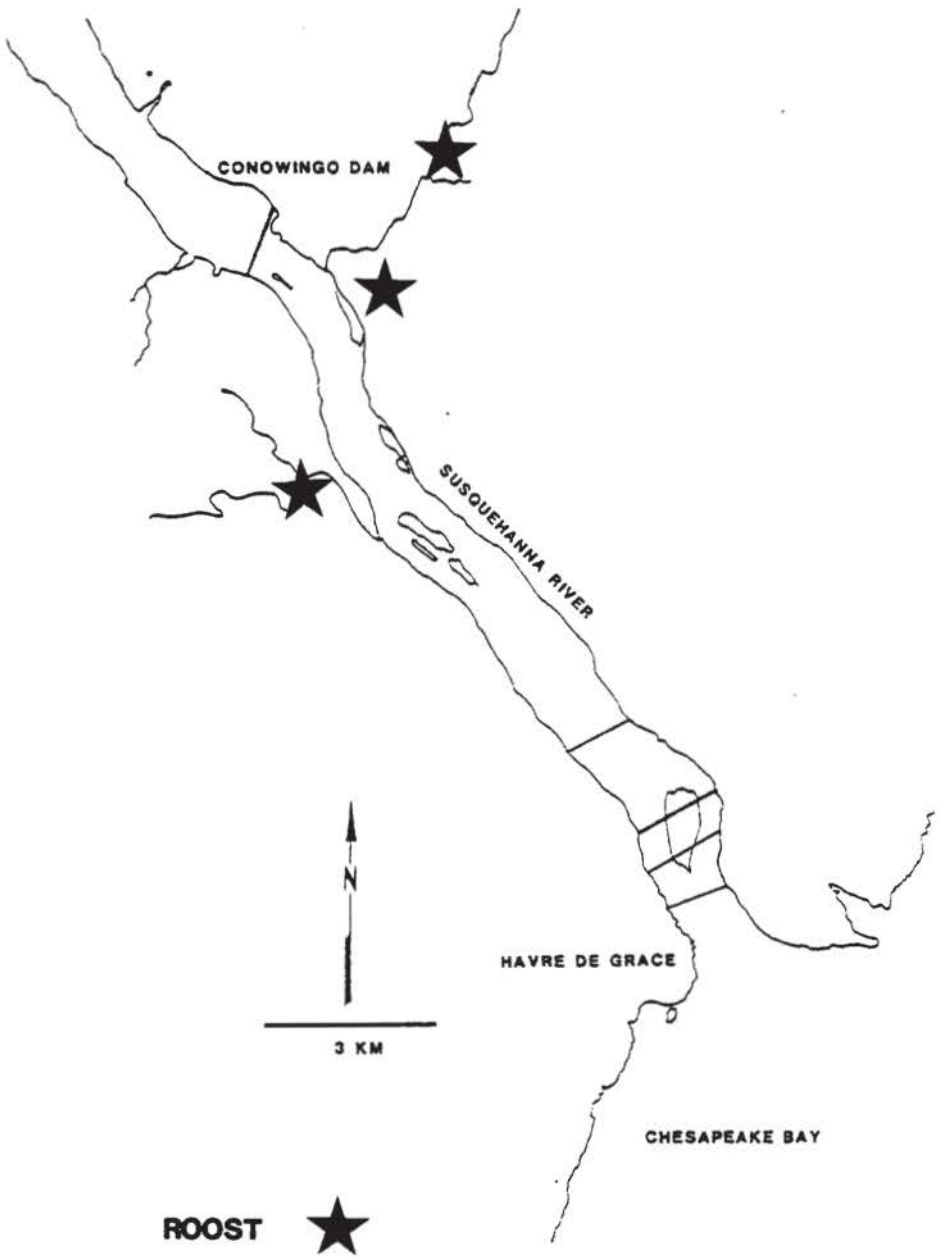


Figure 22. Age distribution of bald eagles seen on aerial shoreline surveys of the Northern Chesapeake Study Area by survey from 8 Apr 1984 - 23 Jun 1985.

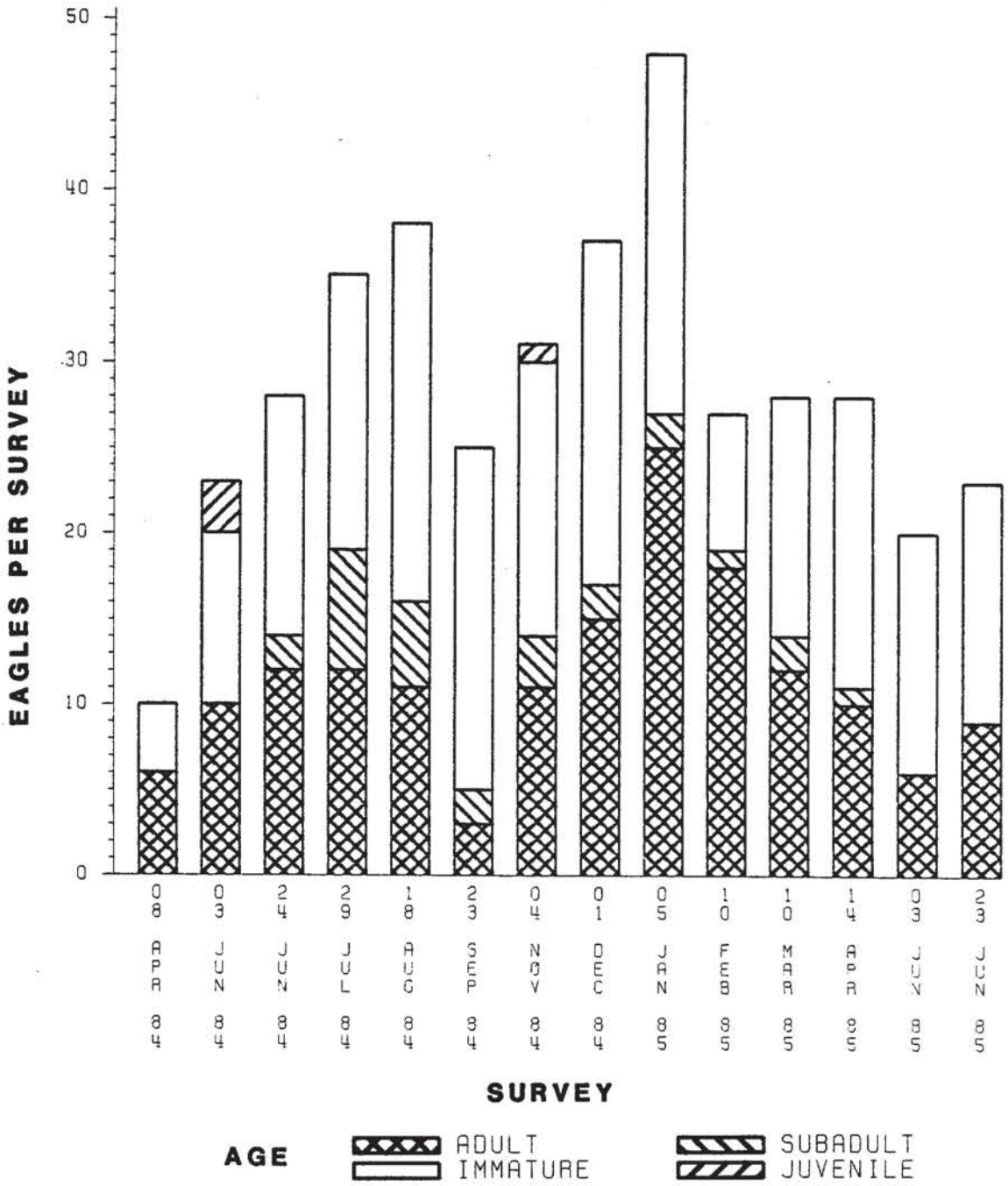
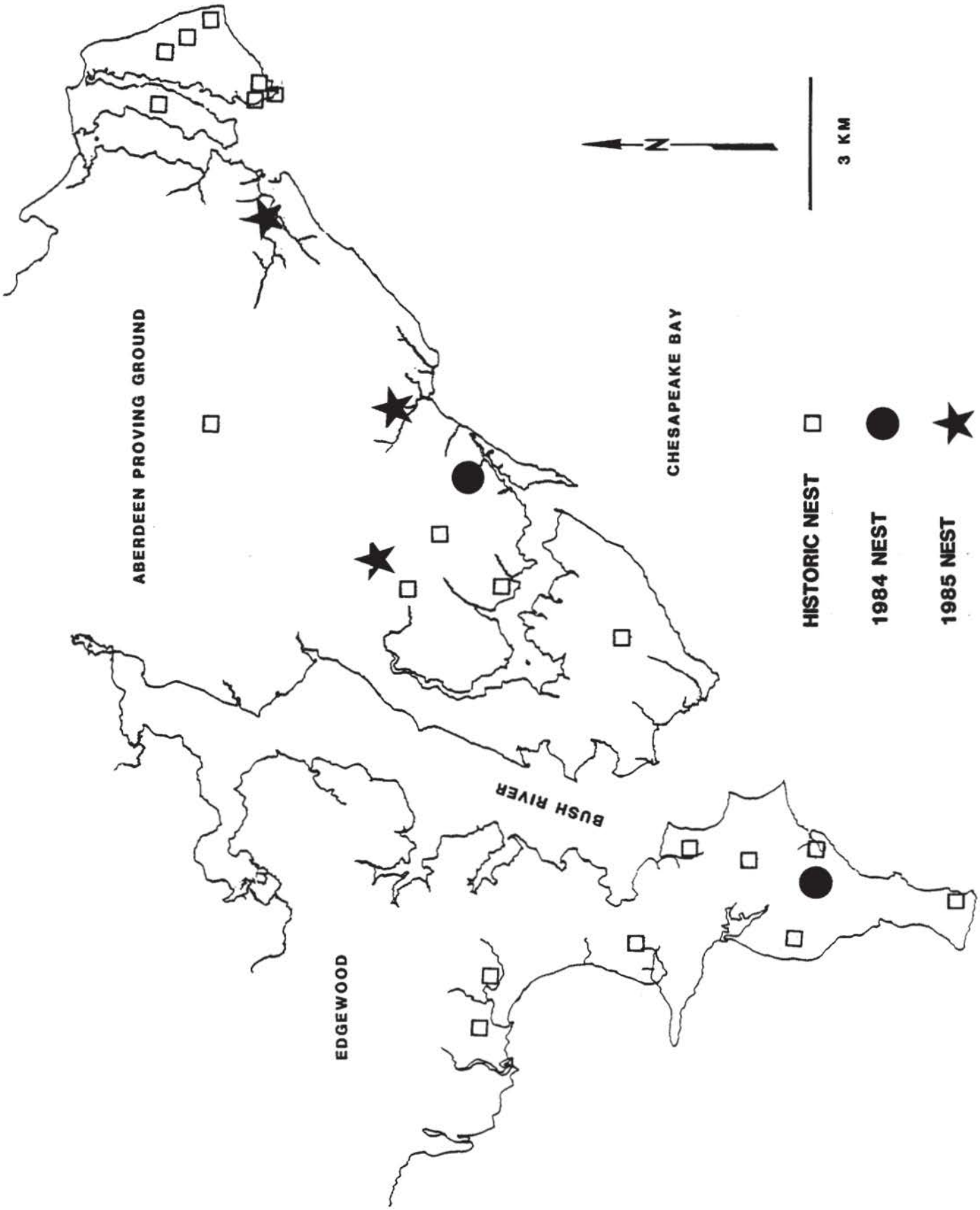


Figure 23. Active nesting territories on the Aberdeen area of the Northern Chesapeake Study Area.



APPENDIX A: LOCATIONS OF RADIO-TAGGED BALD EAGLES OBSERVED OFF OF THE NCSA

Figure 24. Movements of bald eagle E451 on the Chesapeake Bay from 22 Jan 1985 - 15 Feb 1985.

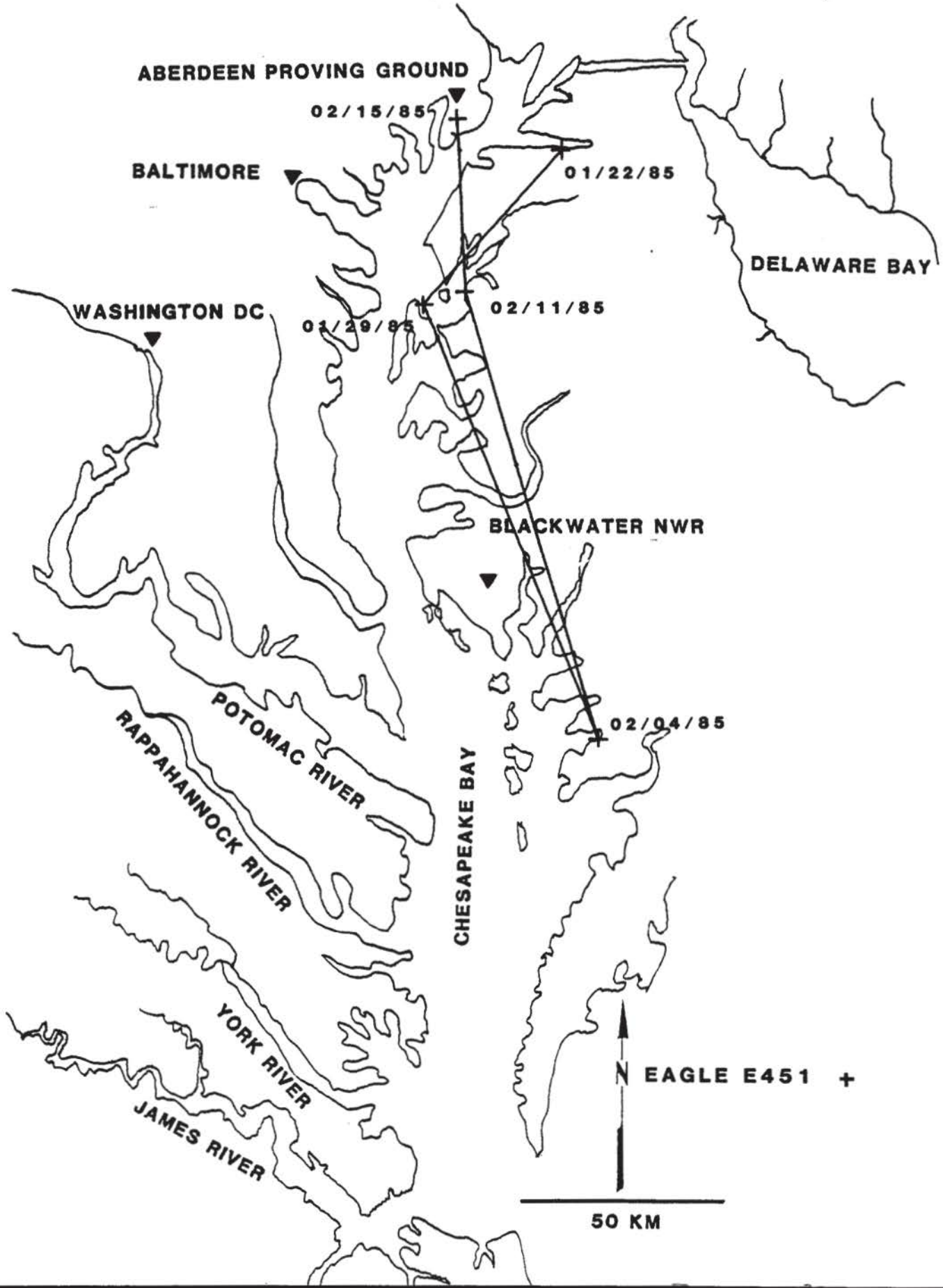


Figure 25. Movements of bald eagle E451 on the Chesapeake Bay from 5 Mar 1985 - 17 Mar 1985.

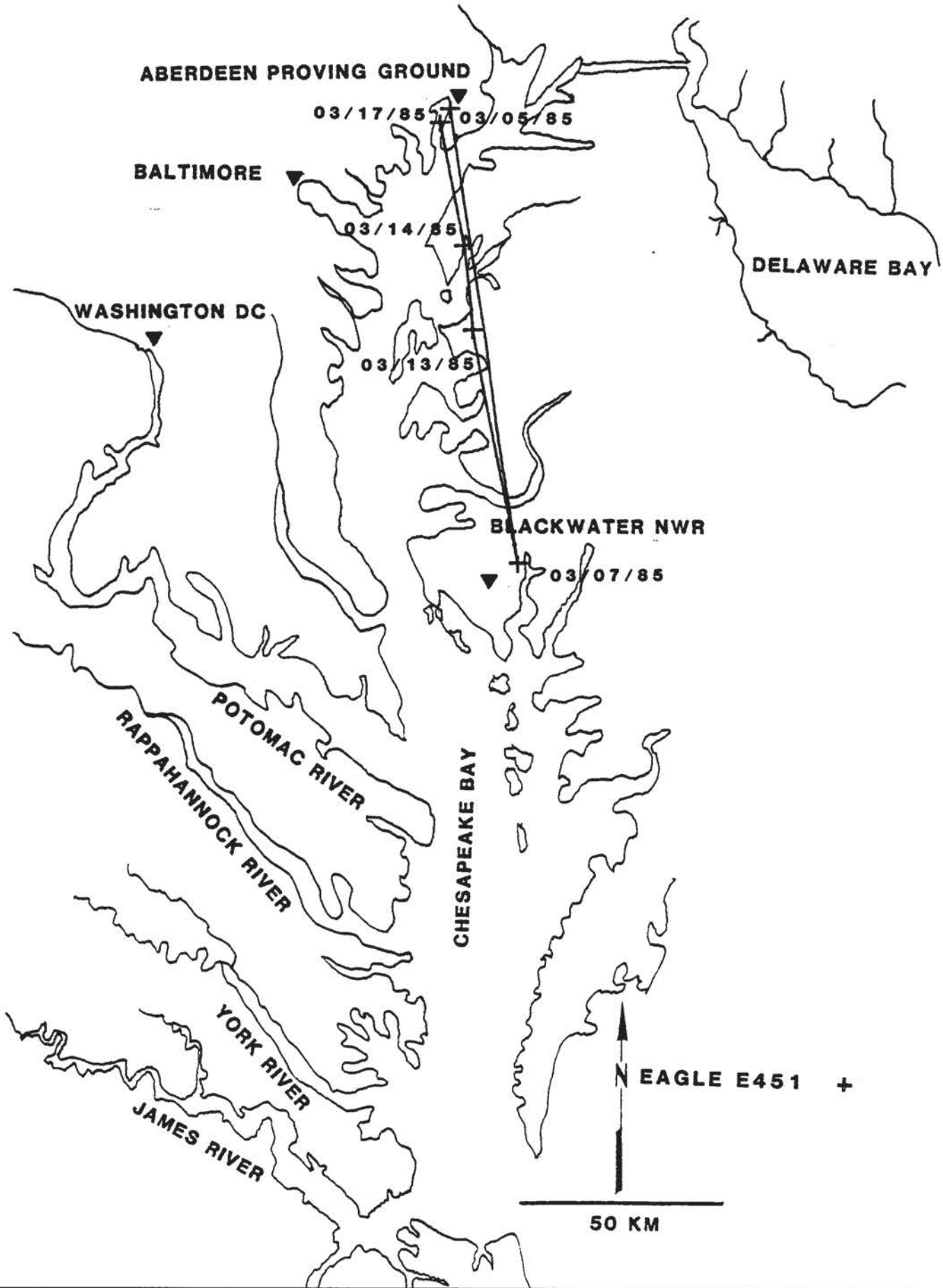


Figure 26. Movements of bald eagle E496 on the Chesapeake Bay from 27 Sep 1984 - 10 Apr 1985.

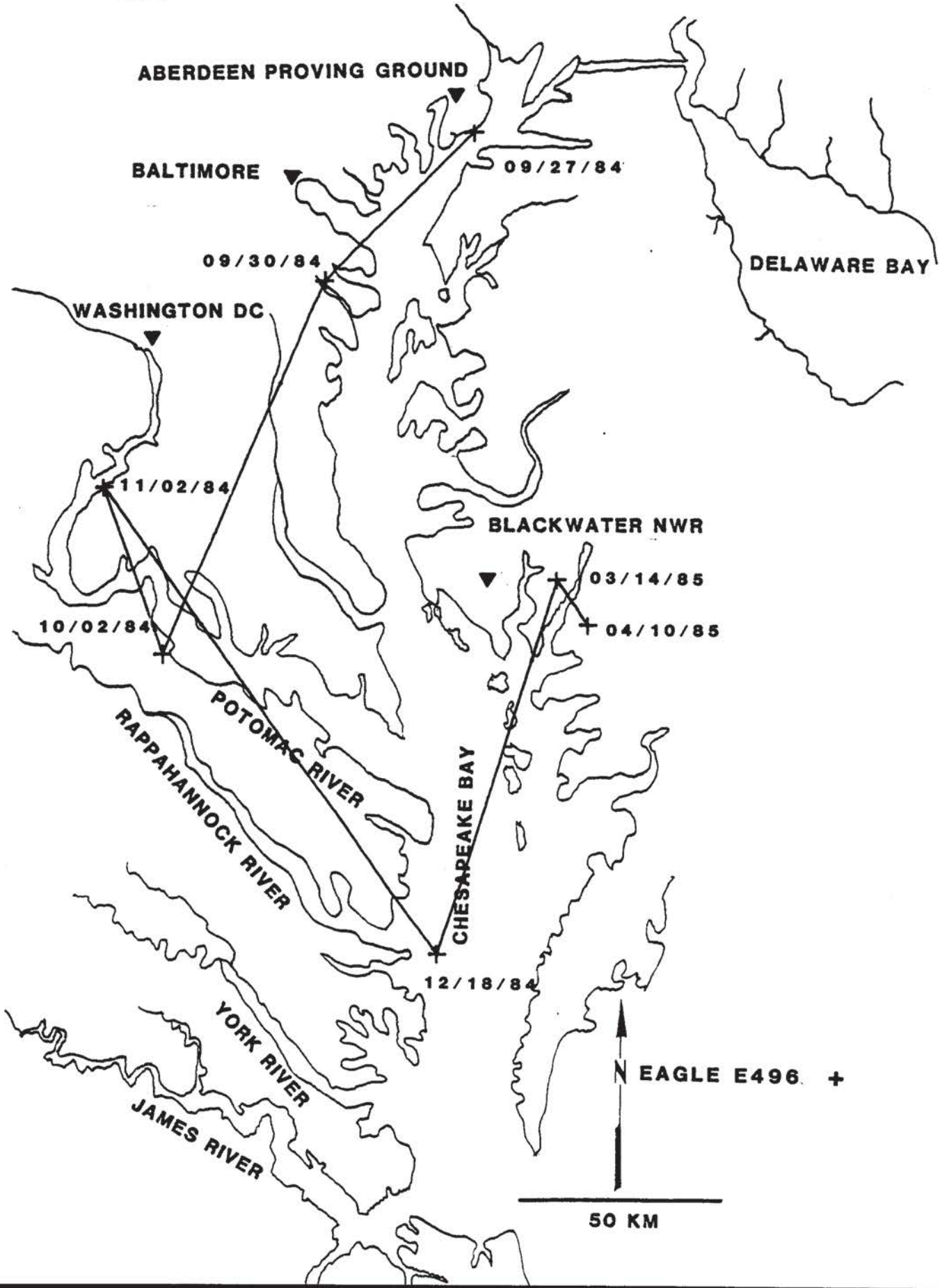


Figure 27. Movements of bald eagle E544 on the Chesapeake Bay from 16 Sep 1984 - 31 Oct 1984.

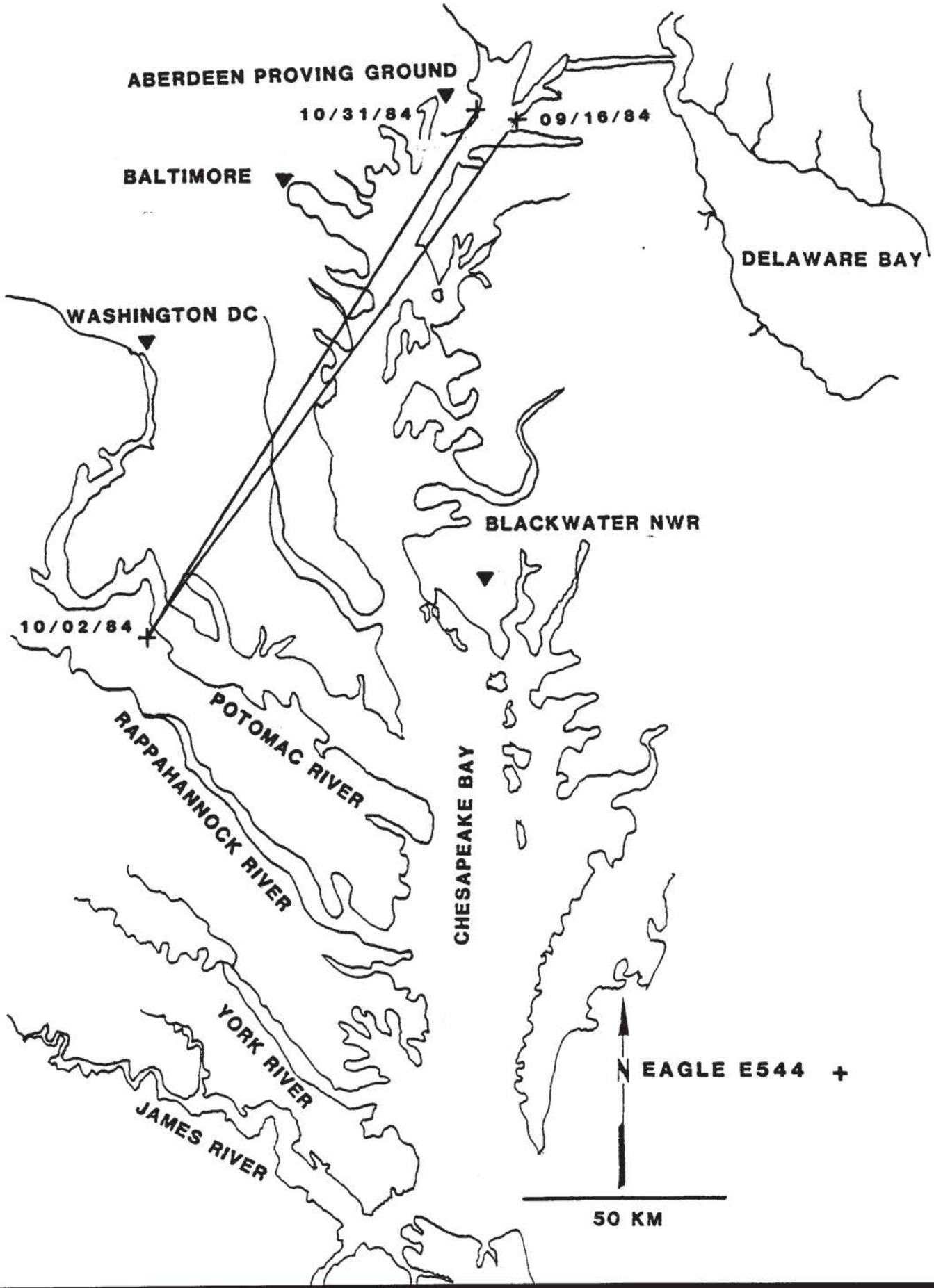


Figure 28. Movements of bald eagle E613 on the Chesapeake Bay from 6 Nov 1984 - 11 Nov 1984.

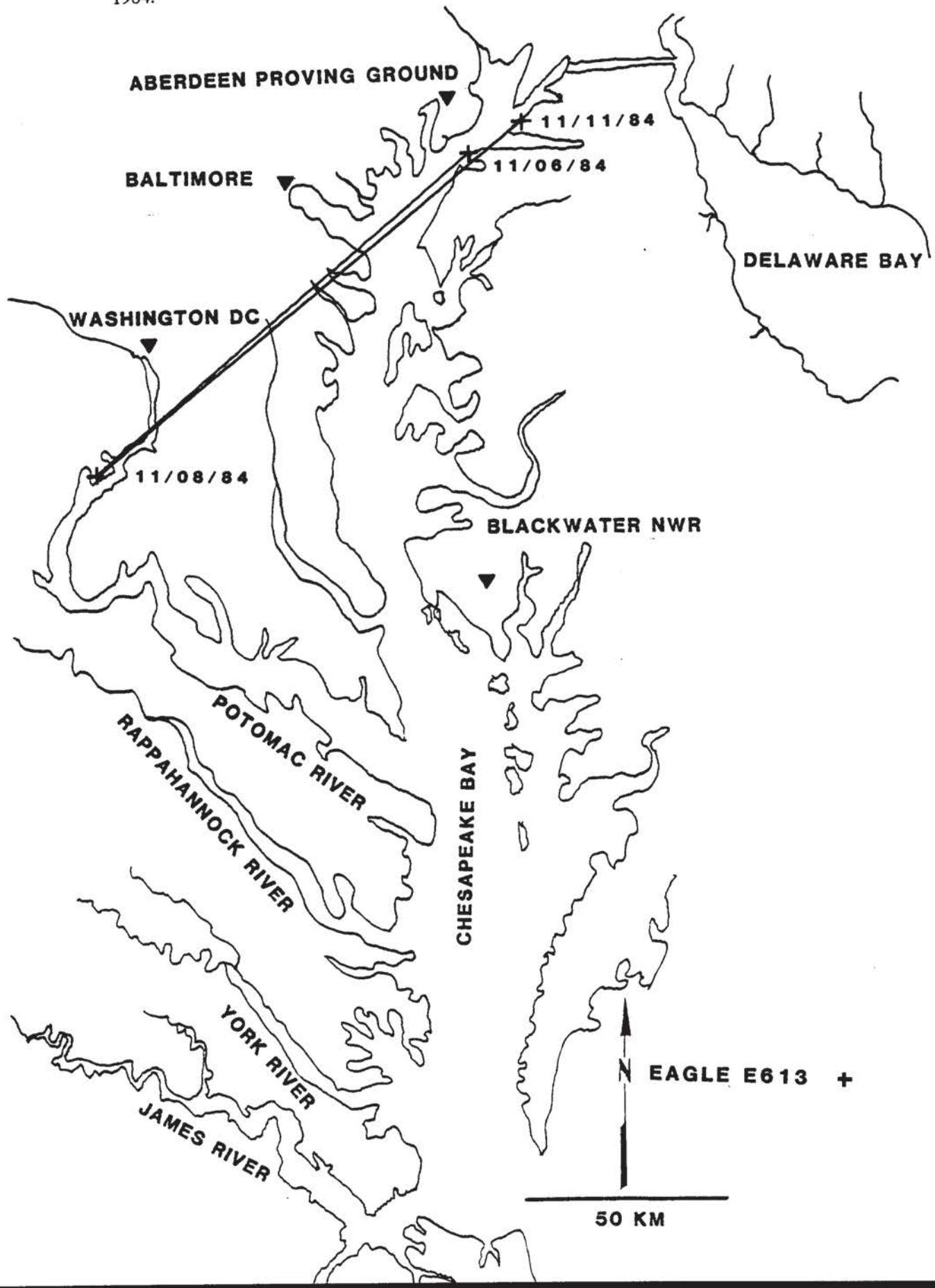


Figure 29. Movements of bald eagle E613 on the Chesapeake Bay from 2 Jan 1985 - 17 Mar 1985.

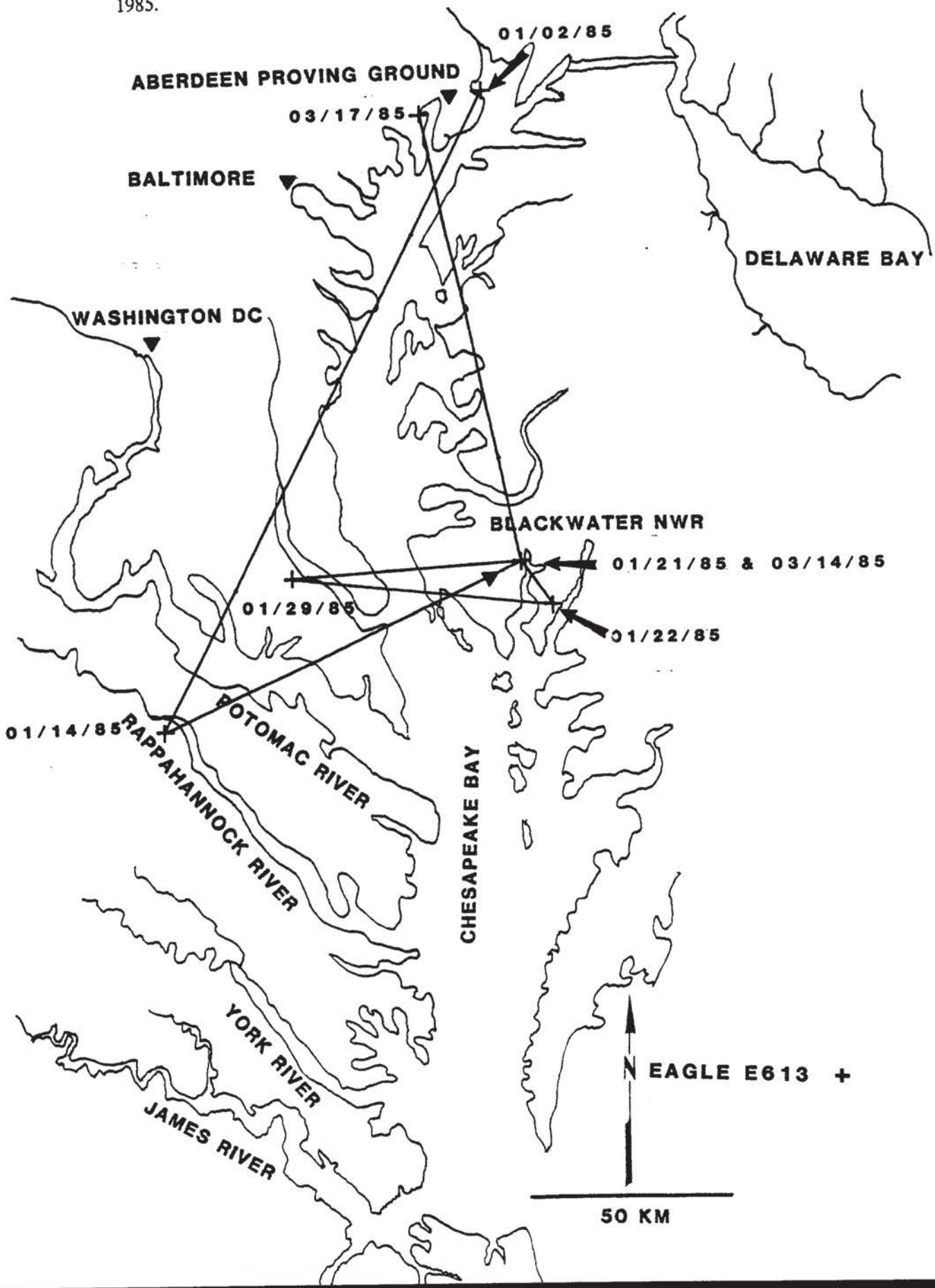


Figure 30. Movements of bald eagle E613 on the Chesapeake Bay from 2 Apr 1985 - 21 Apr 1985.

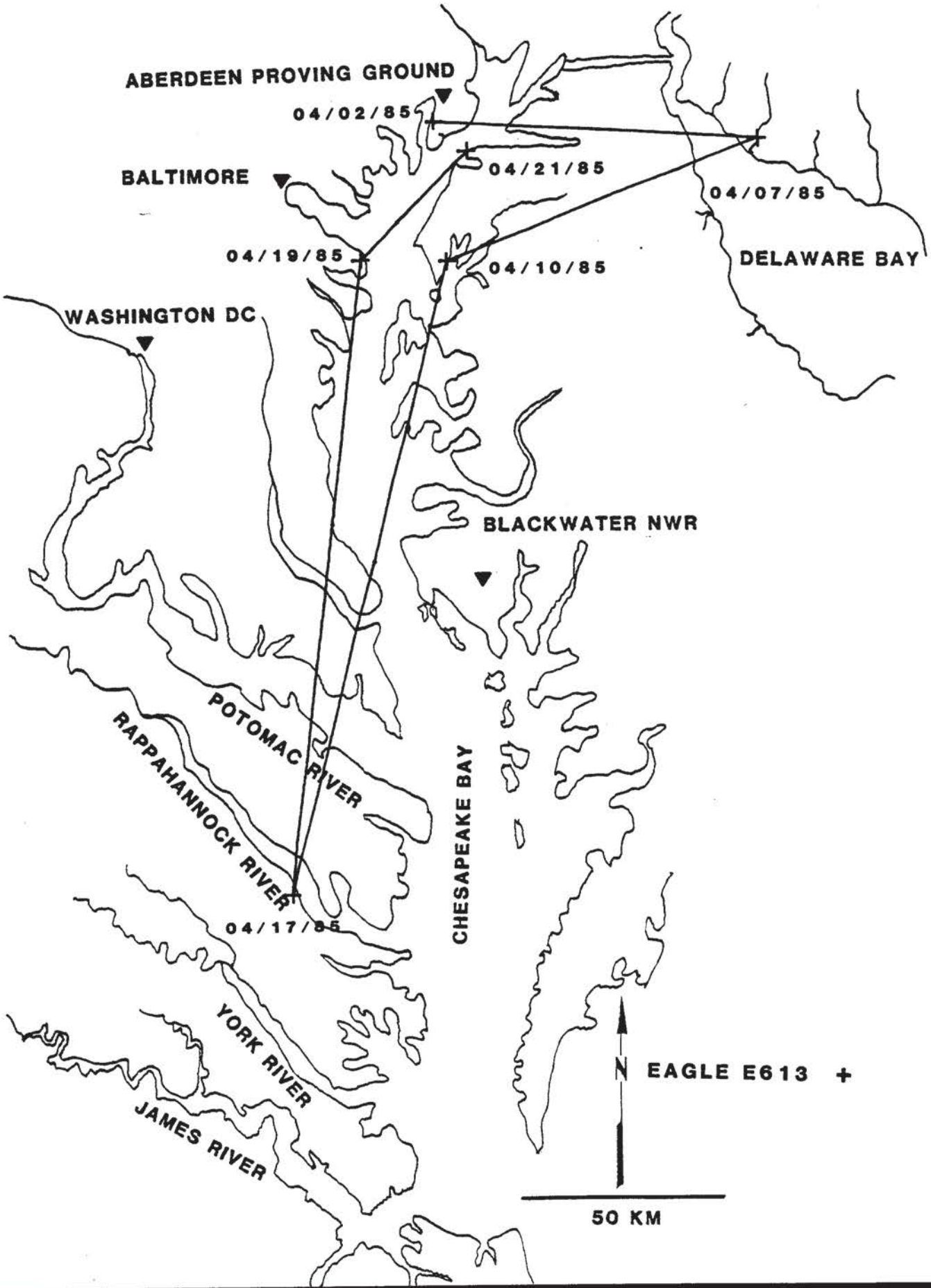


Figure 31. Movements of bald eagle E613 on the Chesapeake Bay from 18 Jun 1985 - 23 Jun 1985.

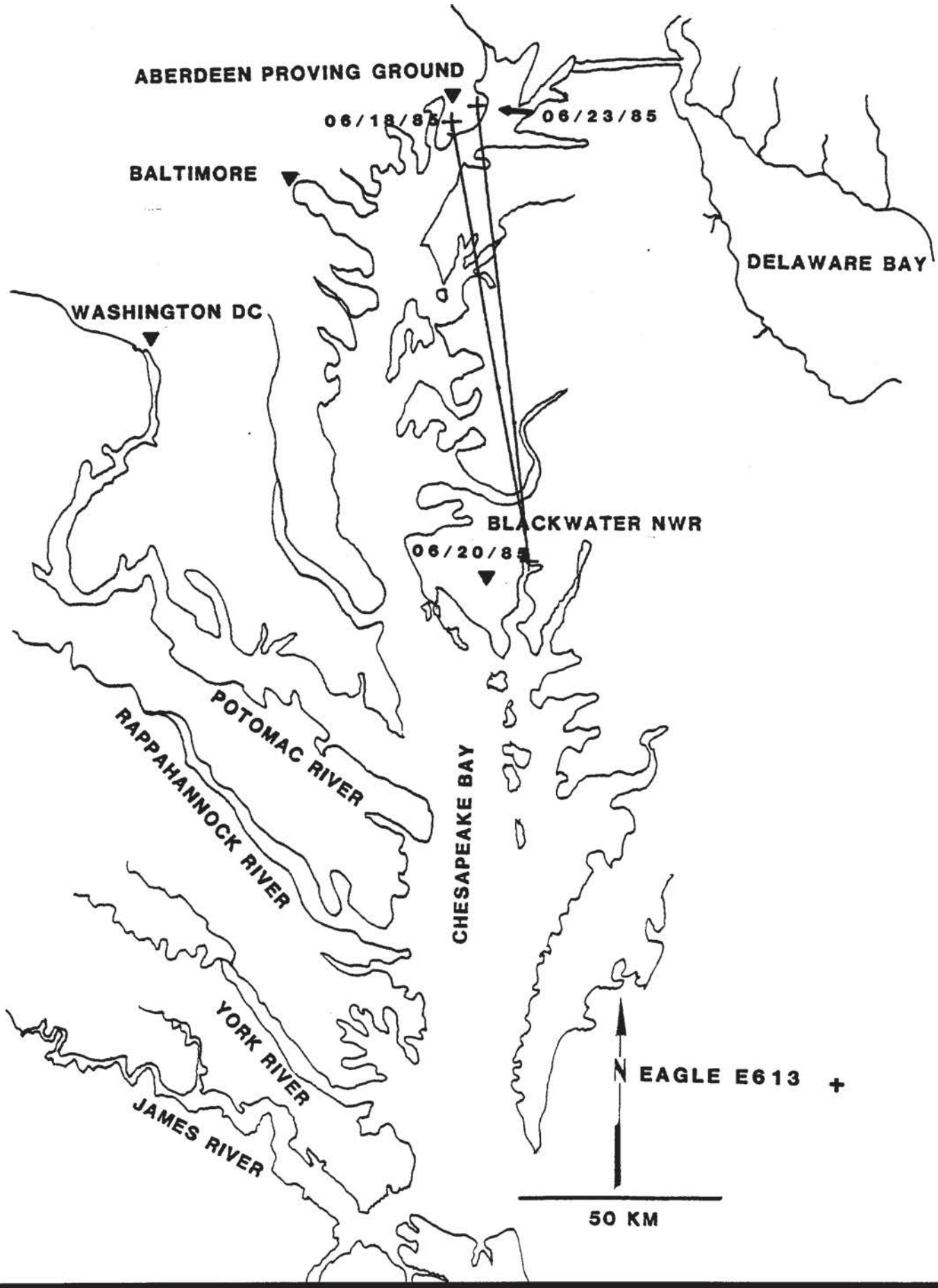


Figure 32. Movements of bald eagle A451 on the Chesapeake Bay from 29 Jan 1985 - 20 Feb 1985.

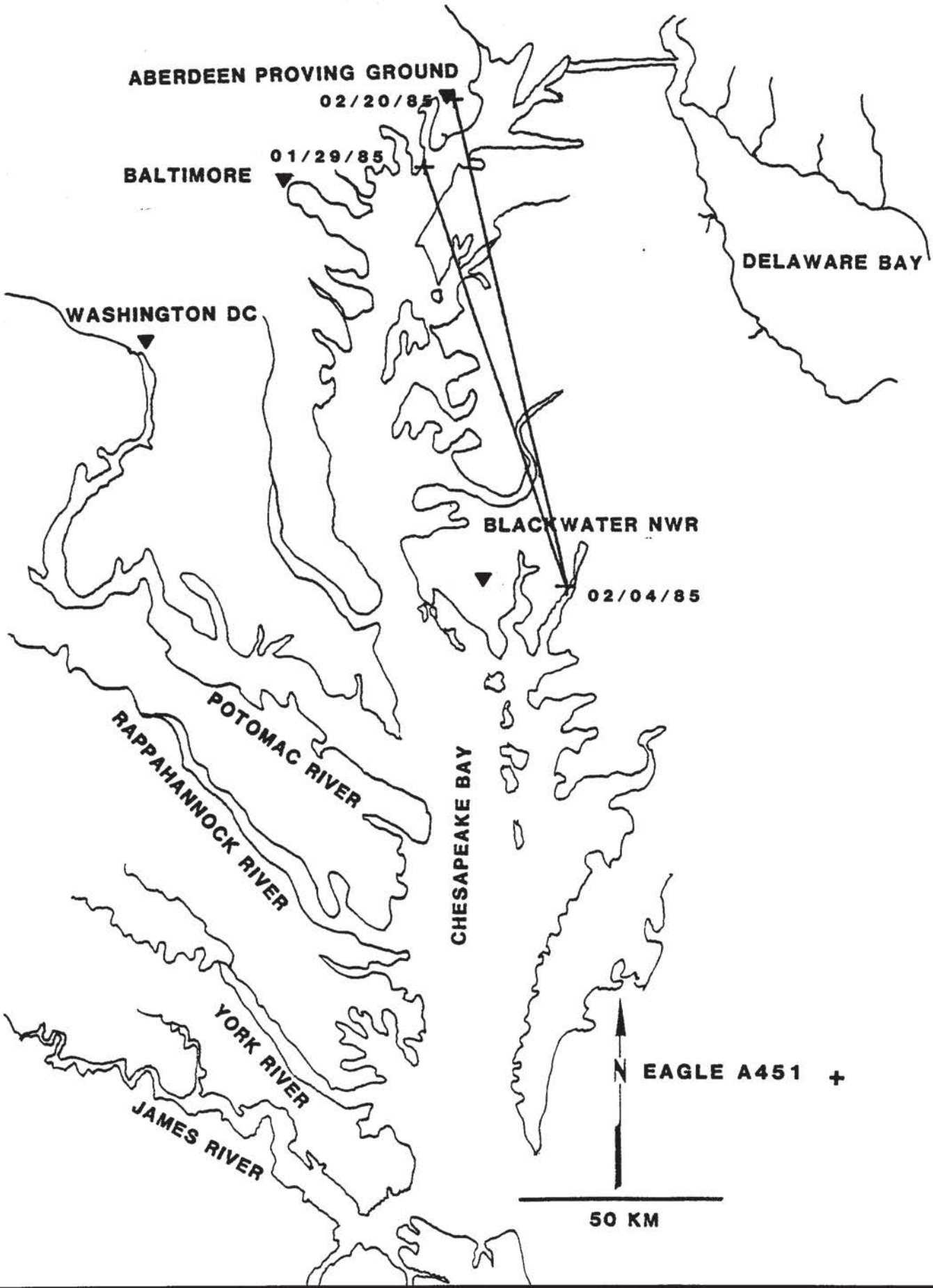


Figure 33. Movements of bald eagle A477 on the Chesapeake Bay from 19 Jan 1985 - 27 Jan 1985.

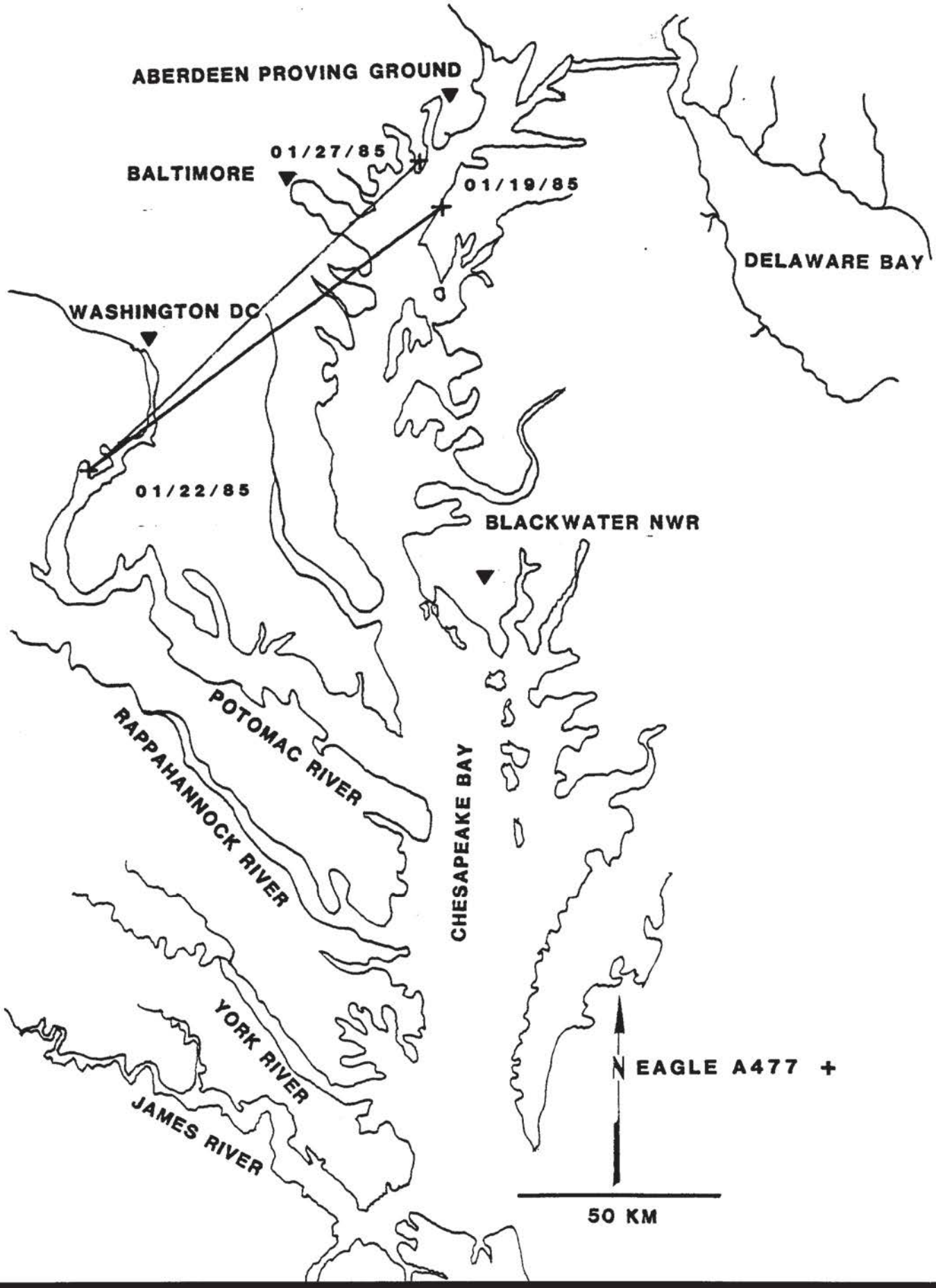
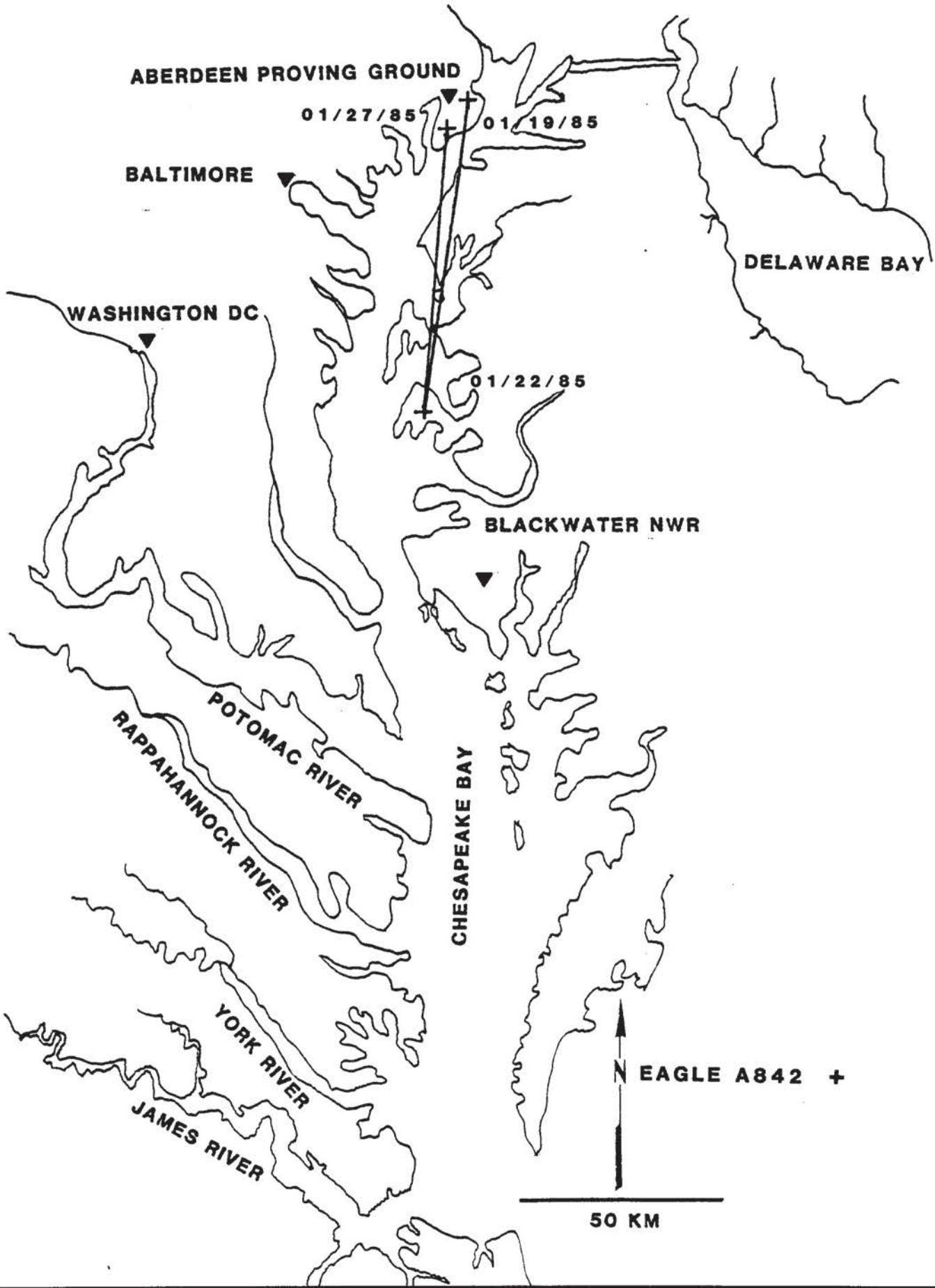


Figure 34. Movements of bald eagle A842 on the Chesapeake Bay from 19 Jan 1985 - 27 Jan 1985.



APPENDIX B: AREAS USED BY BALD EAGLES TRACKED ALL DAY ON APG, 16 MAR 1984 TO 12 AUG 1984

Figure 35. Locations and area of use convex polygons from all-day tracking of eagle E423 on 22 May 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

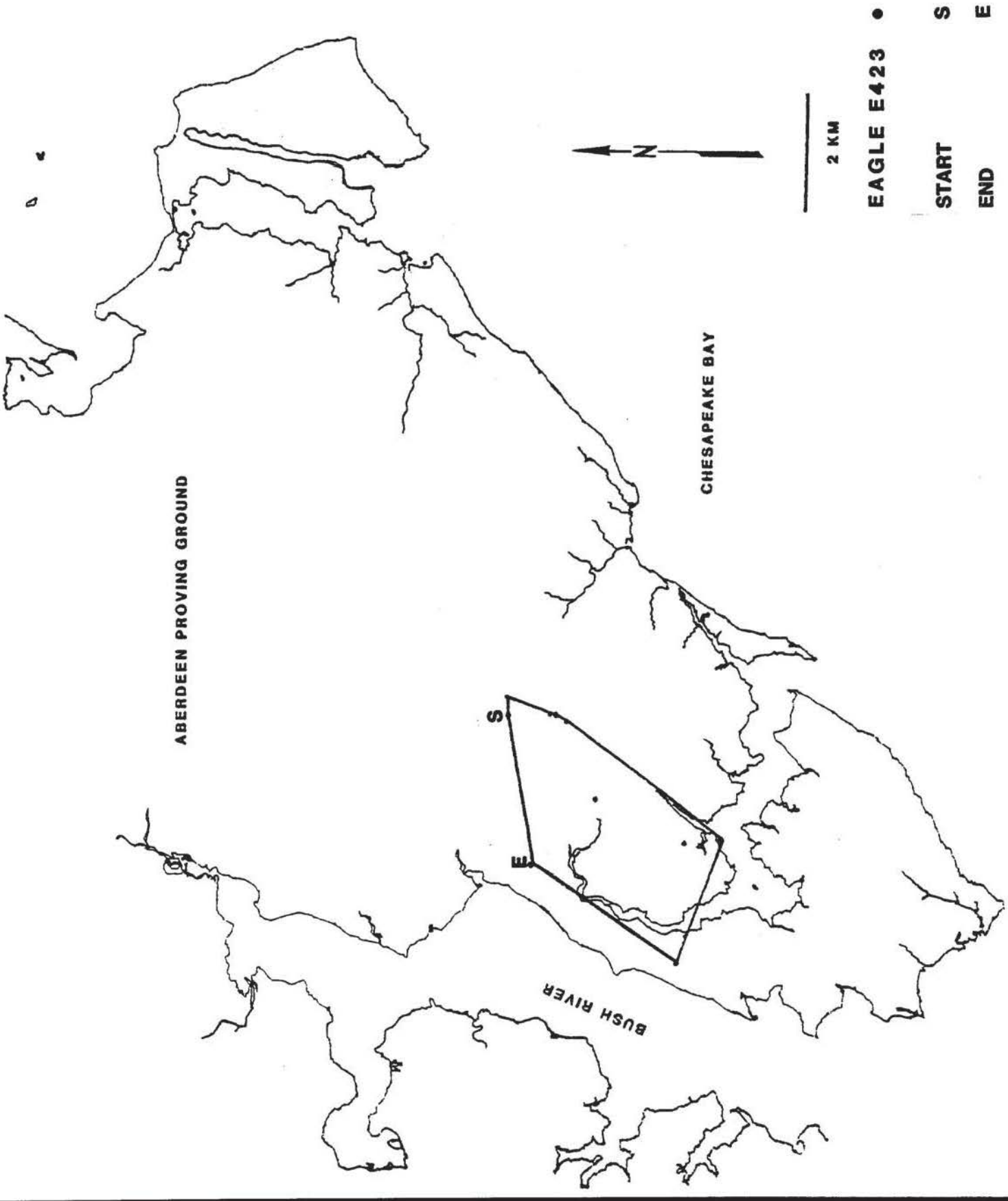


Figure 36. Locations and area of use convex polygons from all-day tracking of eagle E423 on 24 May 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

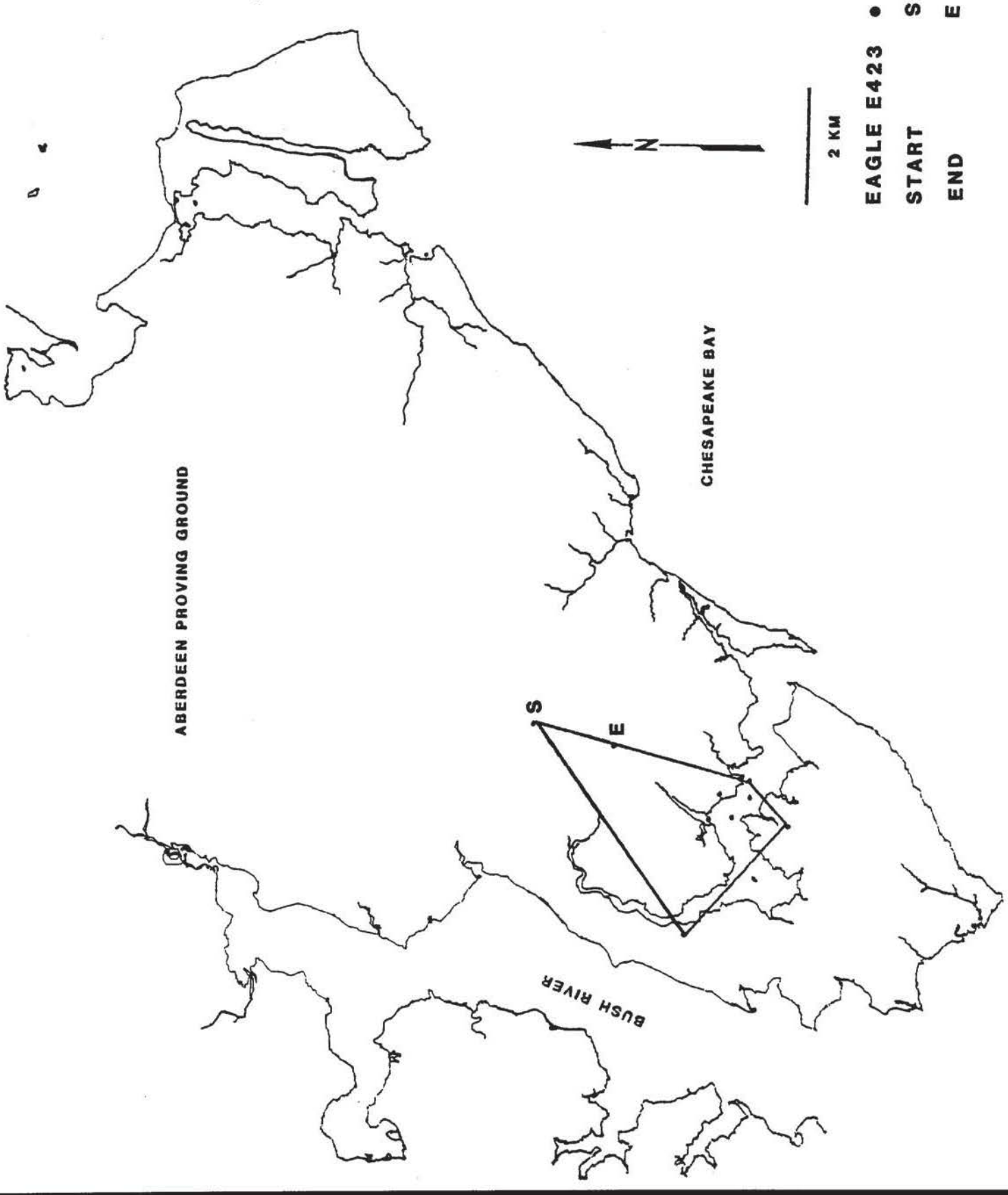


Figure 37. Locations and area of use convex polygons from all-day tracking of eagle E423 on 27 May 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

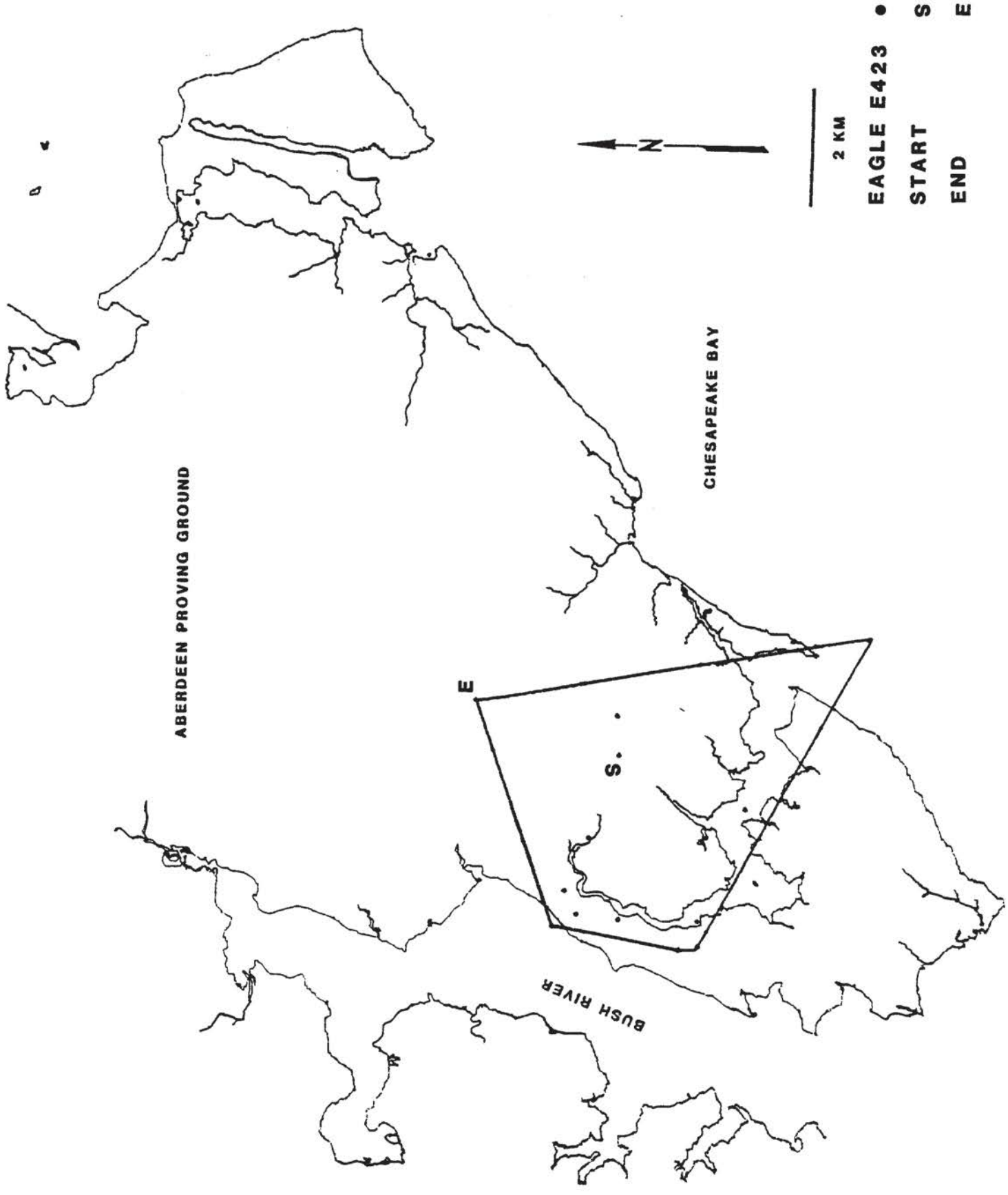


Figure 38. Locations and area of use convex polygons from all-day tracking of eagle E423 on 29 May 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

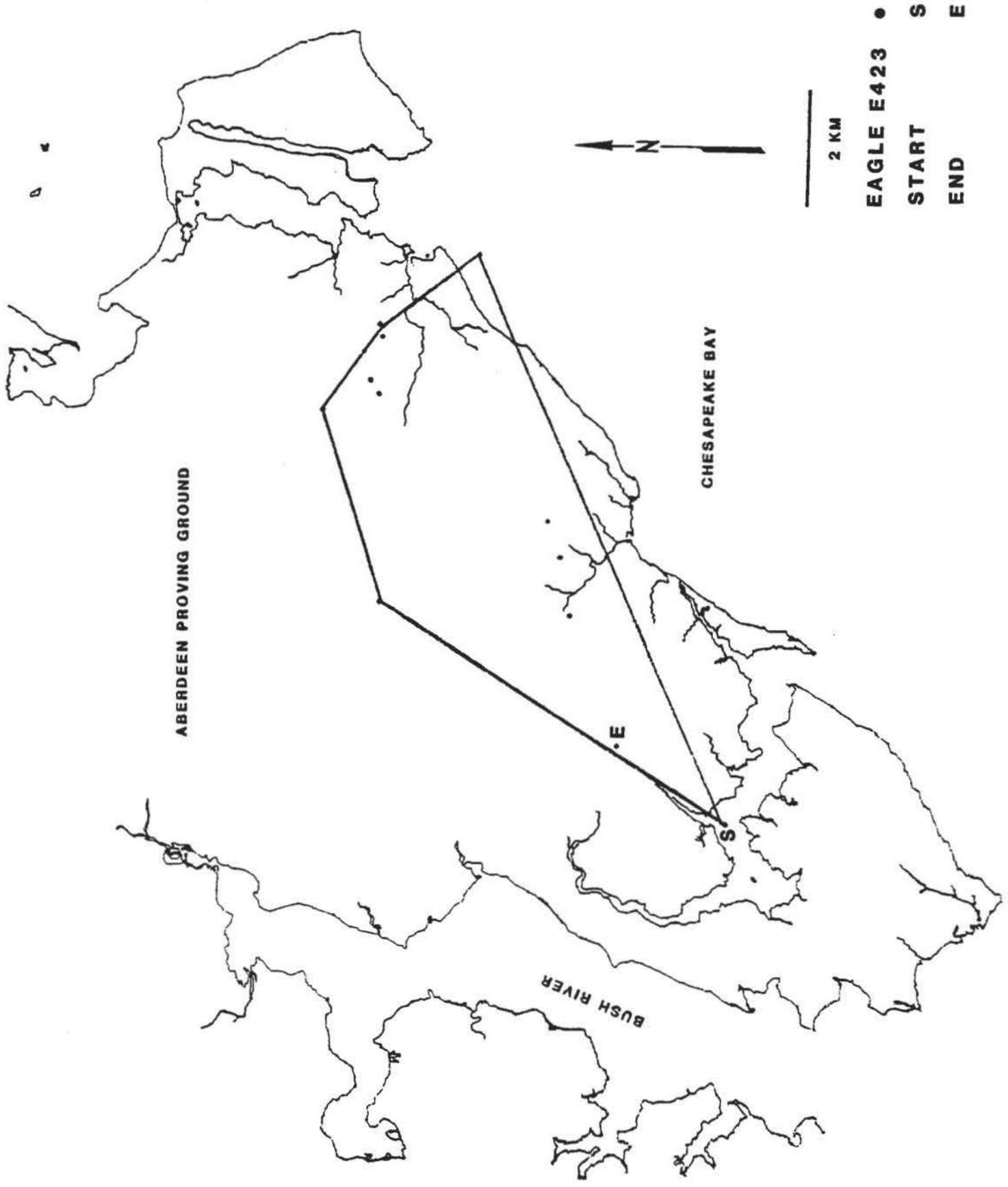


Figure 39. Locations and area of use convex polygons from all-day tracking of eagle E423 on 31 May 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

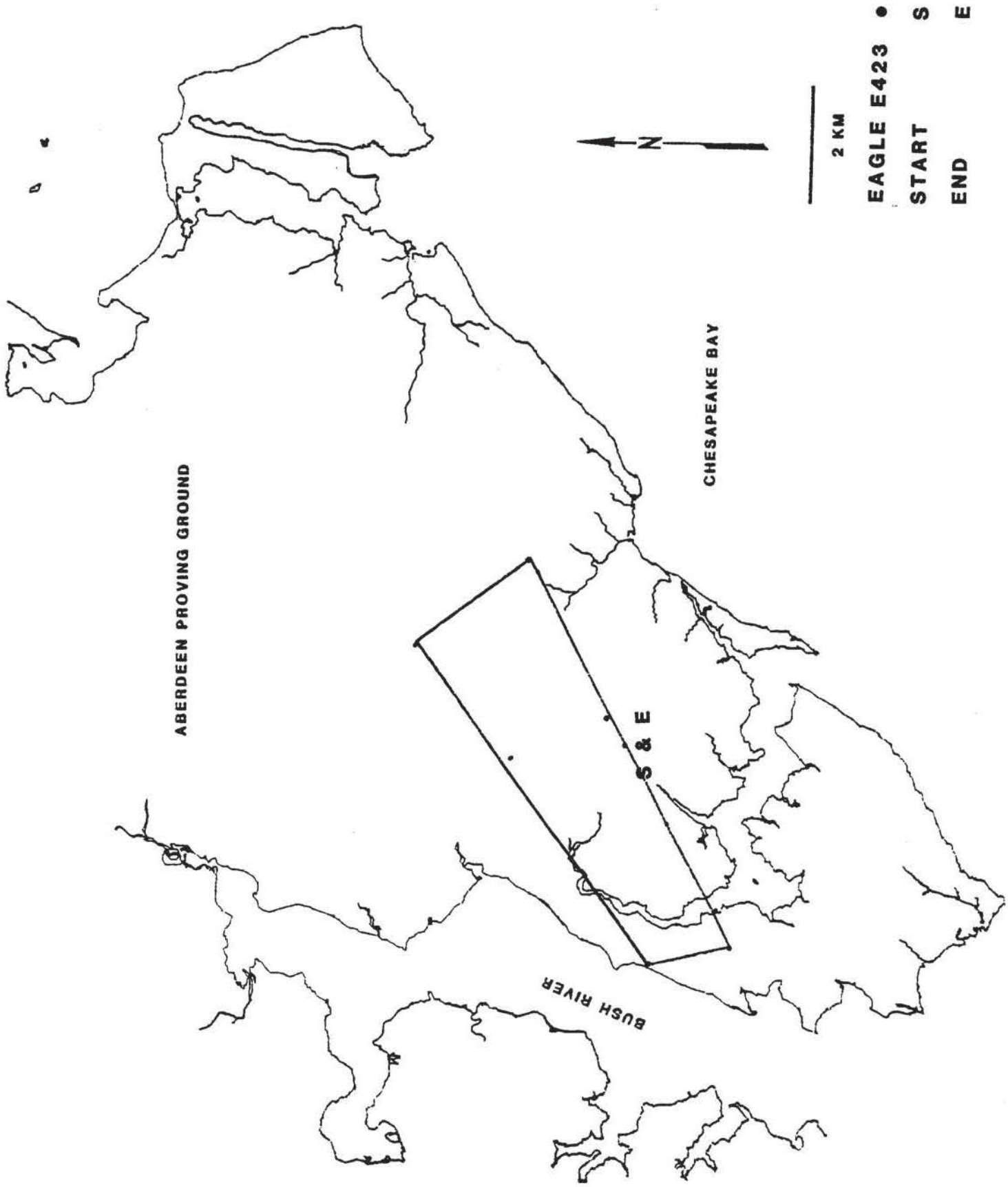


Figure 40. Locations and area of use convex polygons from all-day tracking of eagle E423 on 3 Jun 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

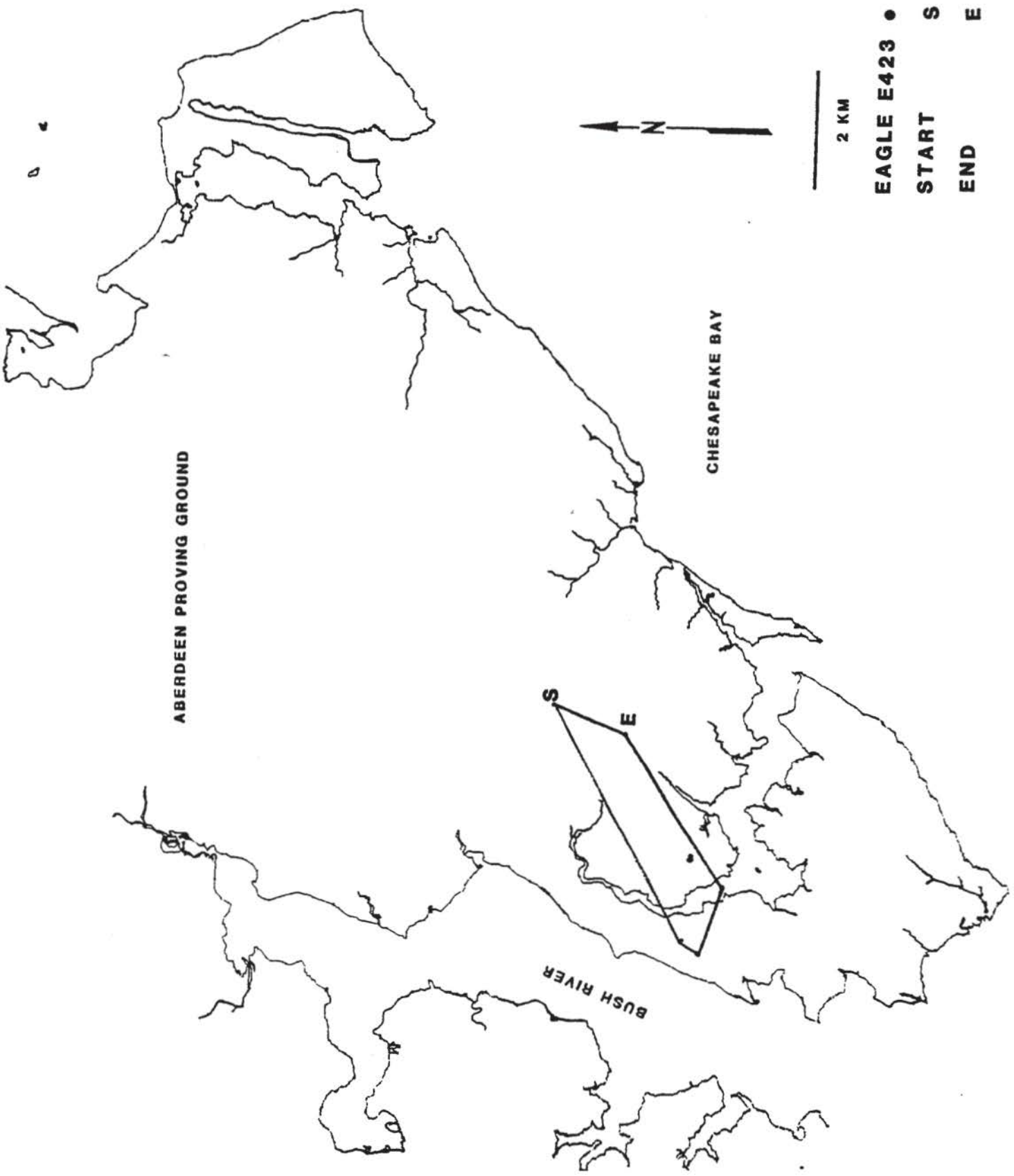


Figure 41. Locations and area of use convex polygons from all-day tracking of eagle E423 on 6 Jun 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

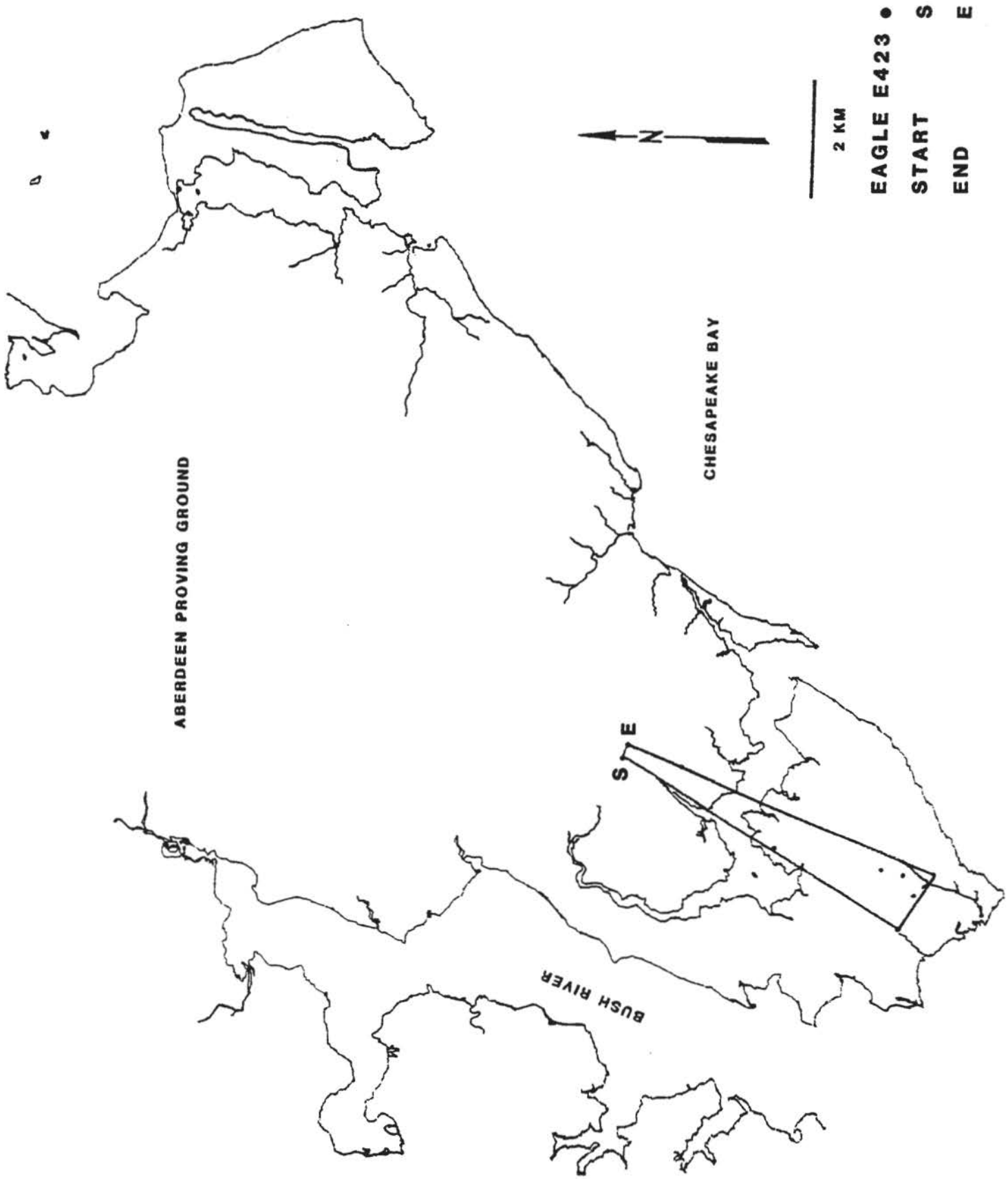


Figure 42. Locations and area of use convex polygons from all-day tracking of eagle E423 on 7 Jun 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

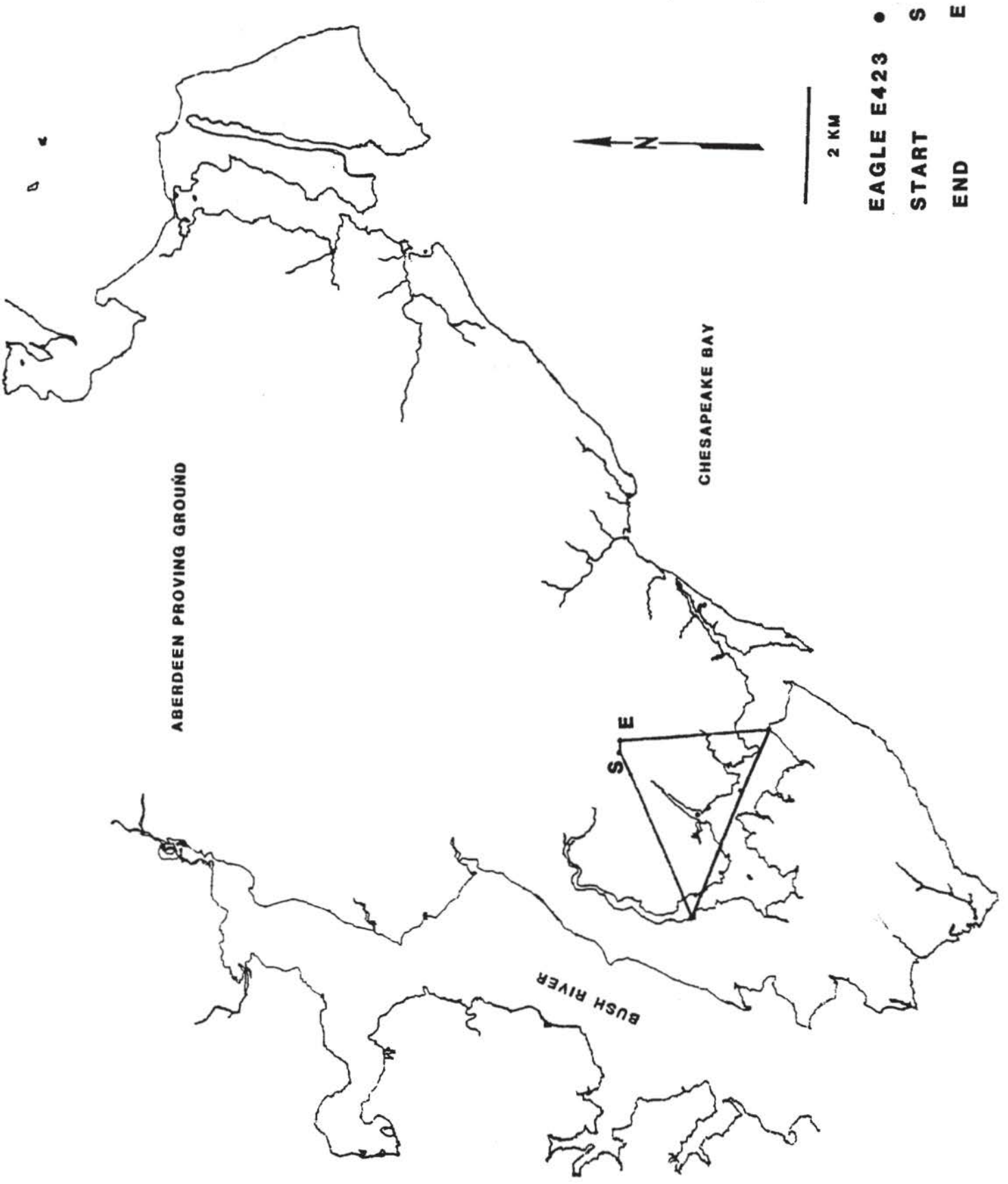


Figure 43. Locations and area of use convex polygons from all-day tracking of eagle E423 on 10 Jun 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

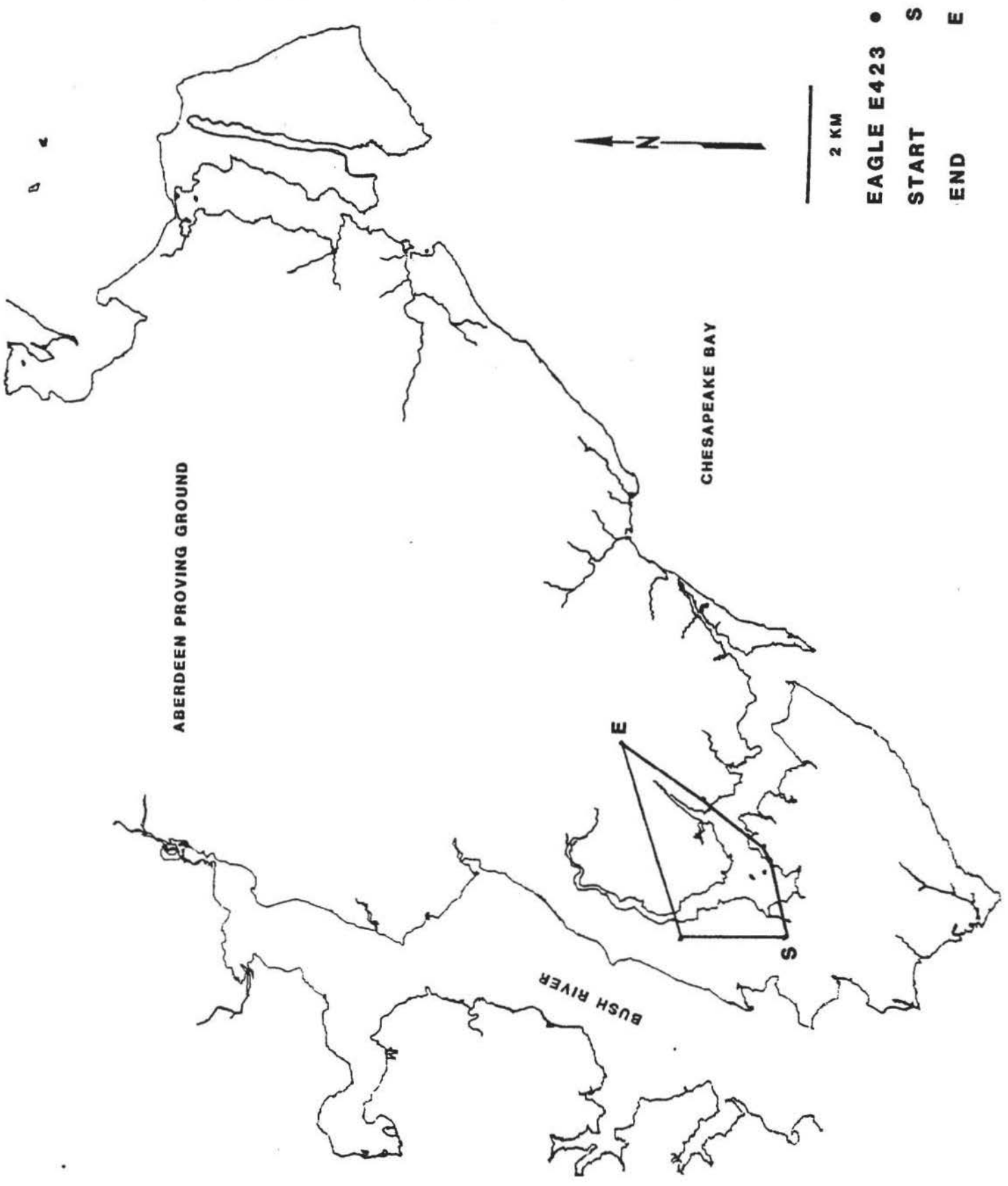


Figure 44. Locations and area of use convex polygons from all-day tracking of eagle E423 on 14 Jun 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

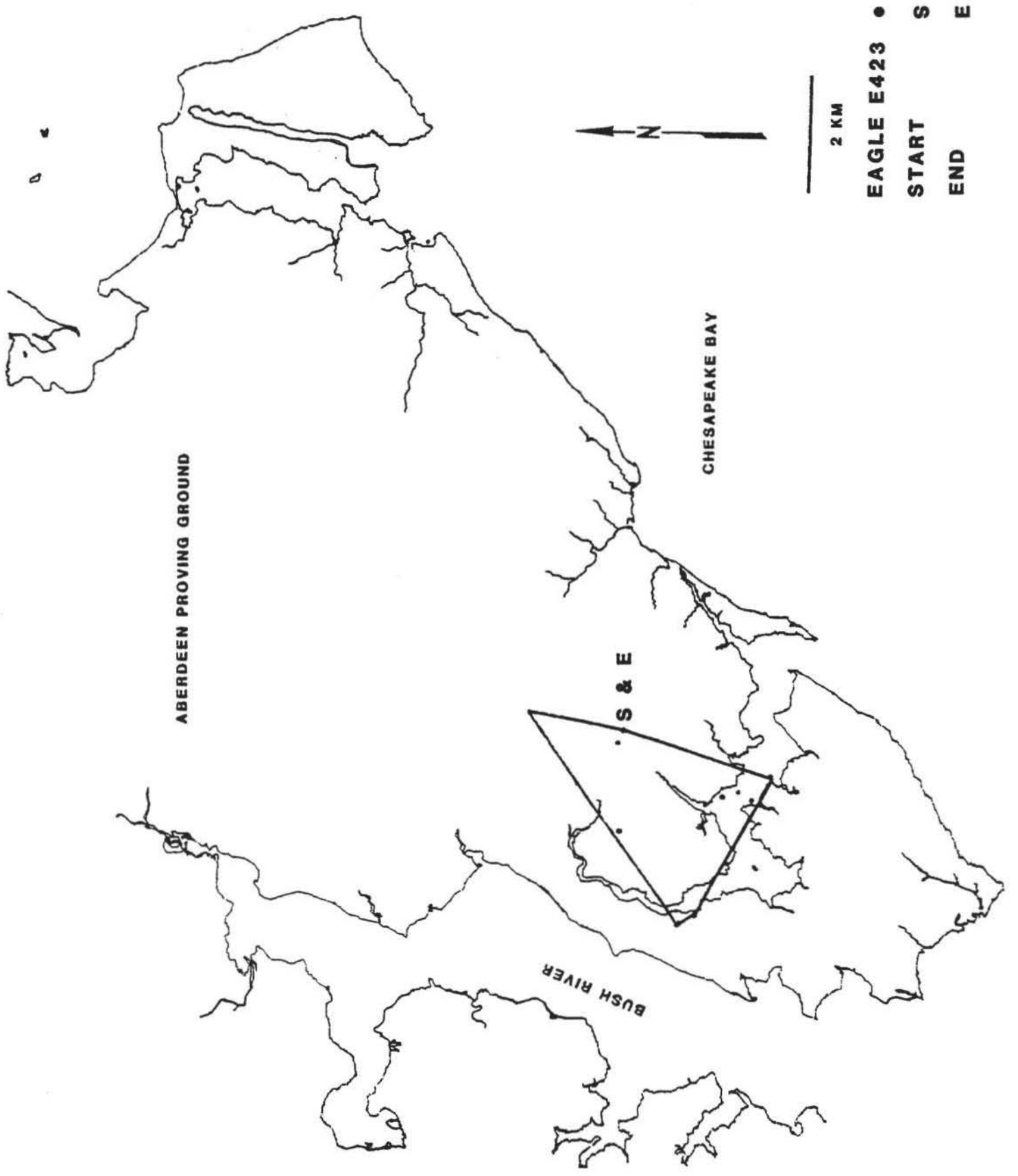


Figure 45. Locations and area of use convex polygons from all-day tracking of eagle E522 on 22 Apr 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

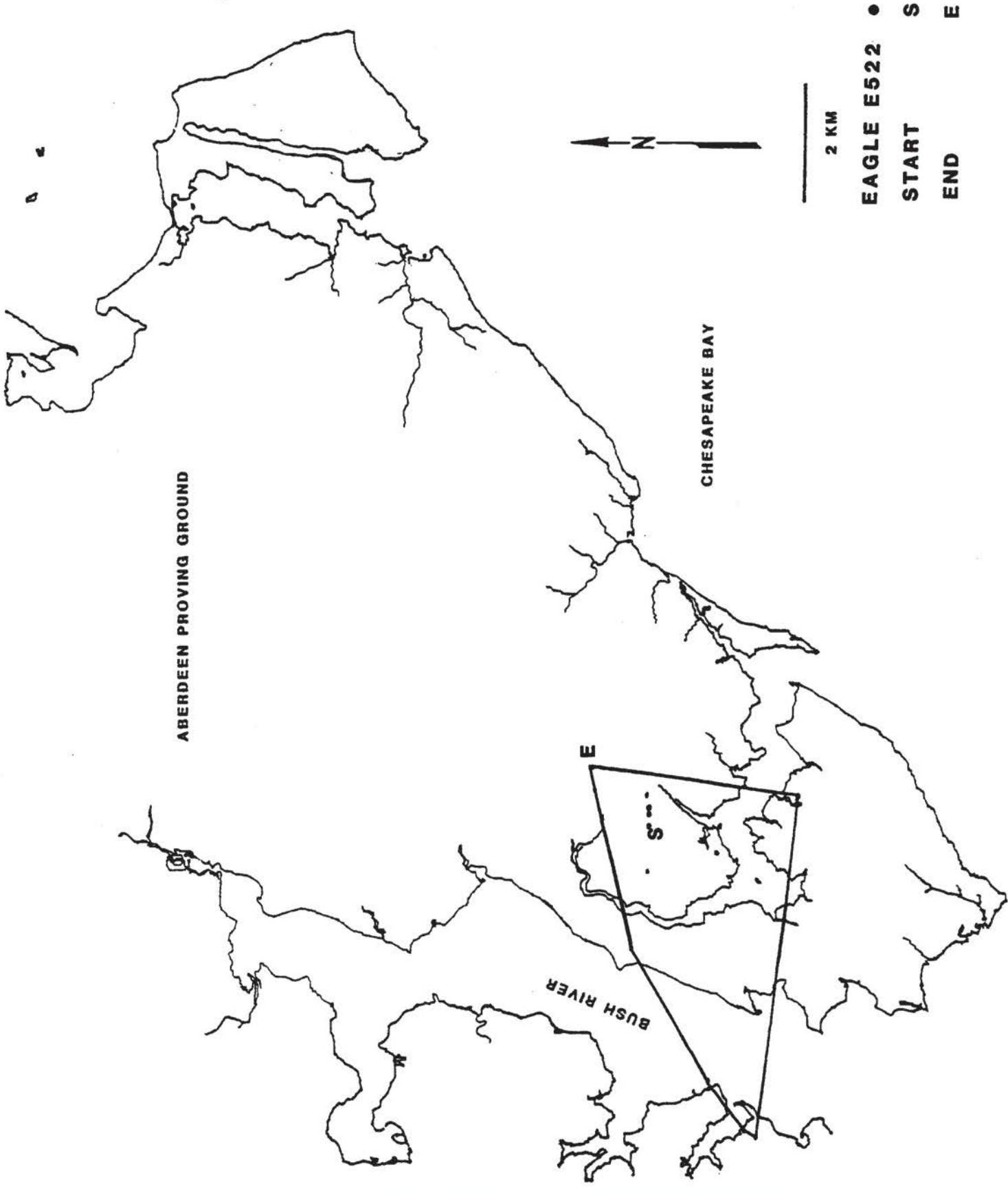


Figure 46. Locations and area of use convex polygons from all-day tracking of eagle E522 on 24 Apr 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

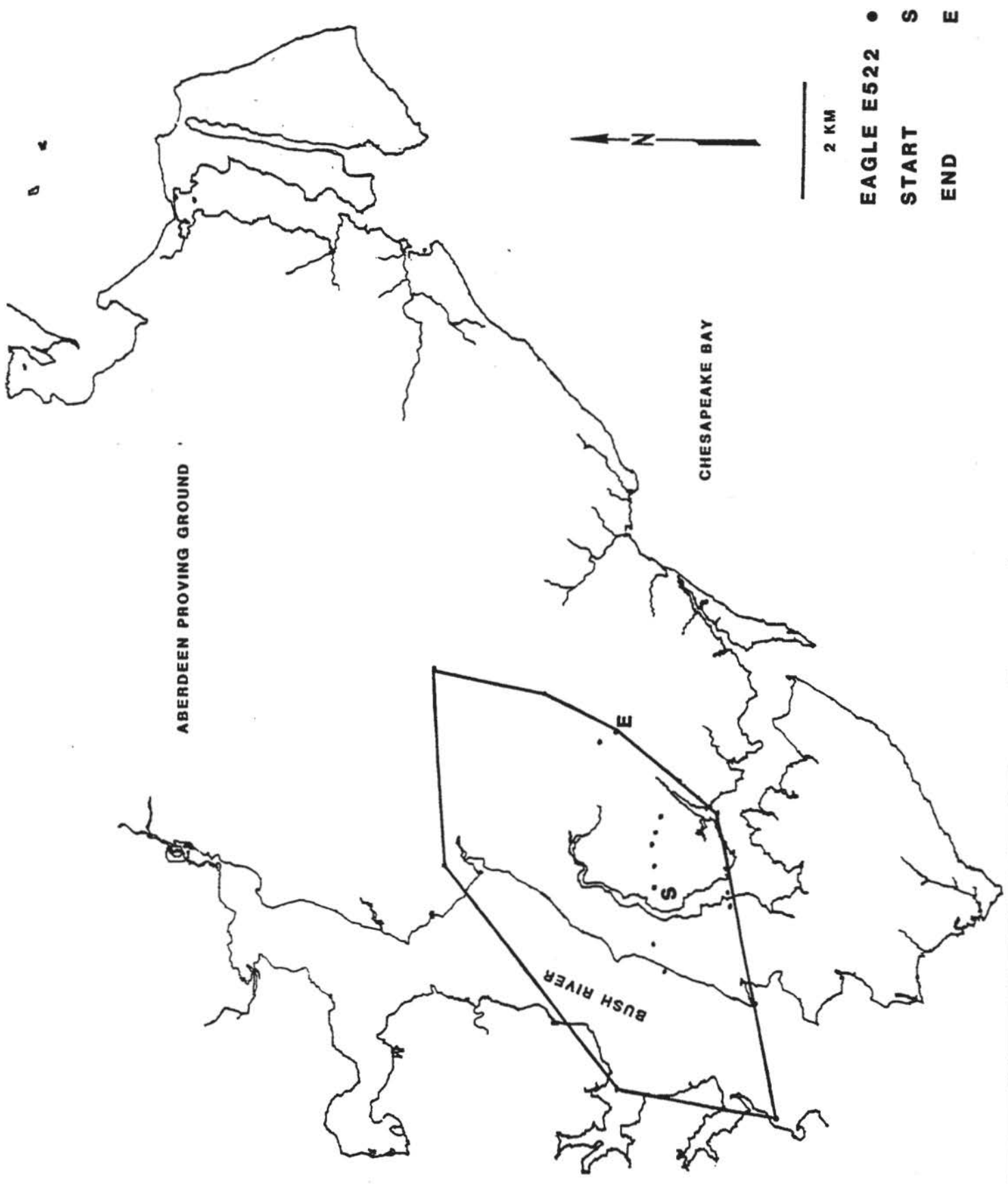


Figure 47. Locations and area of use convex polygons from all-day tracking of eagle E522 on 26 Apr 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

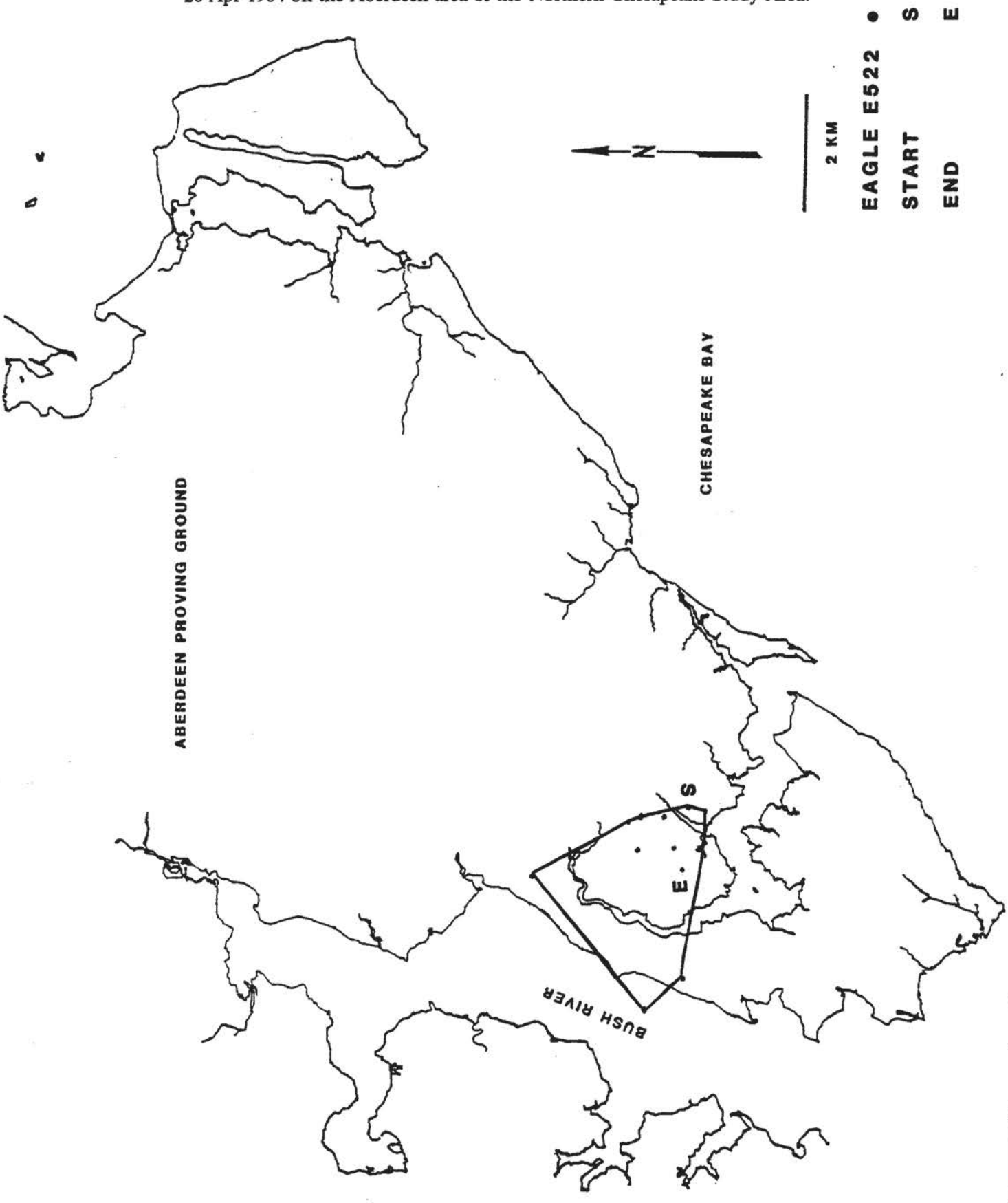


Figure 48. Locations and area of use convex polygons from all-day tracking of eagle E544 on 27 Jul 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

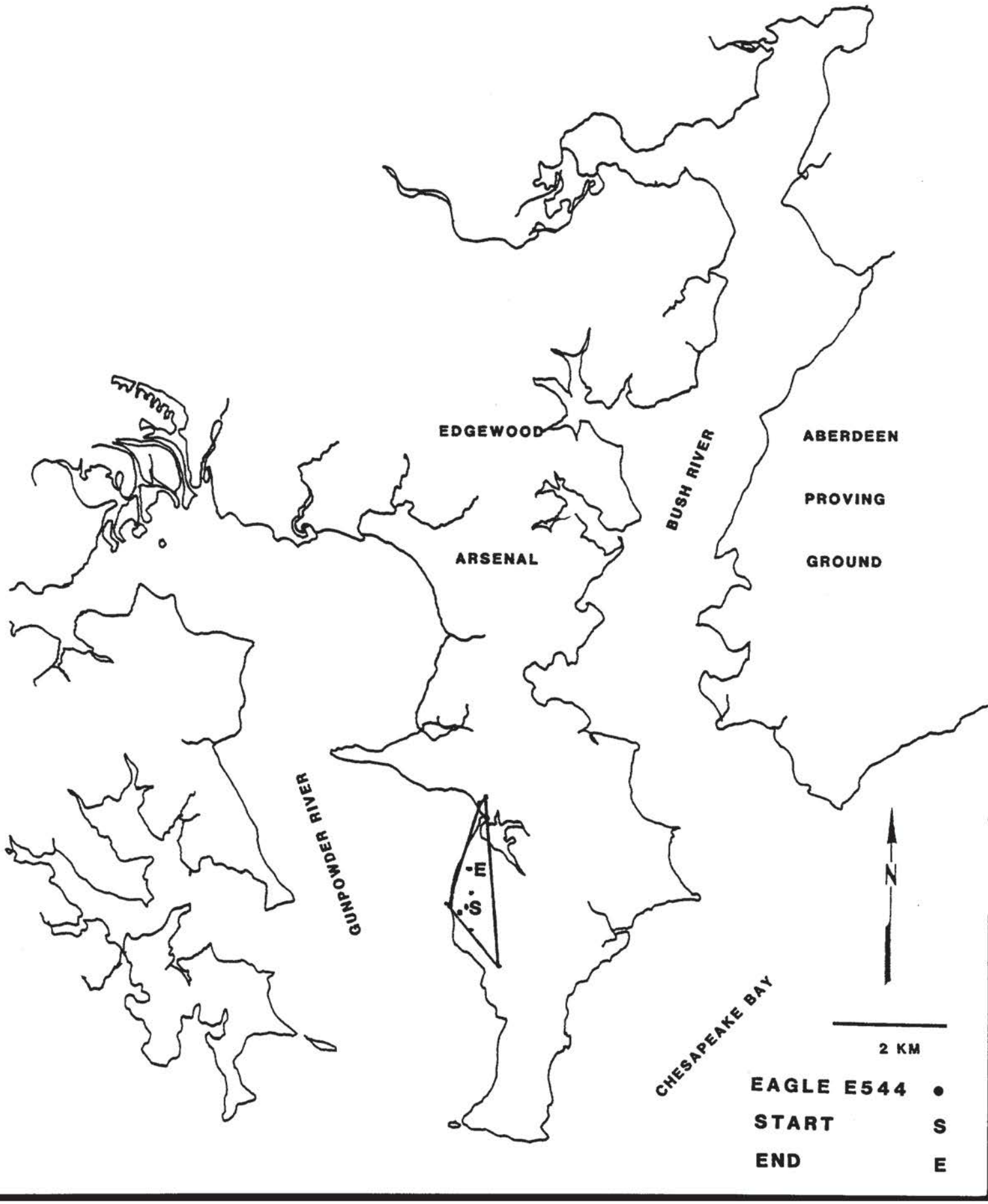


Figure 49. Locations and area of use convex polygons from all-day tracking of eagle E552 on 16 Mar 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

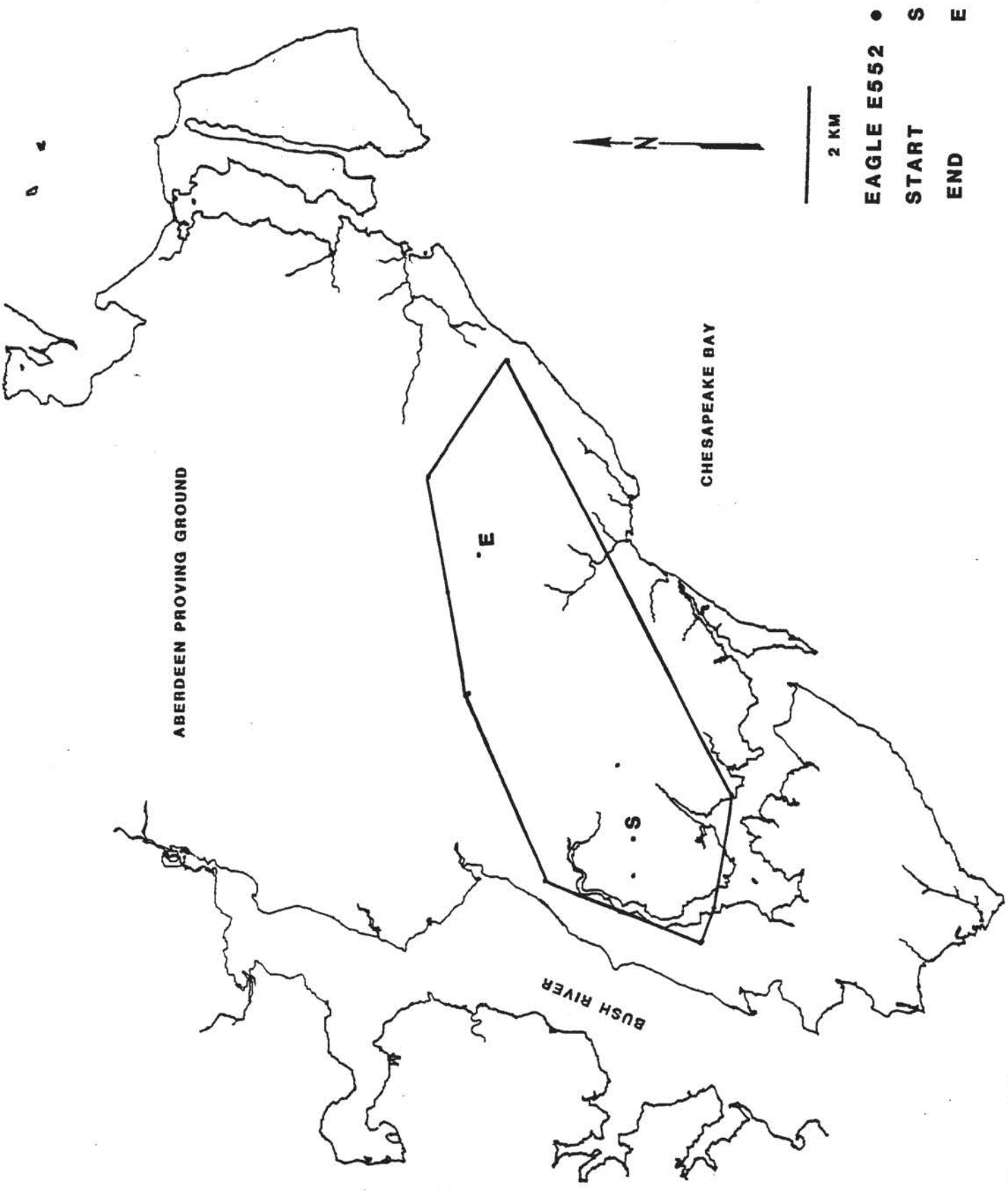


Figure 50. Locations and area of use convex polygons from all-day tracking of eagle E552 on 27 Mar 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

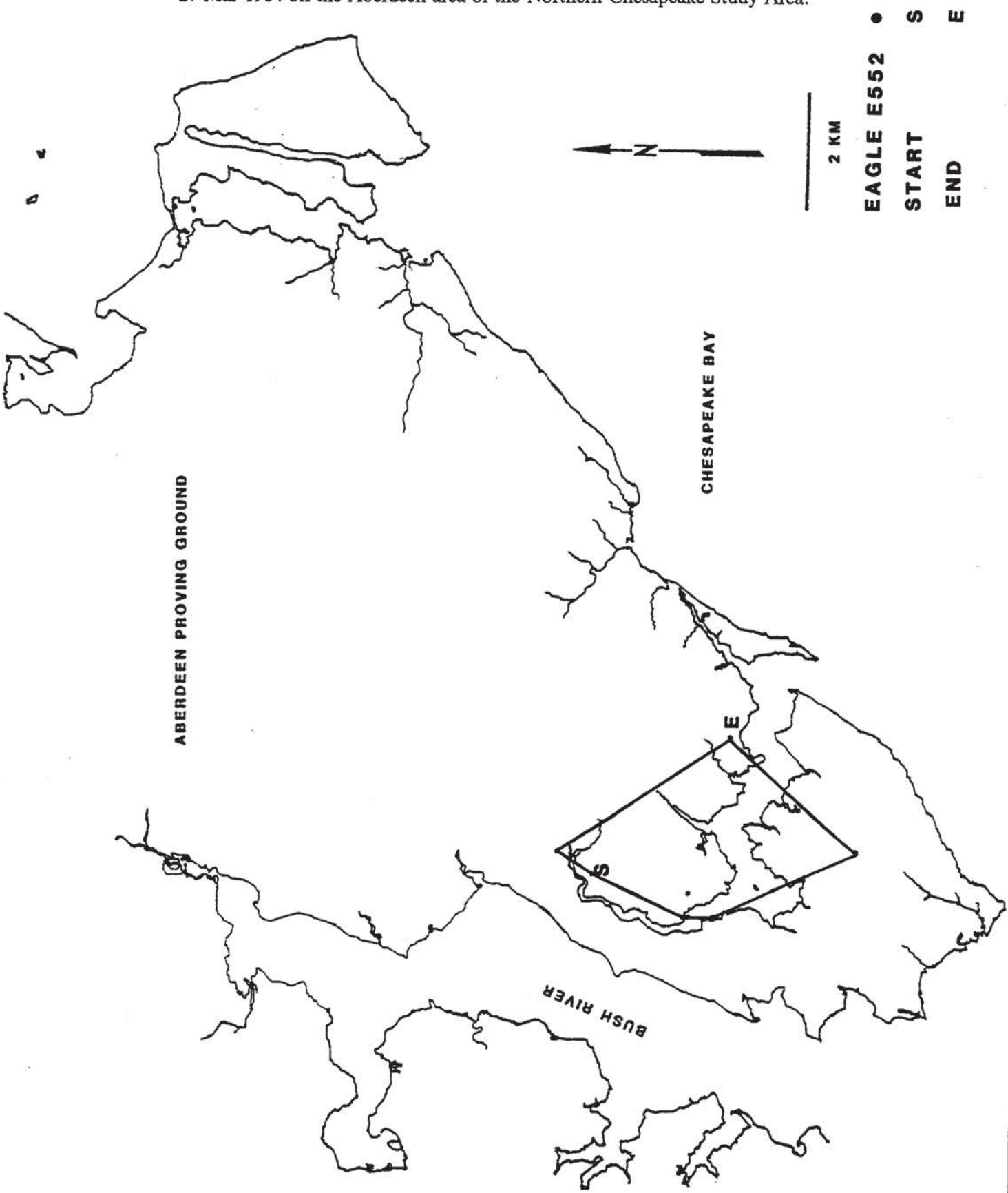


Figure 51. Locations and area of use convex polygons from all-day tracking of eagle E641 on 26 Jun 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

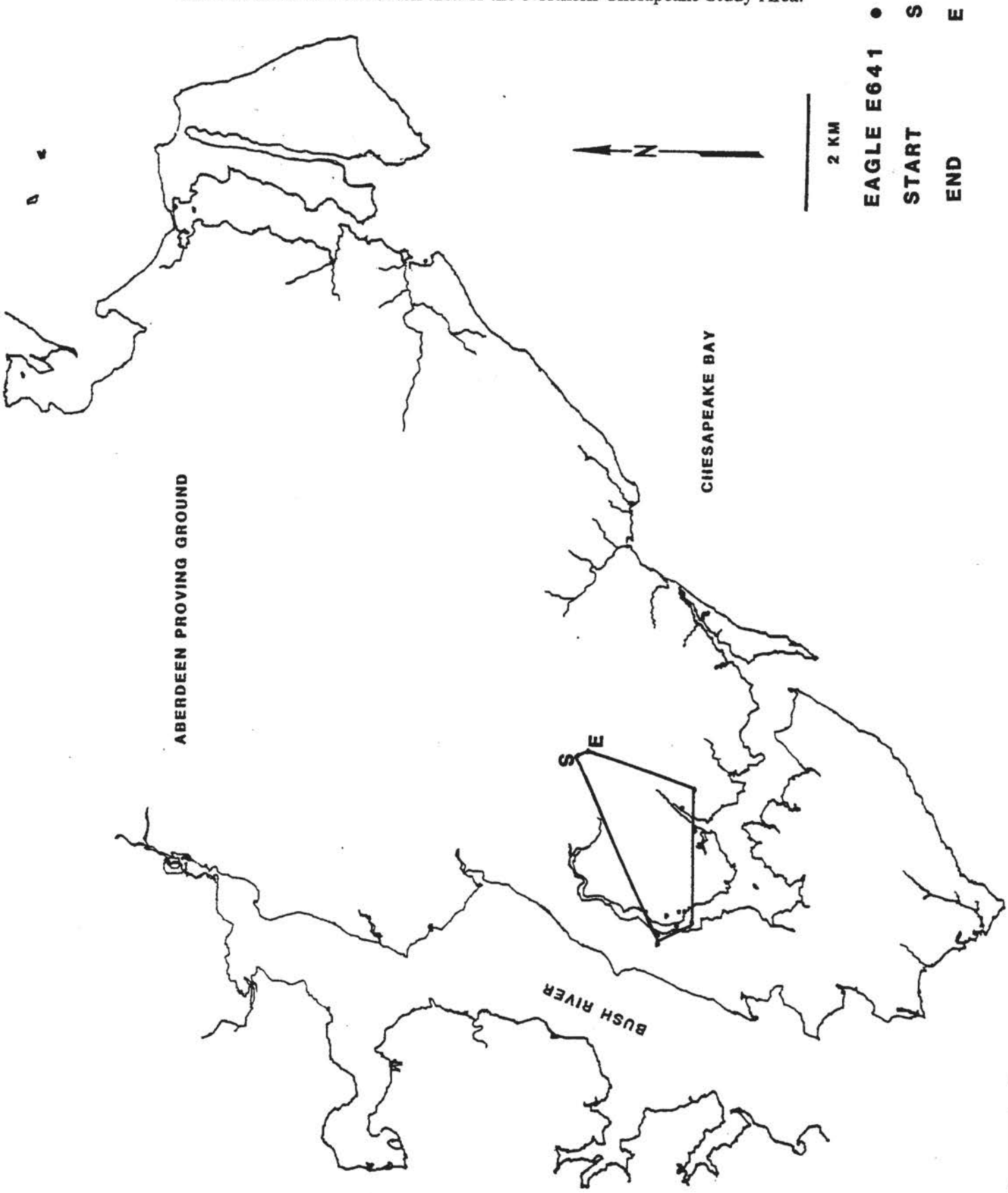


Figure 52. Locations and area of use convex polygons from all-day tracking of eagle E641 on 28 Jun 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

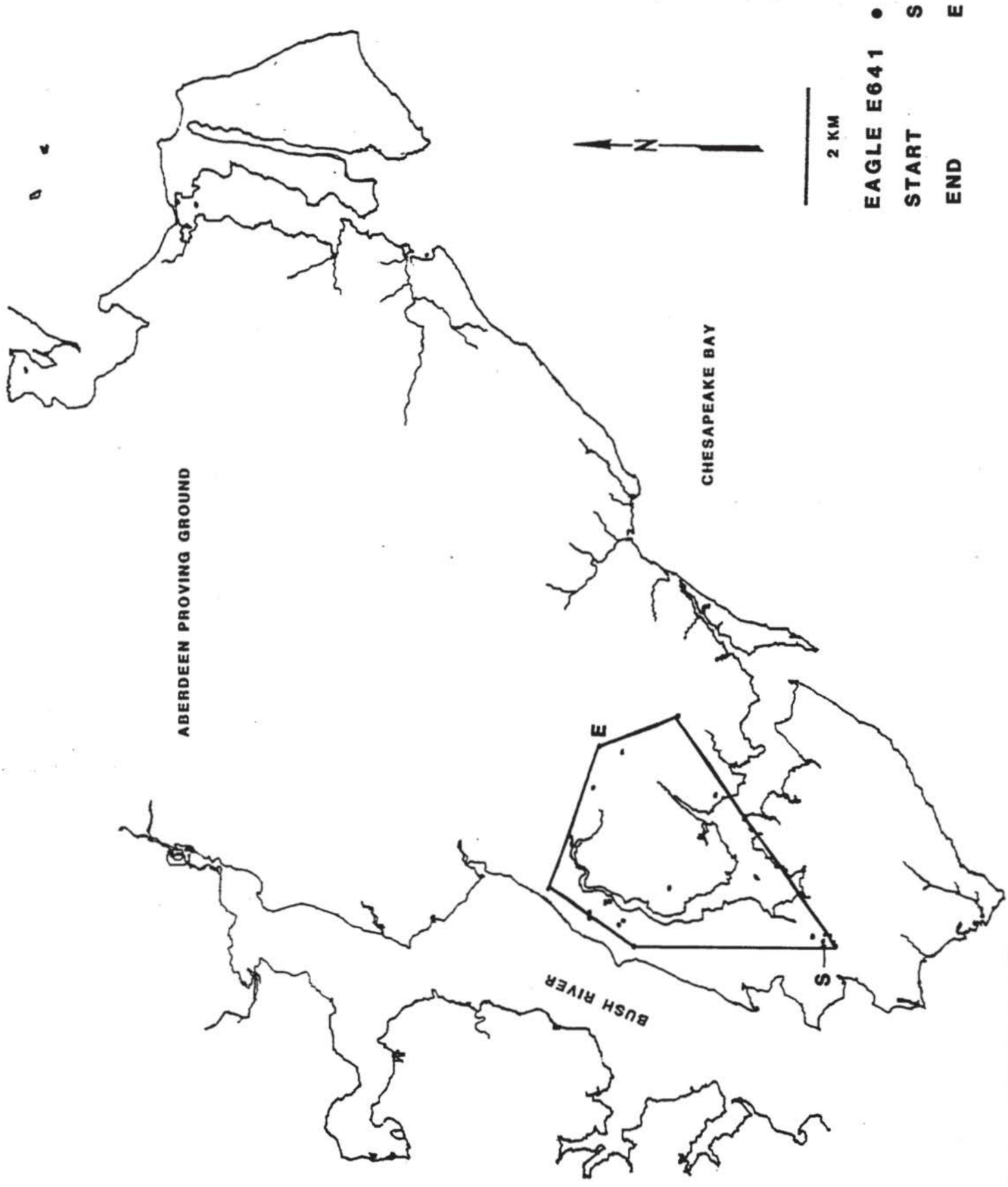


Figure 53. Locations and area of use convex polygons from all-day tracking of eagle E641 on 1 Jul 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

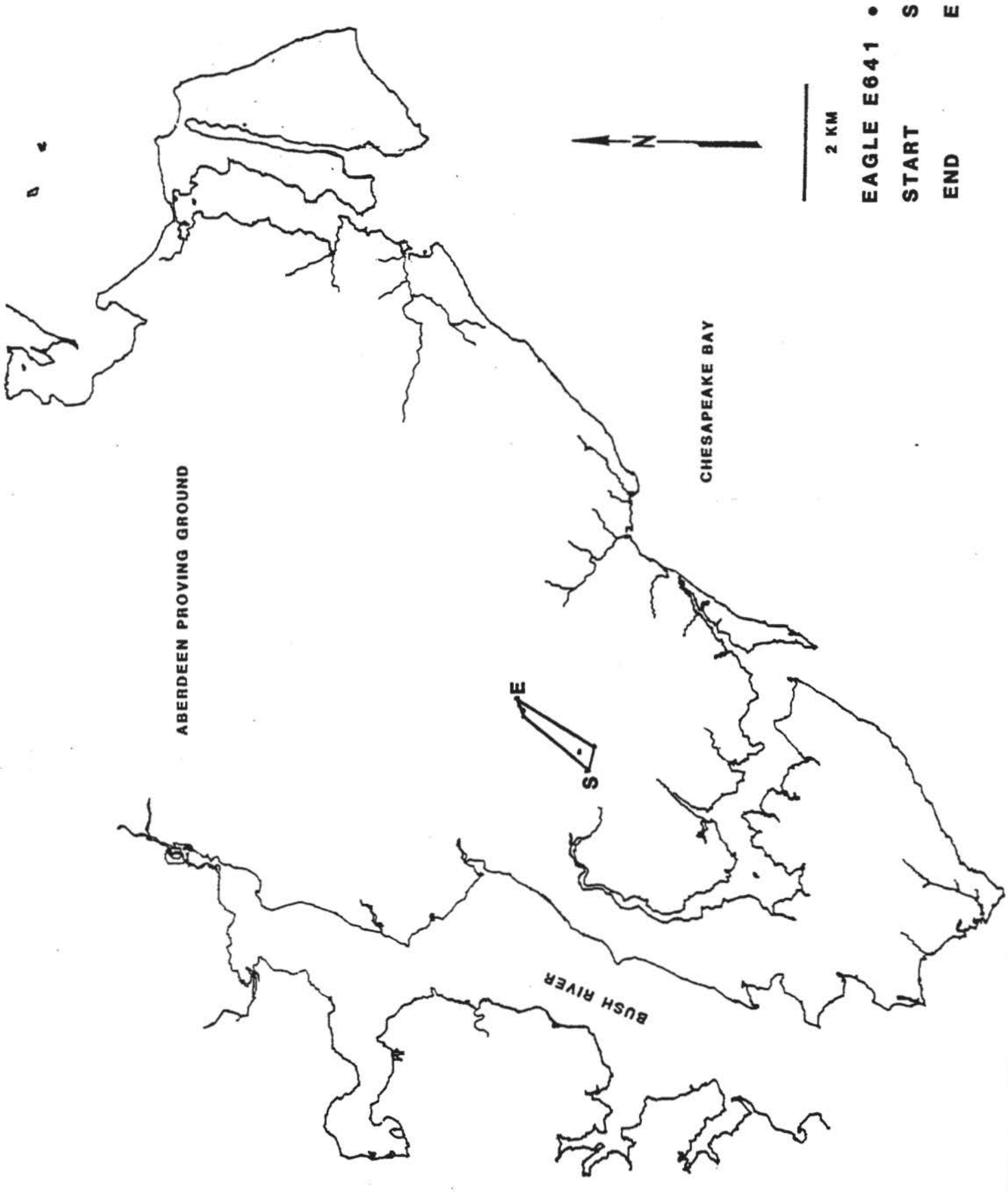


Figure 54. Locations and area of use convex polygons from all-day tracking of eagle E641 on 3 Jul 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

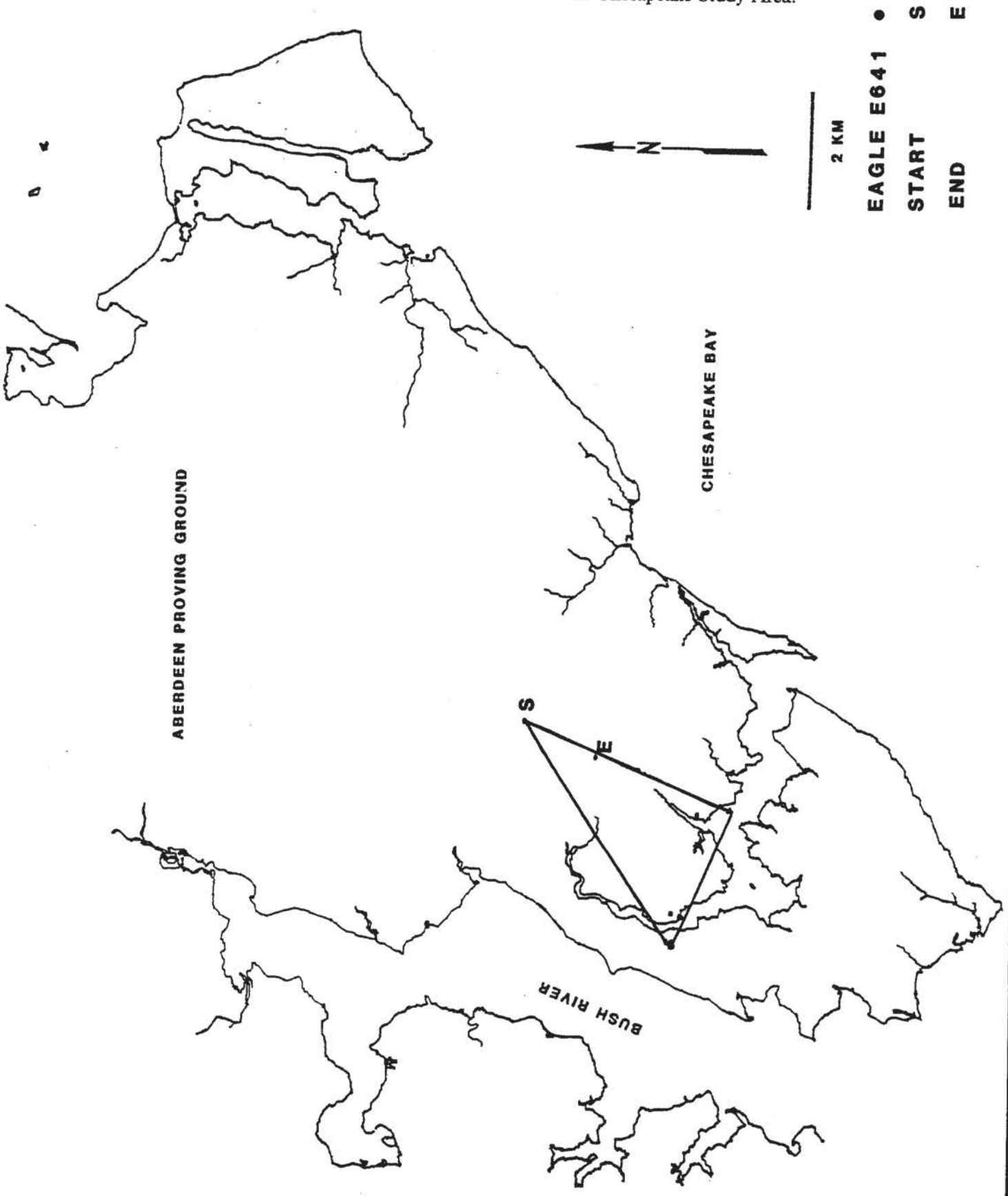


Figure 55. Locations and area of use convex polygons from all-day tracking of eagle E641 on 5 Jul 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

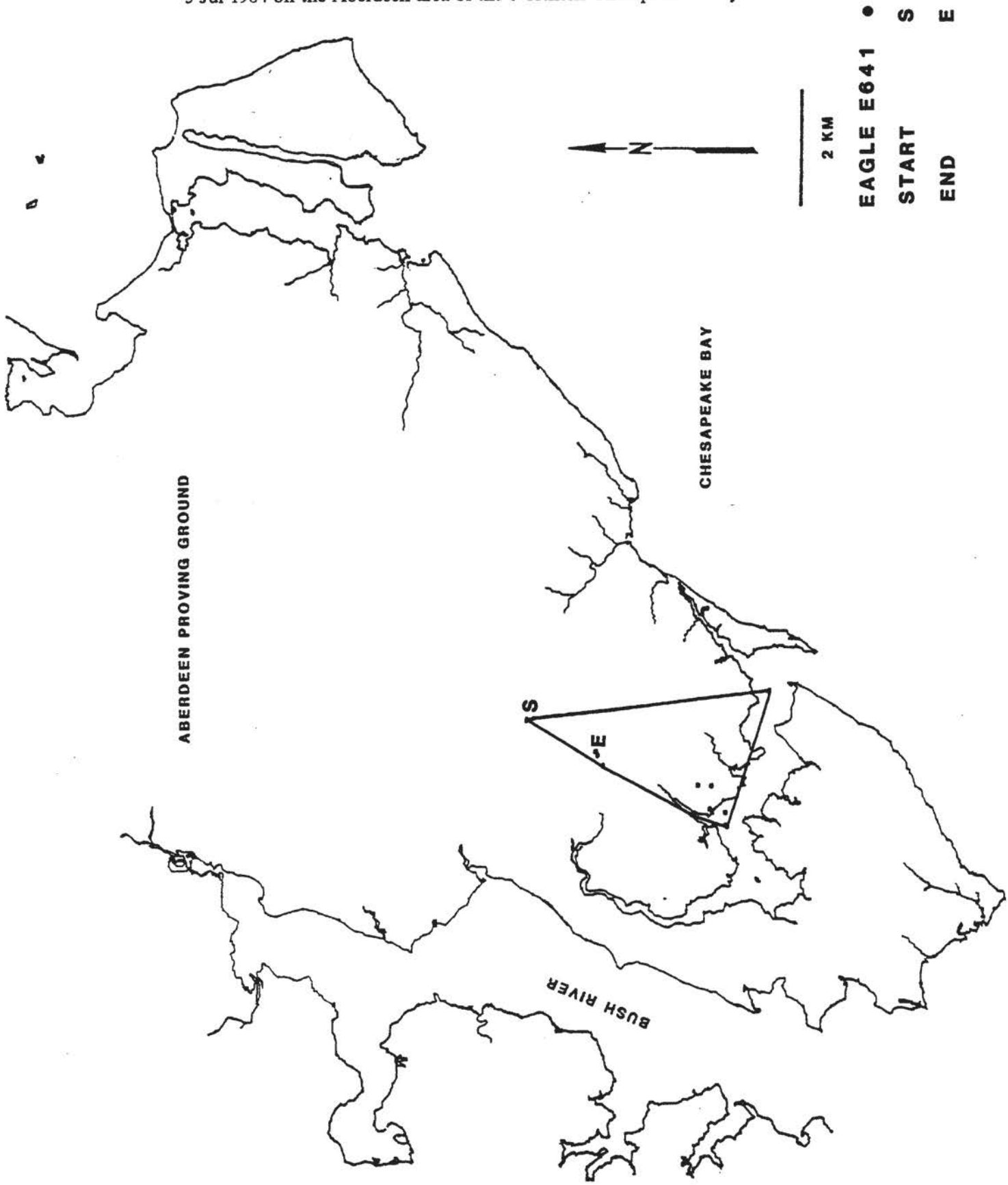


Figure 56. Locations and area of use convex polygons from all-day tracking of eagle E641 on 8 Jul 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

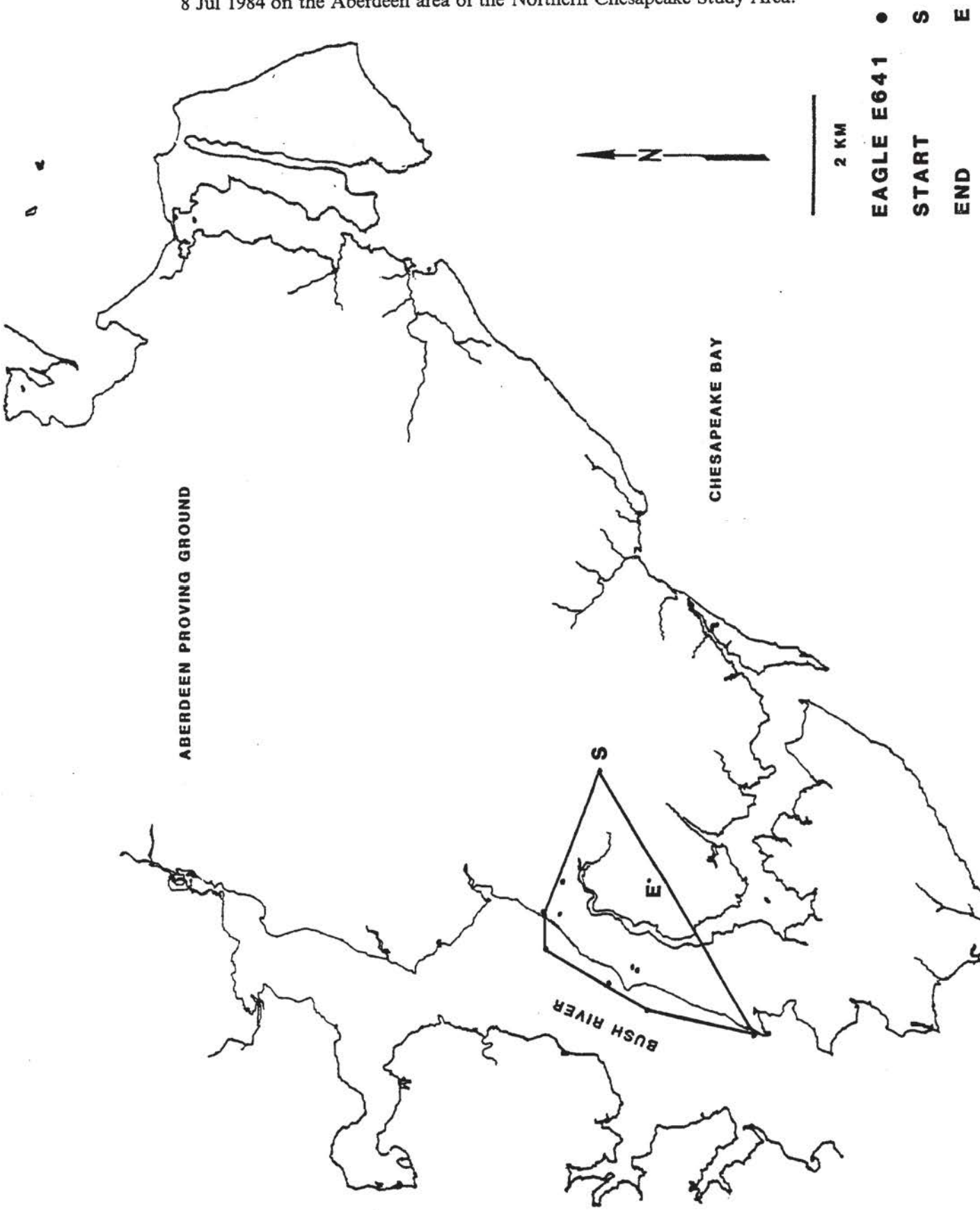


Figure 57. Locations and area of use convex polygons from all-day tracking of eagle E641 on 10 Jul 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

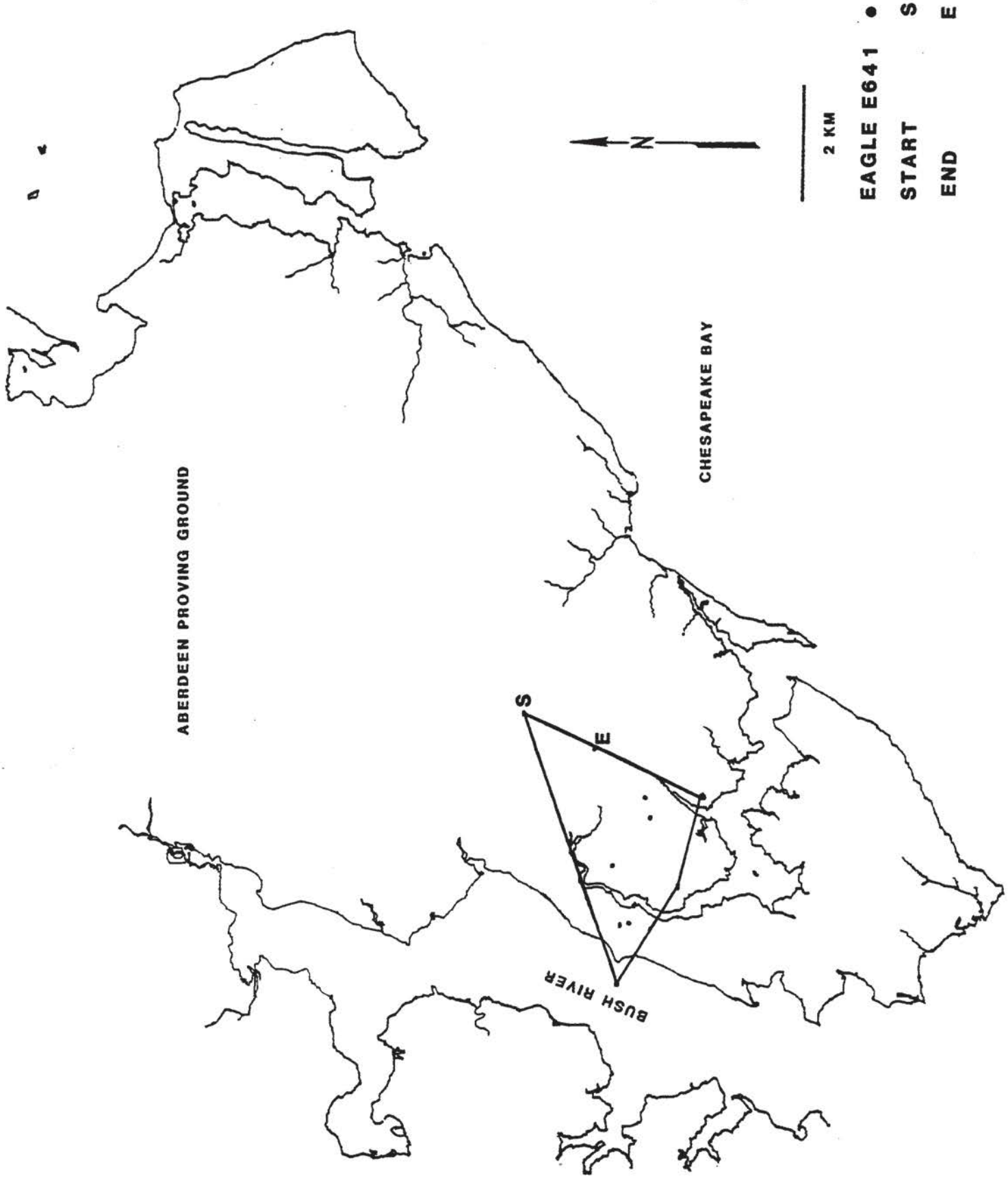


Figure 58. Locations and area of use convex polygons from all-day tracking of eagle E641 on 15 Jul 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

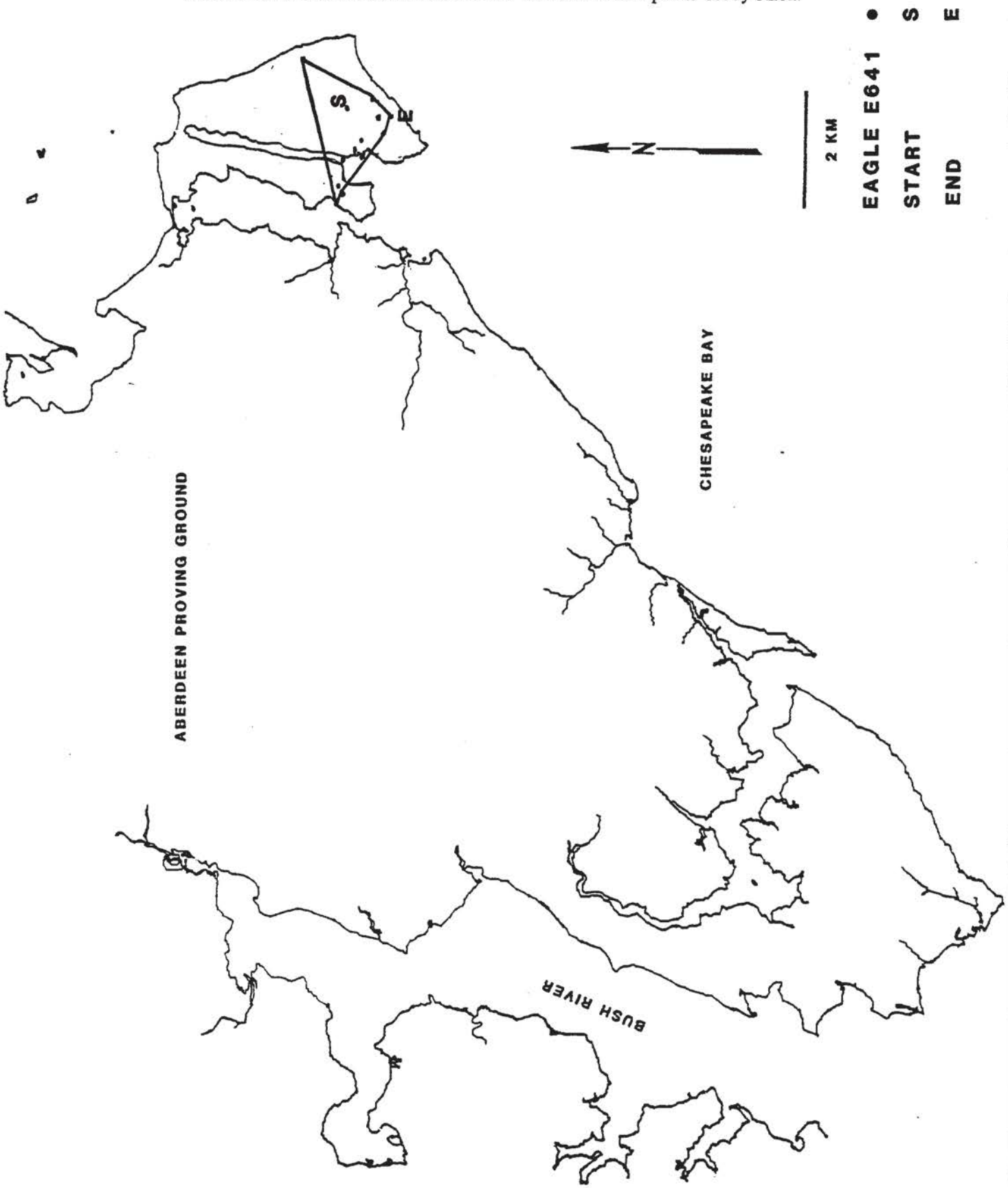


Figure 59. Locations and area of use convex polygons from all-day tracking of eagle E641 on 17 Jul 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

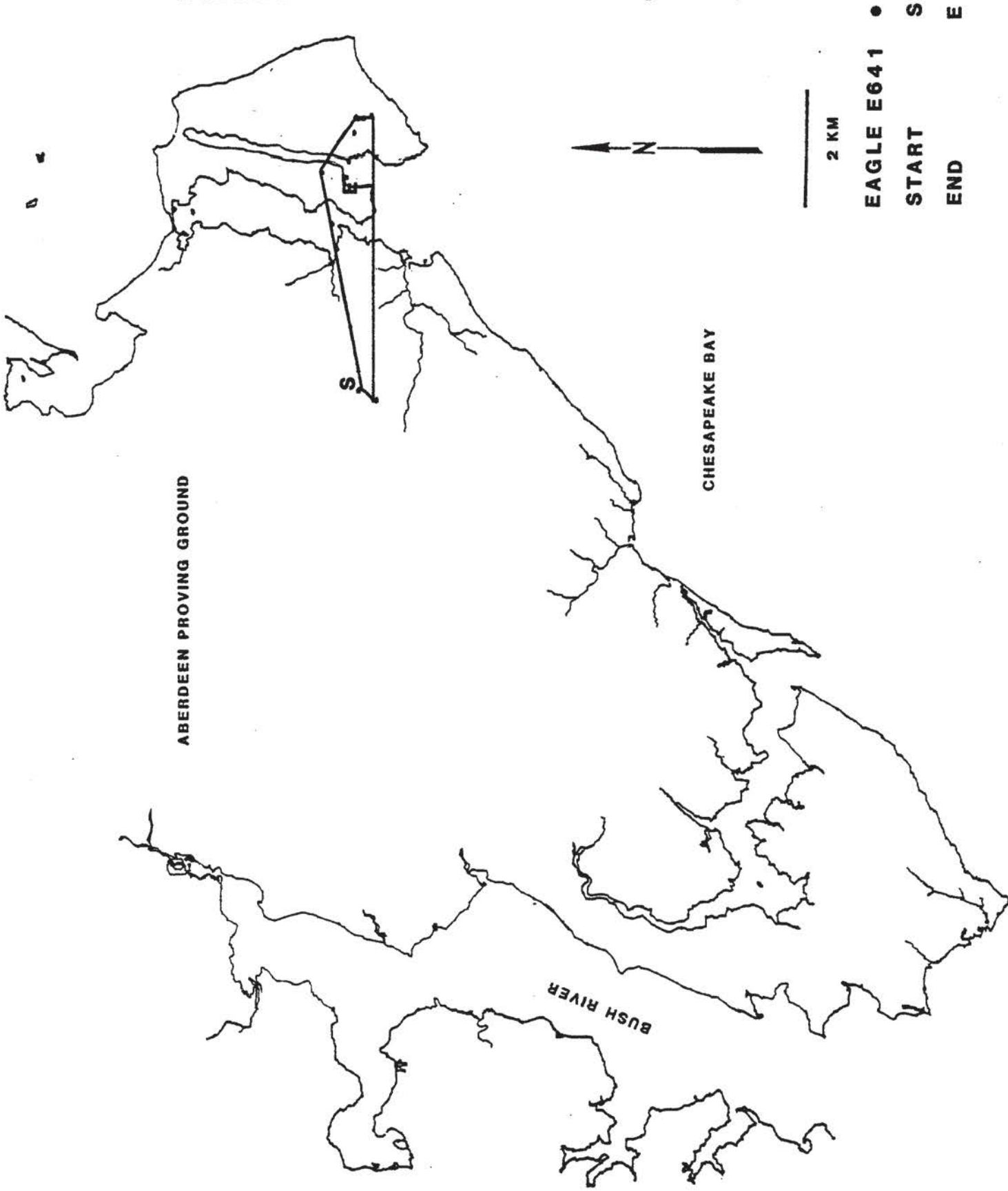


Figure 60. Locations and area of use convex polygons from all-day tracking of eagle E641 on 9 Aug 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

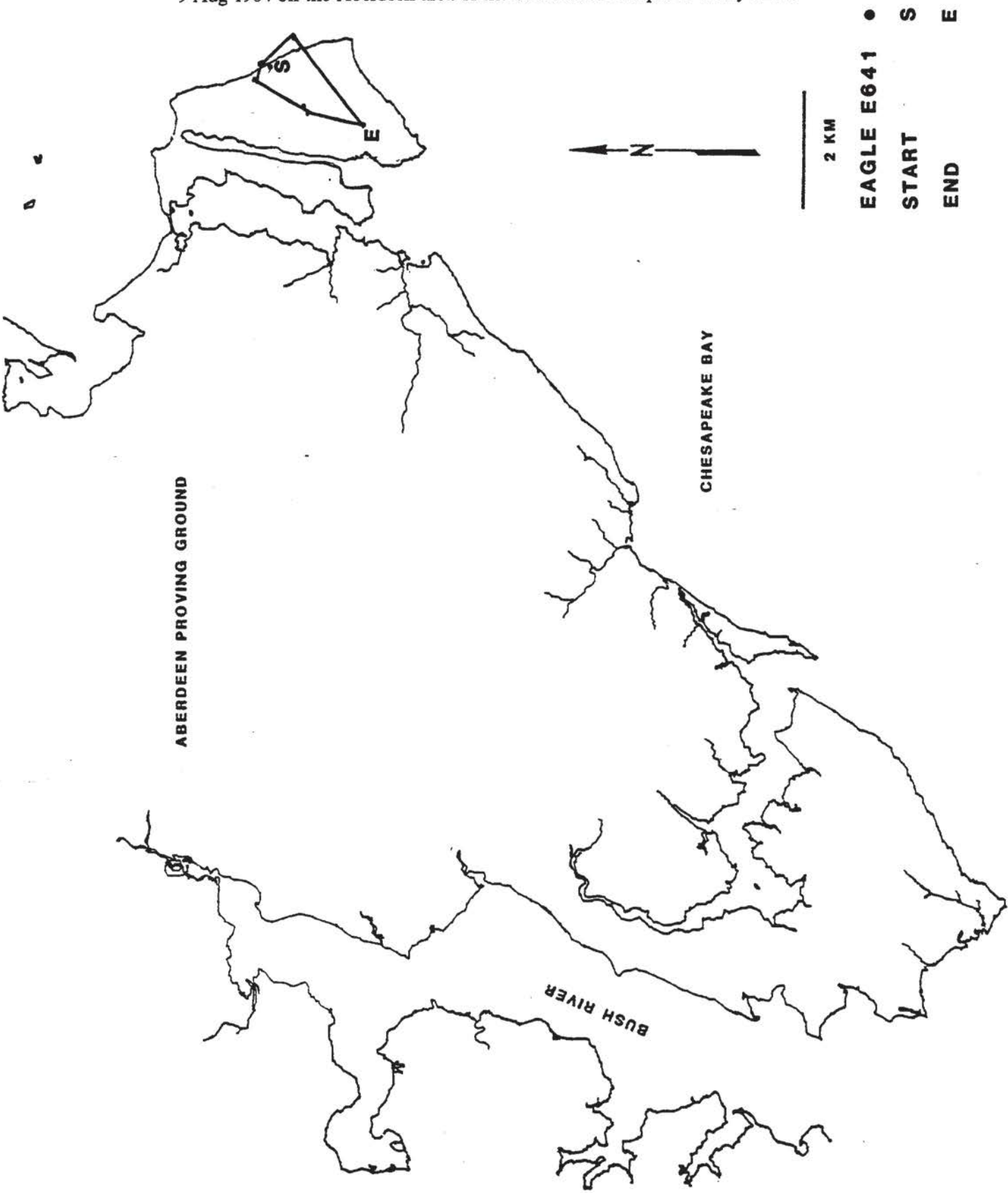


Figure 61. Locations and area of use convex polygons from all-day tracking of eagle E641 on 12 Aug 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

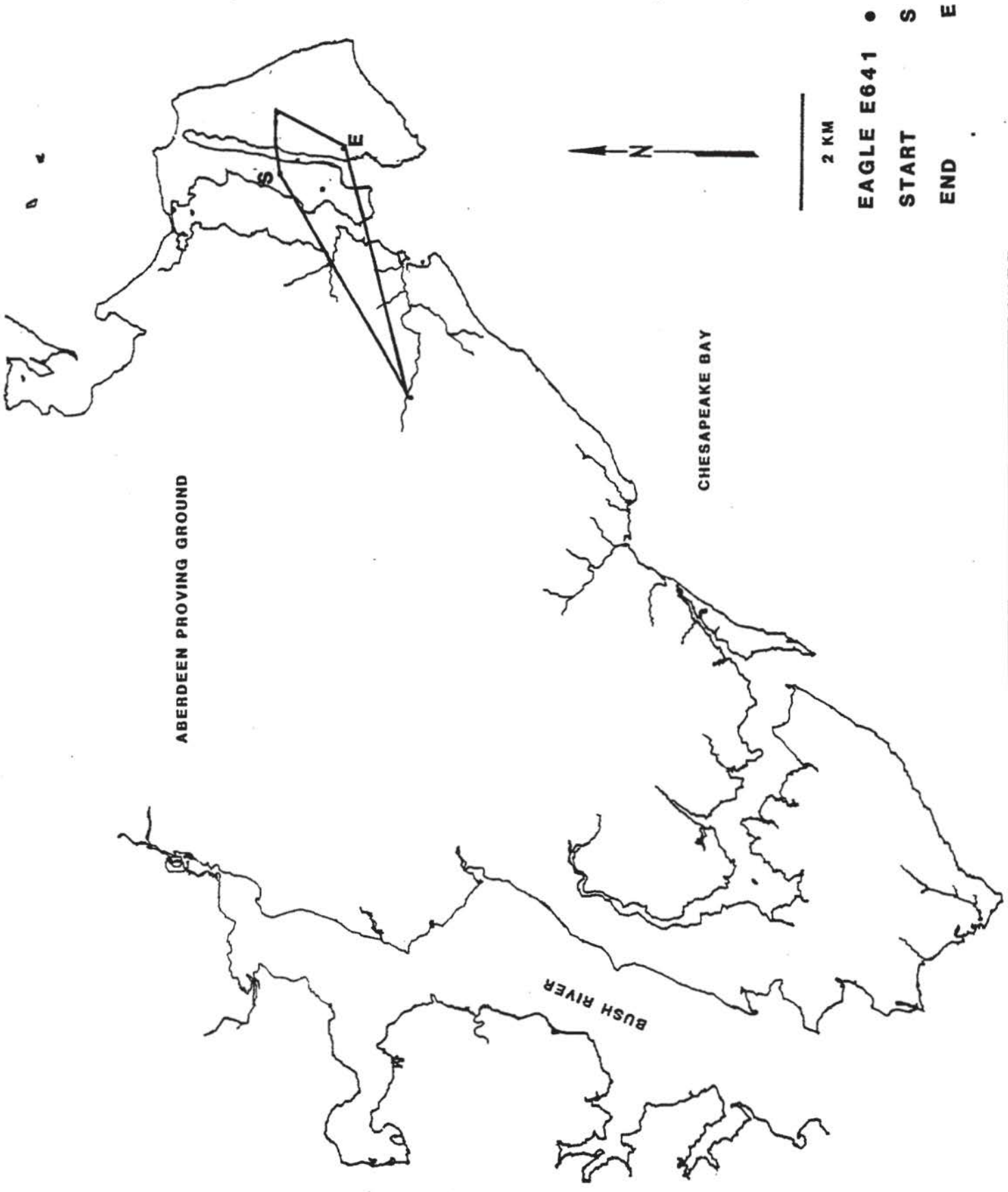


Figure 62. Locations and area of use convex polygons from all-day tracking of eagle E700 on 6 Jun 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

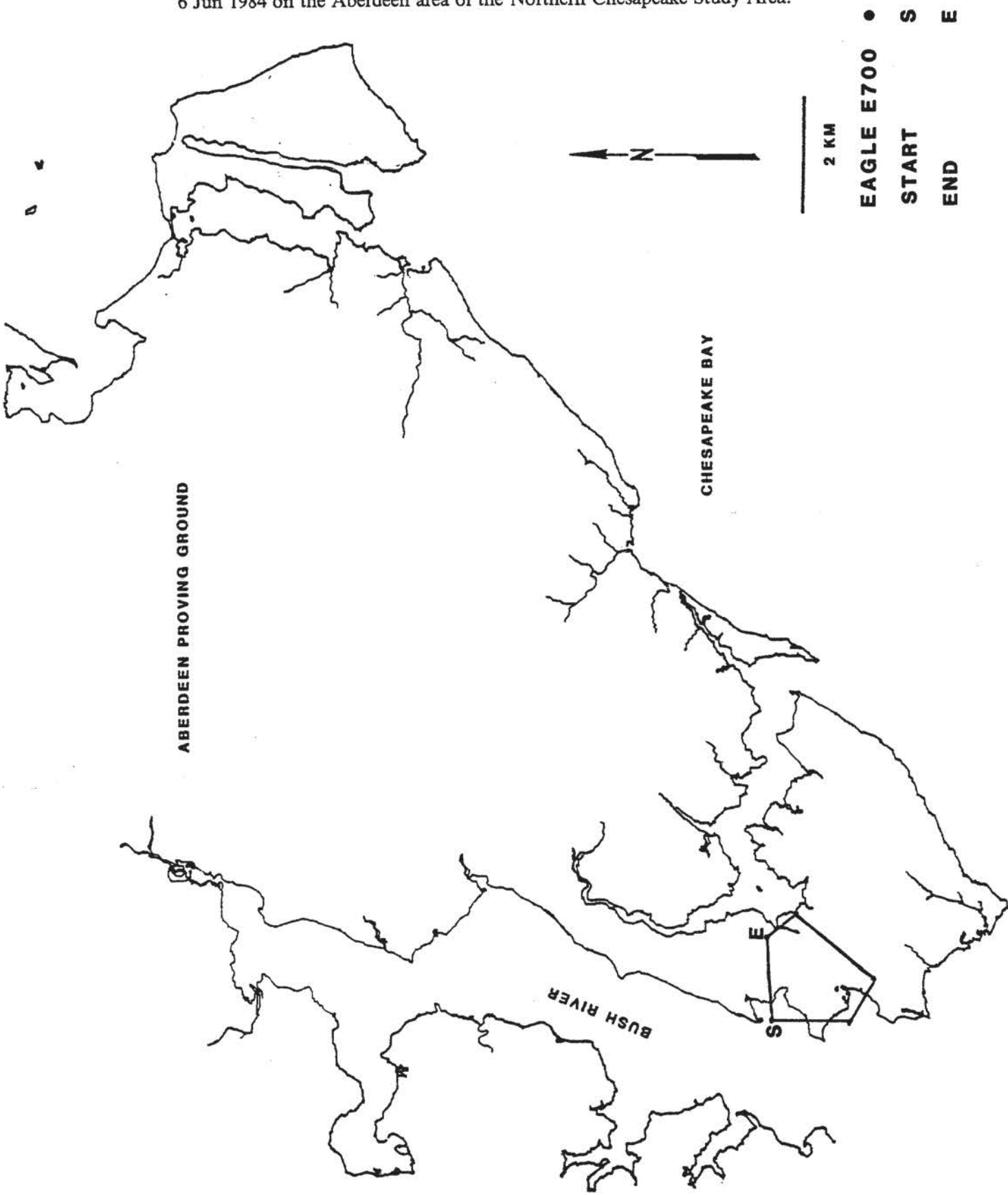


Figure 63. Locations and area of use convex polygons from all-day tracking of eagle E700 on 14 Jun 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

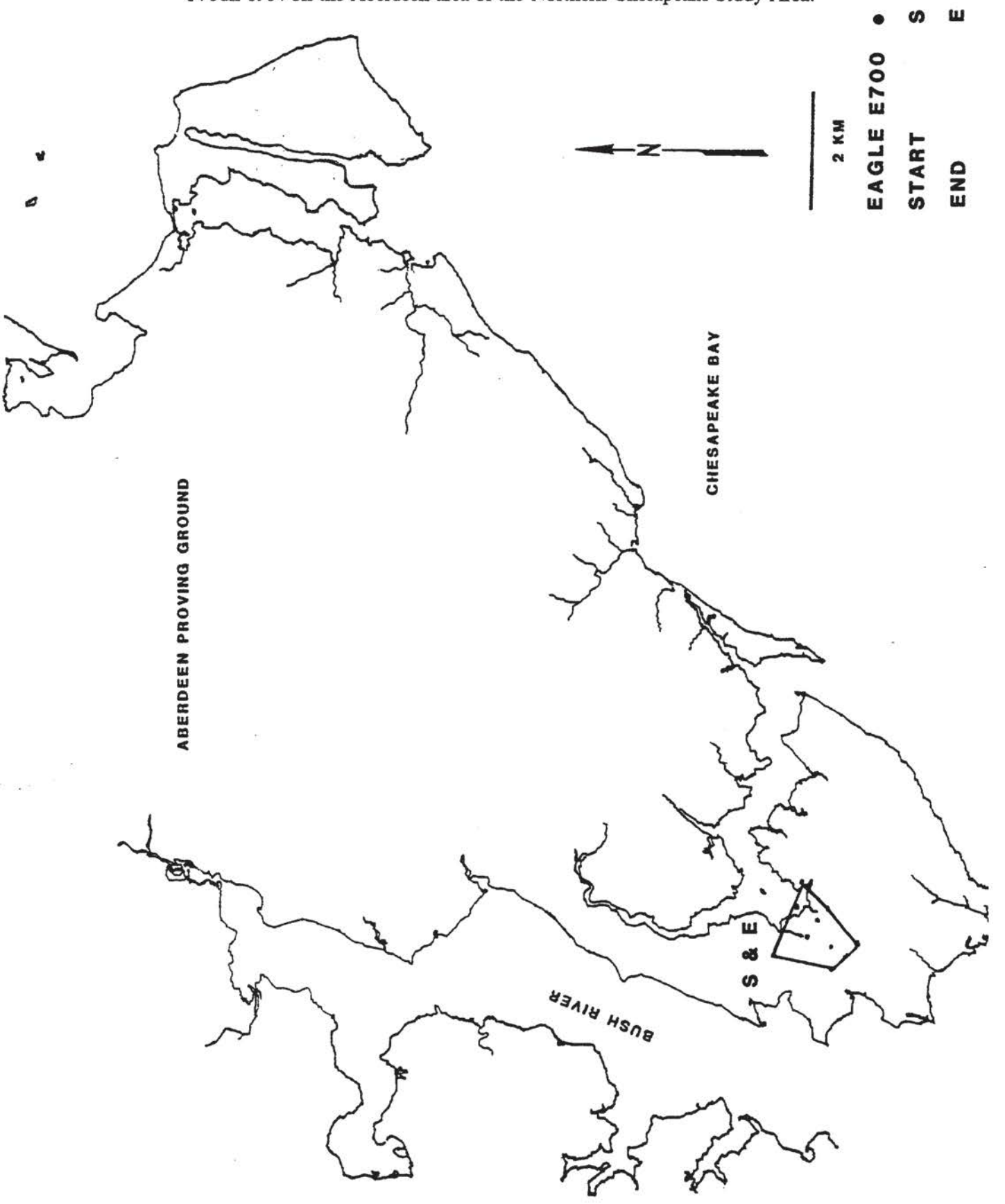


Figure 64. Locations and area of use convex polygons from all-day tracking of eagle E700 on 17 Jun 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

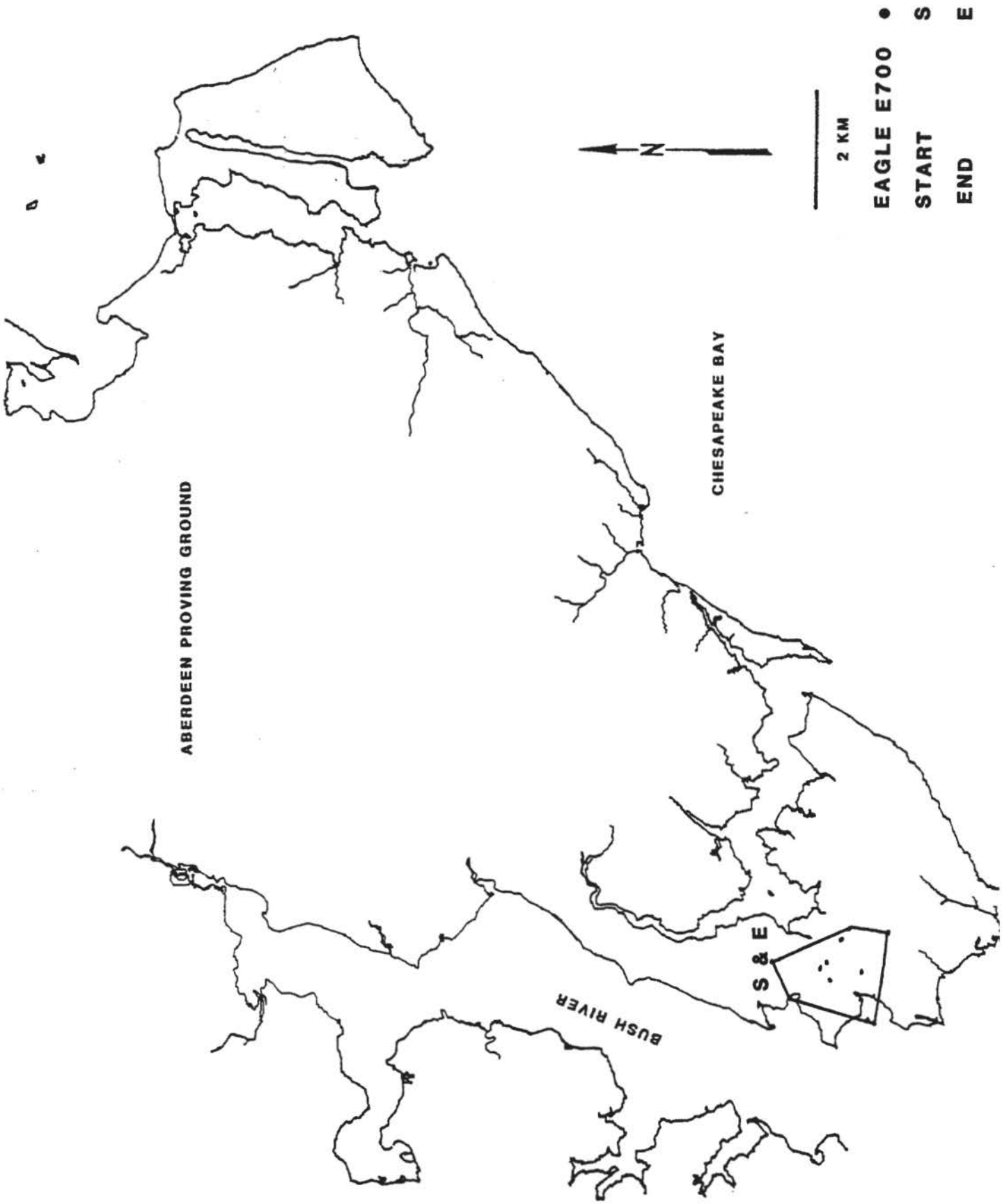


Figure 65. Locations and area of use convex polygons from all-day tracking of eagle E700 on 19 Jun 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

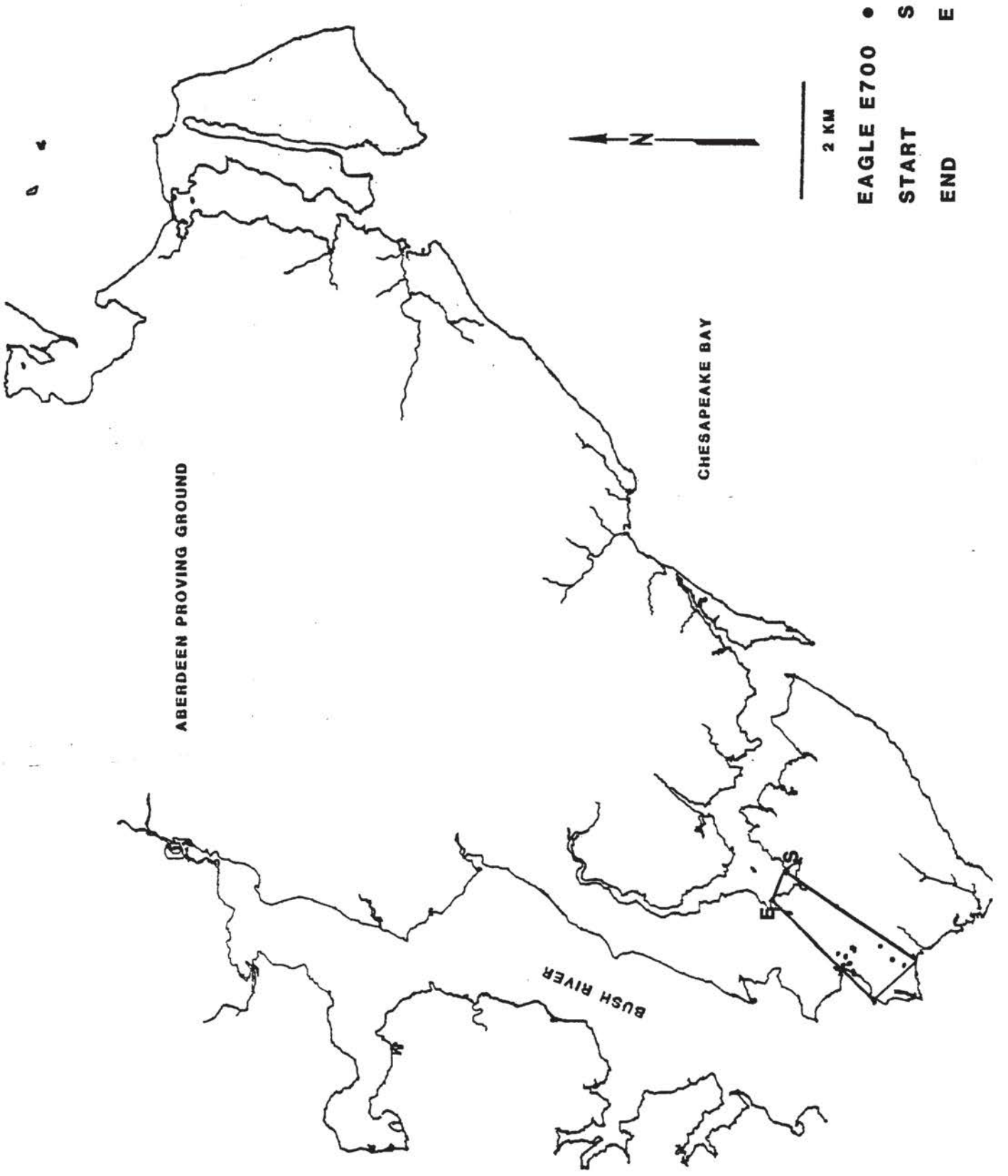


Figure 66. Locations and area of use convex polygons from all-day tracking of eagle E700 on 21 Jun 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

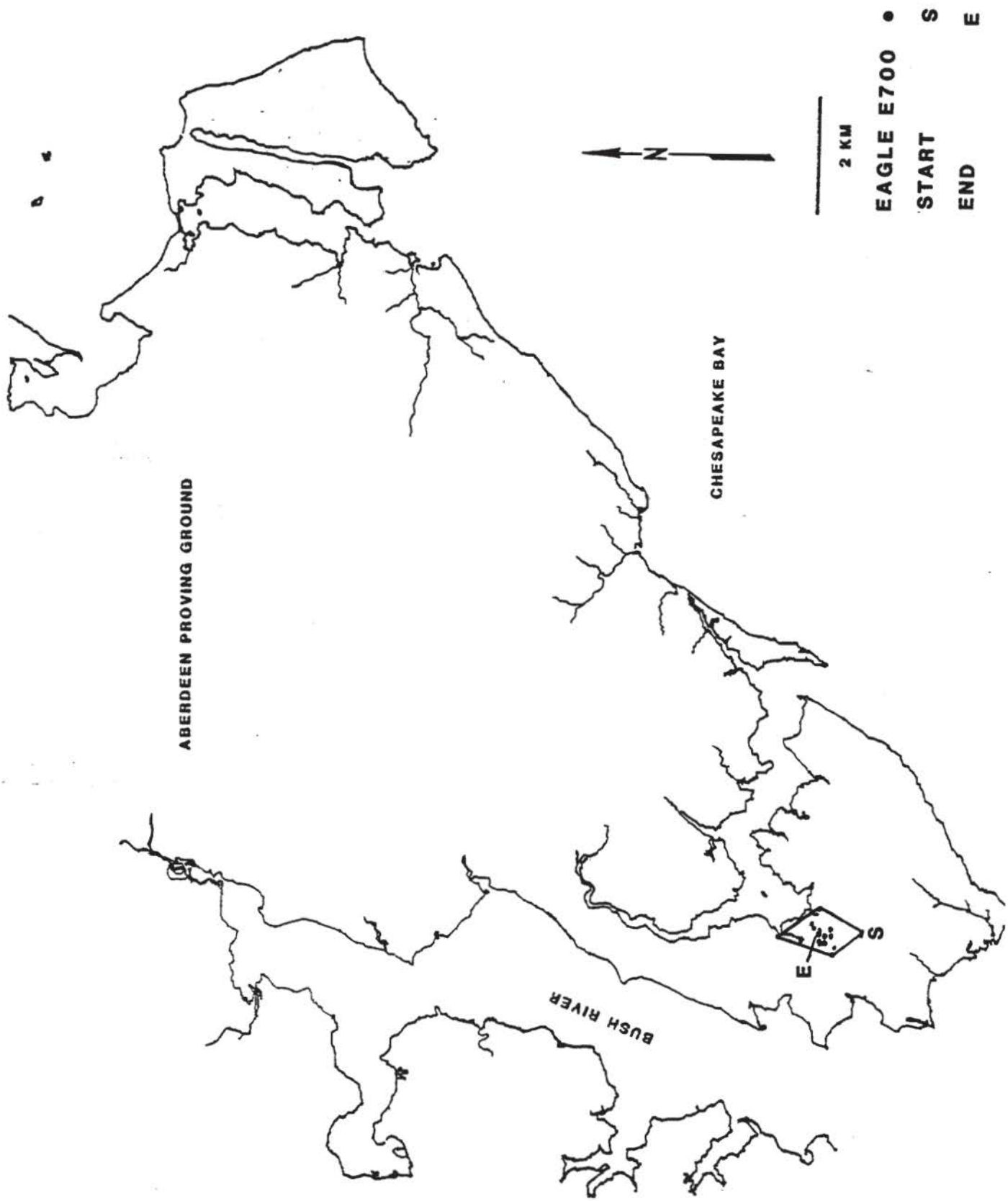


Figure 67. Locations and area of use convex polygons from all-day tracking of eagle E842 on 31 Aug 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

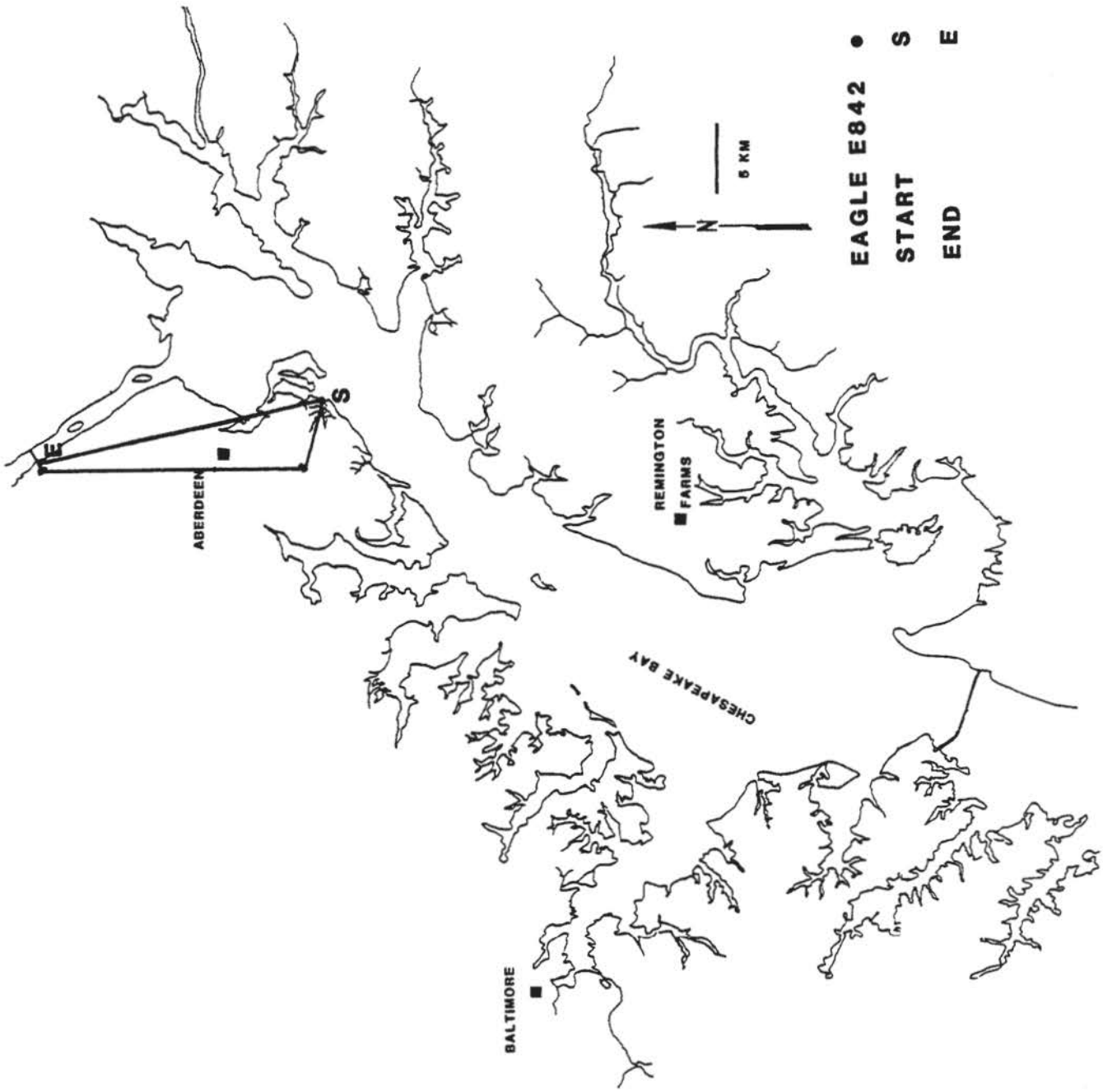


Figure 68. Locations and area of use convex polygons from all-day tracking of eagle E842 on 7 Aug 1984 on the Aberdeen area of the Northern Chesapeake Study Area.

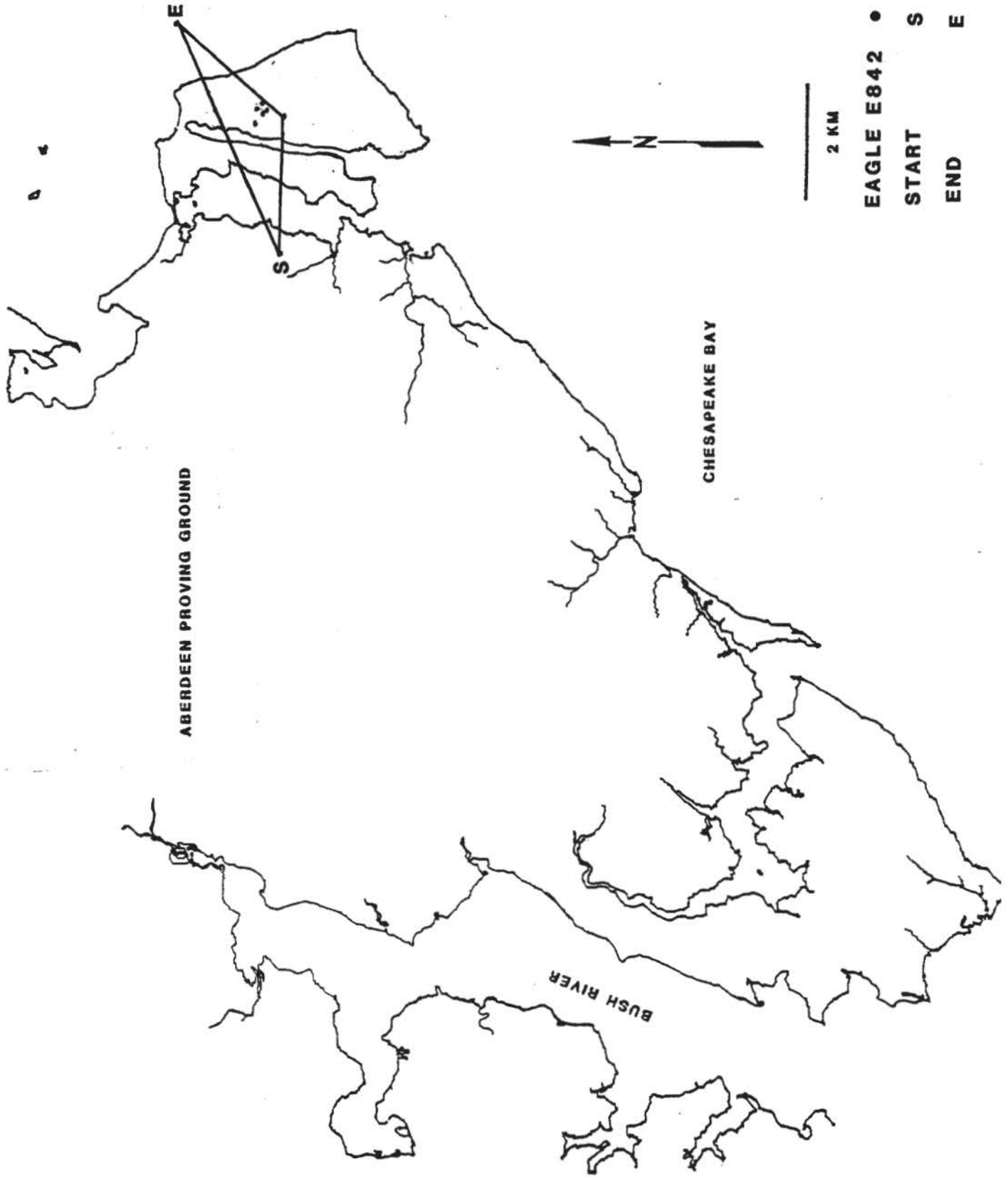
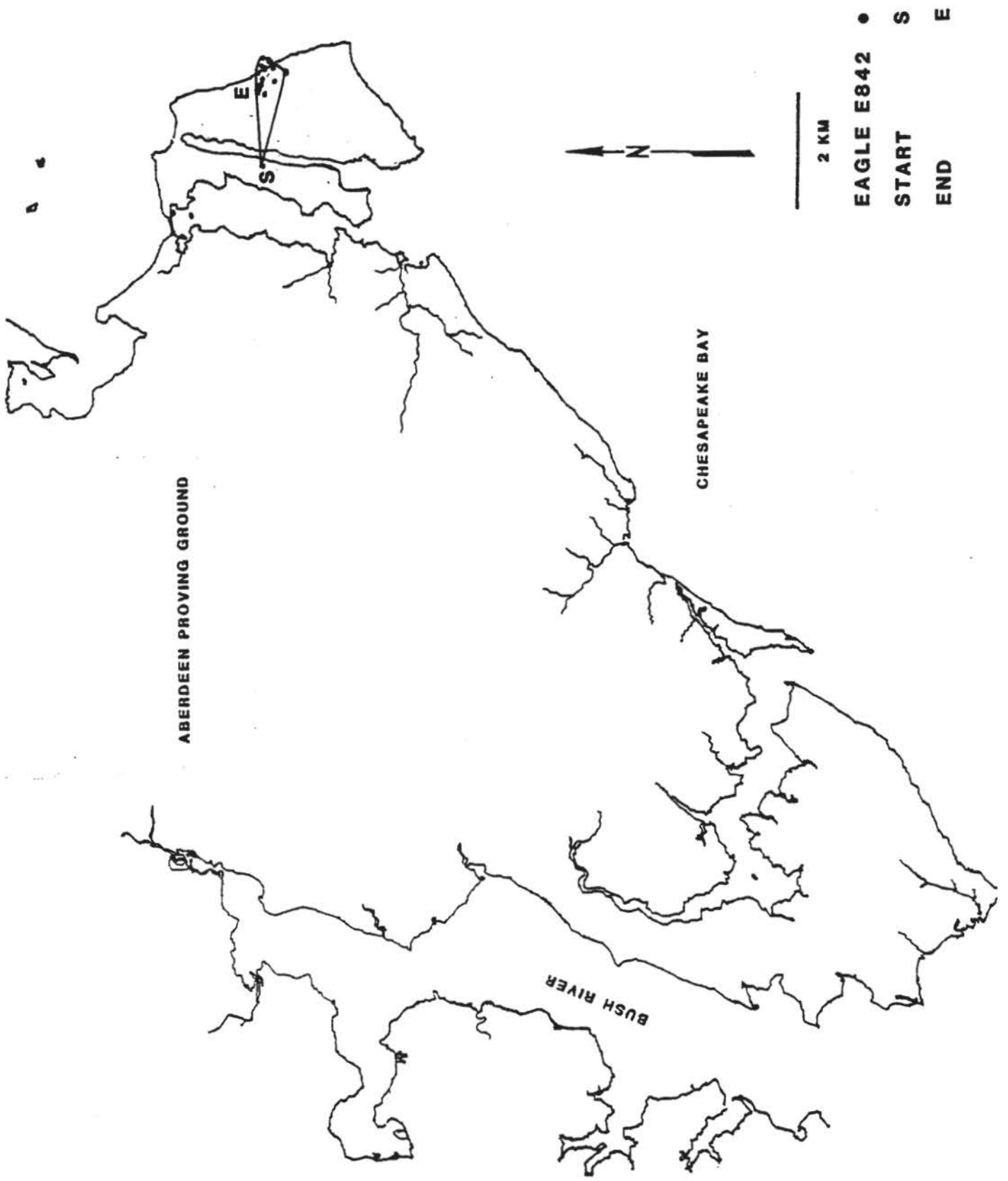


Figure 69. Locations and area of use convex polygons from all-day tracking of eagle E842 on 9 Aug 1984 on the Aberdeen area of the Northern Chesapeake Study Area.



APPENDIX C: LOCATIONS OF ALL BALD EAGLES TRACKED 28 FEB 1984 TO 1 JULY 1985

Figure 70. All locations and total convex polygon home range of eagle E232 on the Chesapeake Bay from Nov 1984 - Mar 1985.

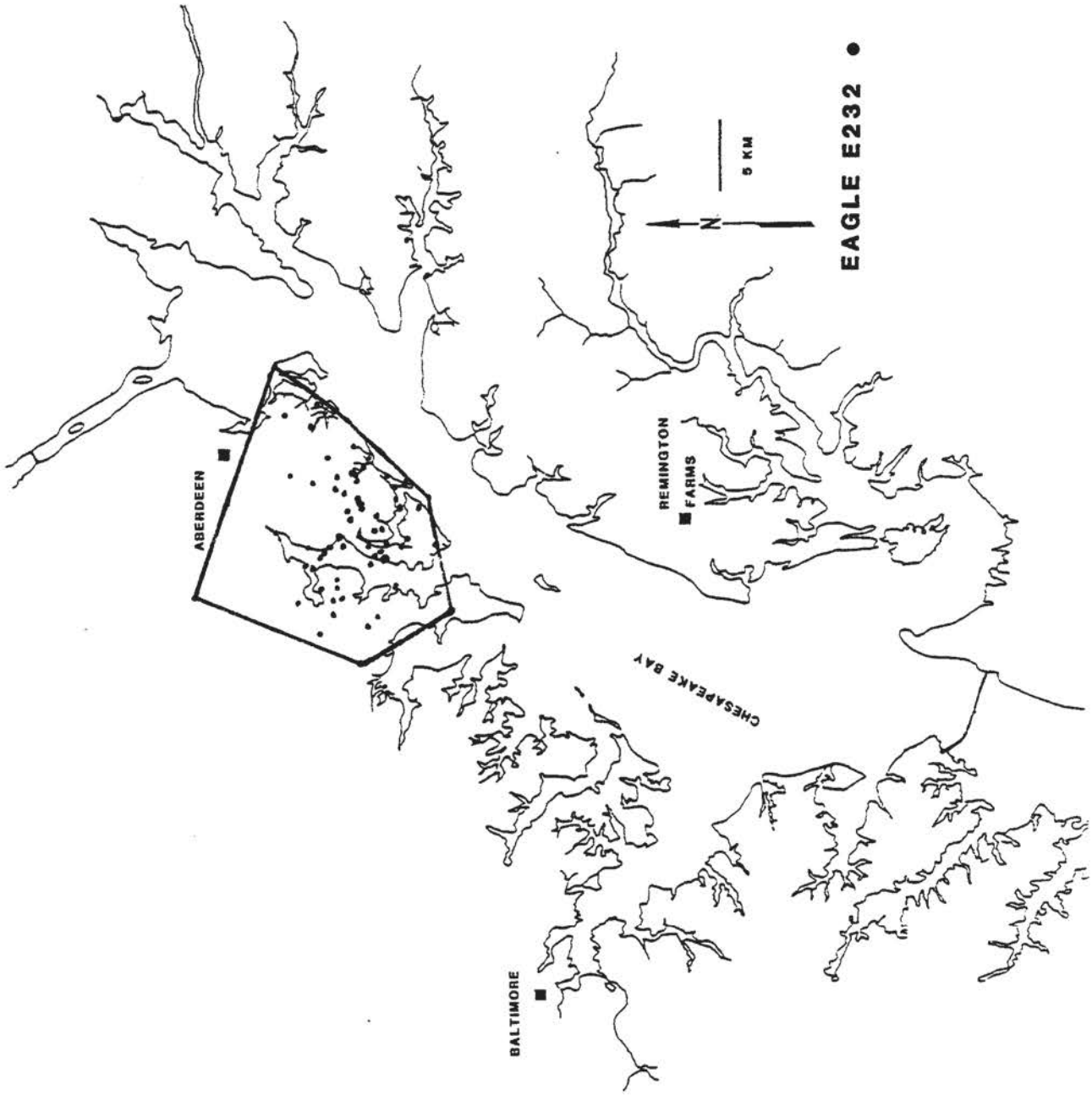


Figure 71. Locations and seasonal convex polygon home range of eagle E232 on the Northern Chesapeake Study Area during fall 1984.

Figure 72. Locations and seasonal convex polygon home range of eagle E232 on the Northern Chesapeake Study Area during winter 1984-1985.

Figure 73. Locations and seasonal convex polygon home range of eagle E232 on the Northern Chesapeake Study Area during spring 1985.

Figure 74. All locations and total convex polygon home range of eagle E423 on the Aberdeen-Edgewood area from May 1984 - Jun 1984.

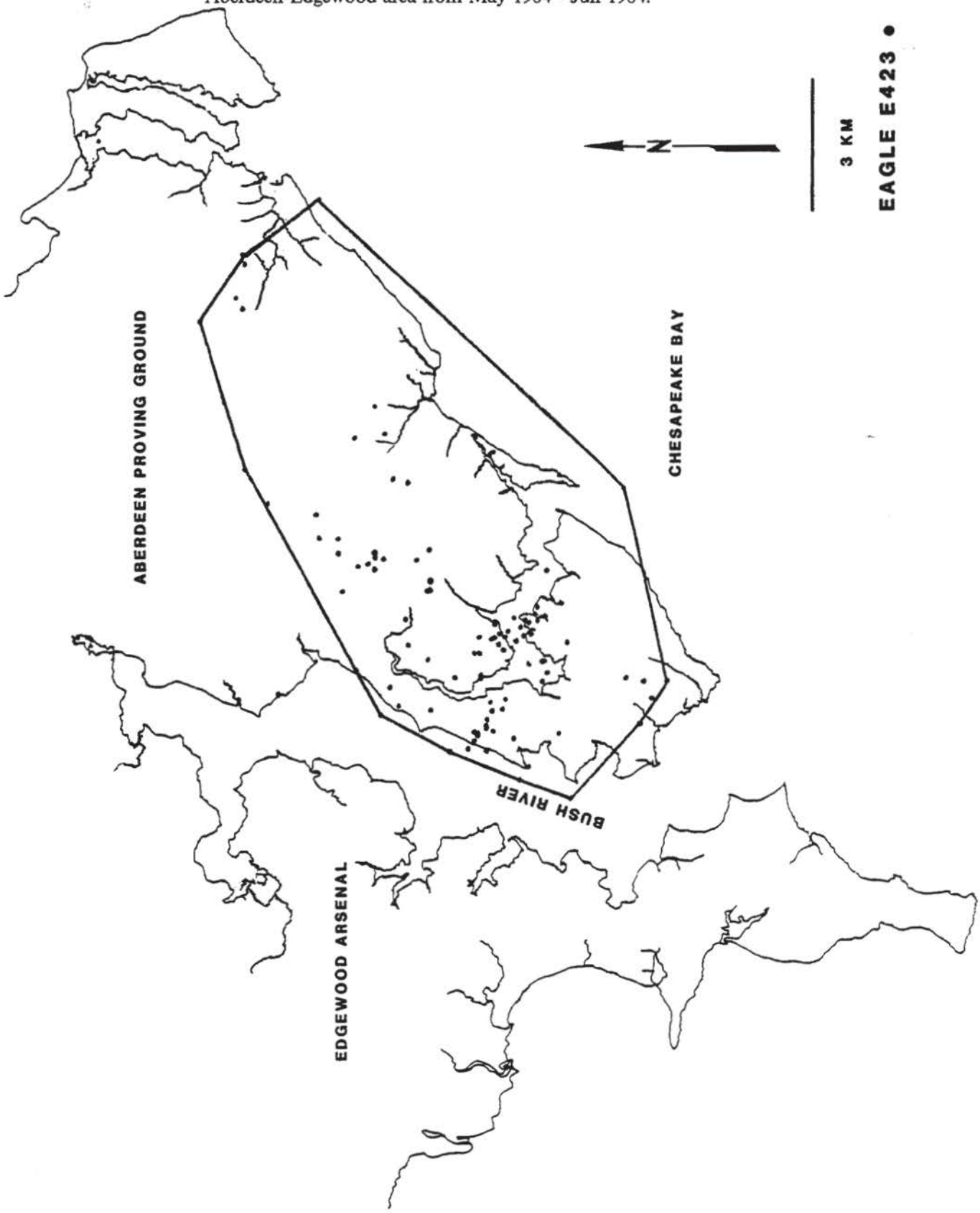


Figure 75. Locations and seasonal convex polygon home range of eagle E423 on the Aberdeen-Edgewood area during spring 1984.

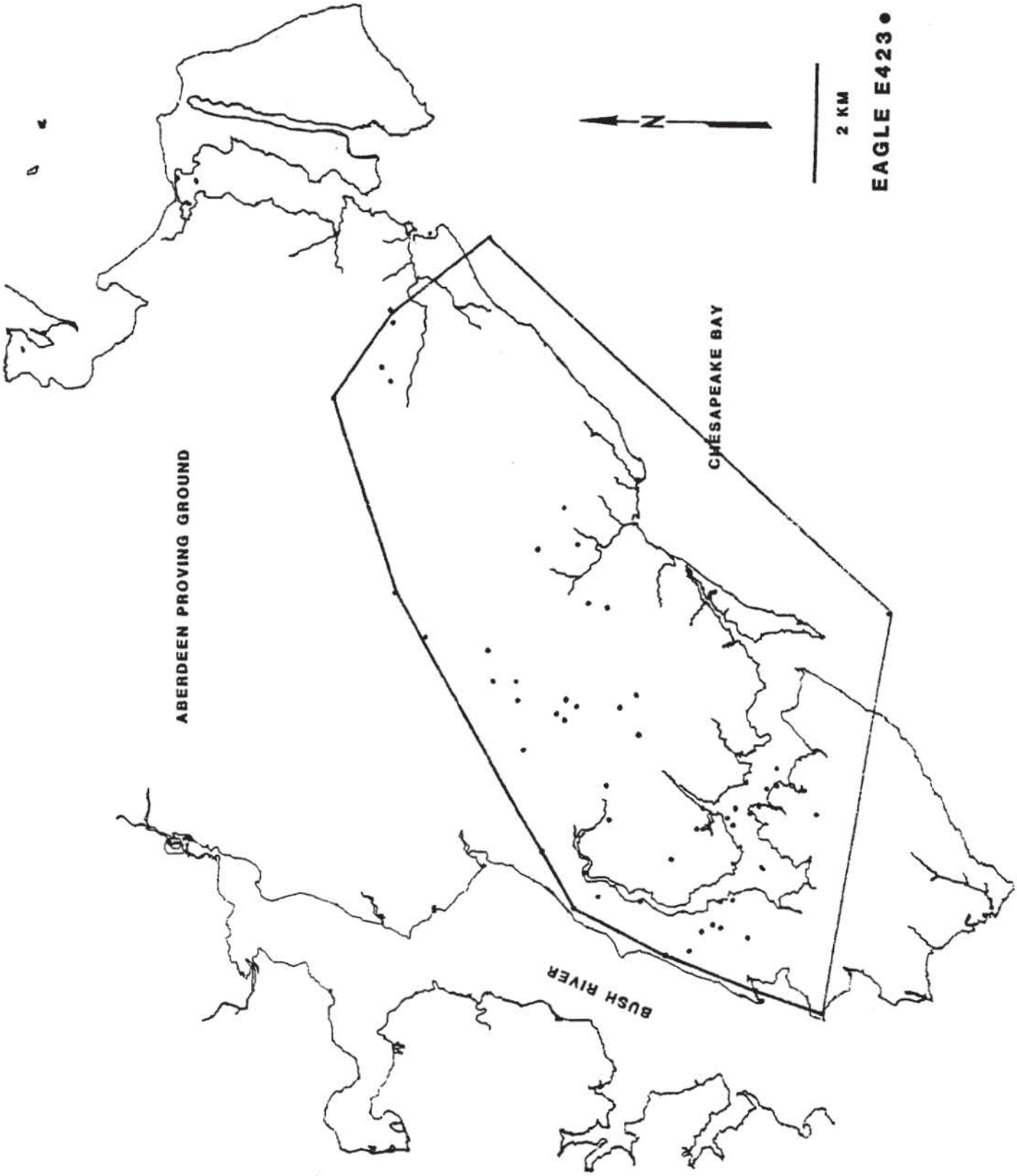


Figure 76. Locations and seasonal convex polygon home range of eagle E423 on the Aberdeen-Edgewood area during summer 1984.

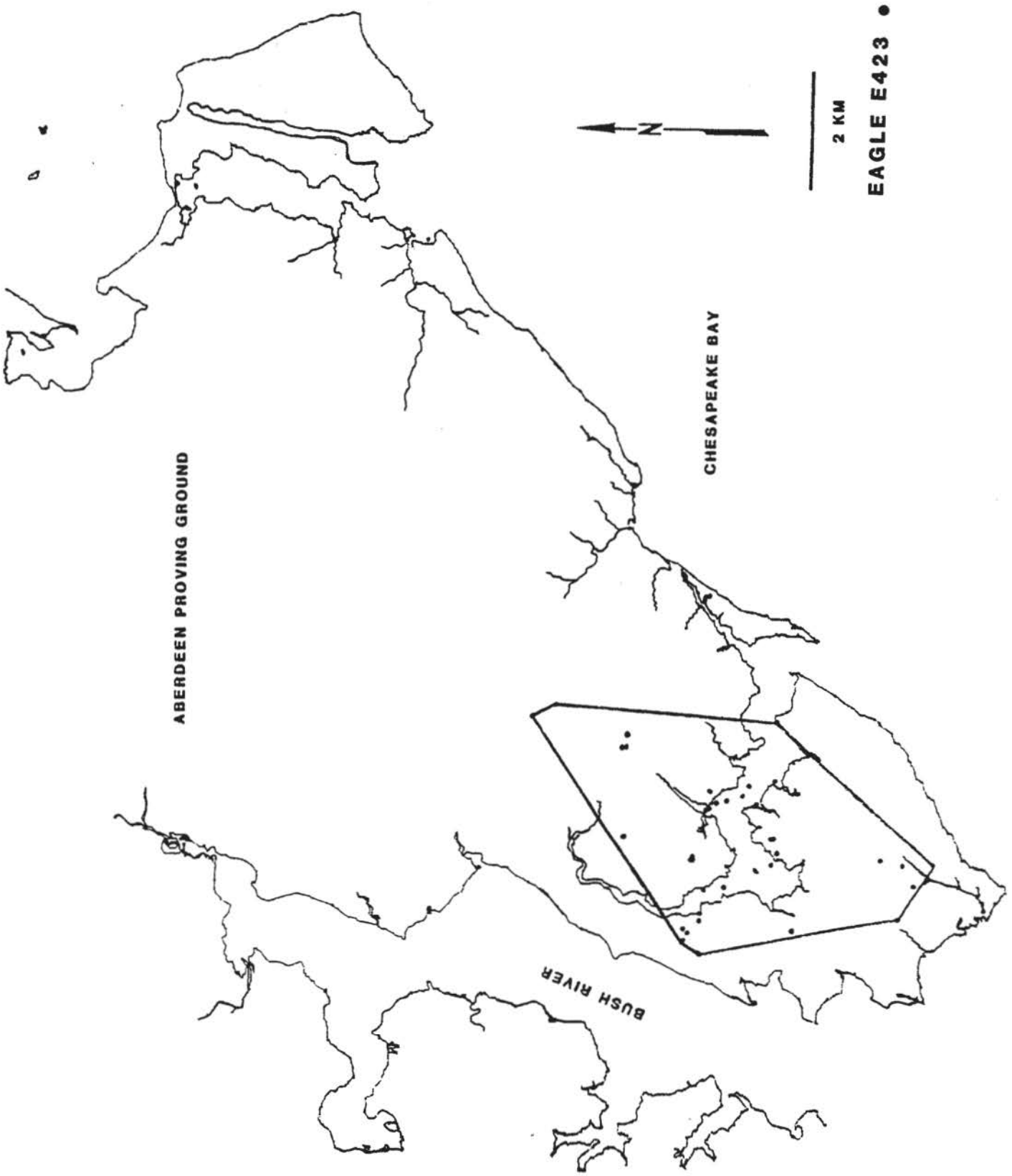


Figure 77. Total convex polygon home range of eagle E451 on the Chesapeake Bay from Oct 1984 - Apr 1985.

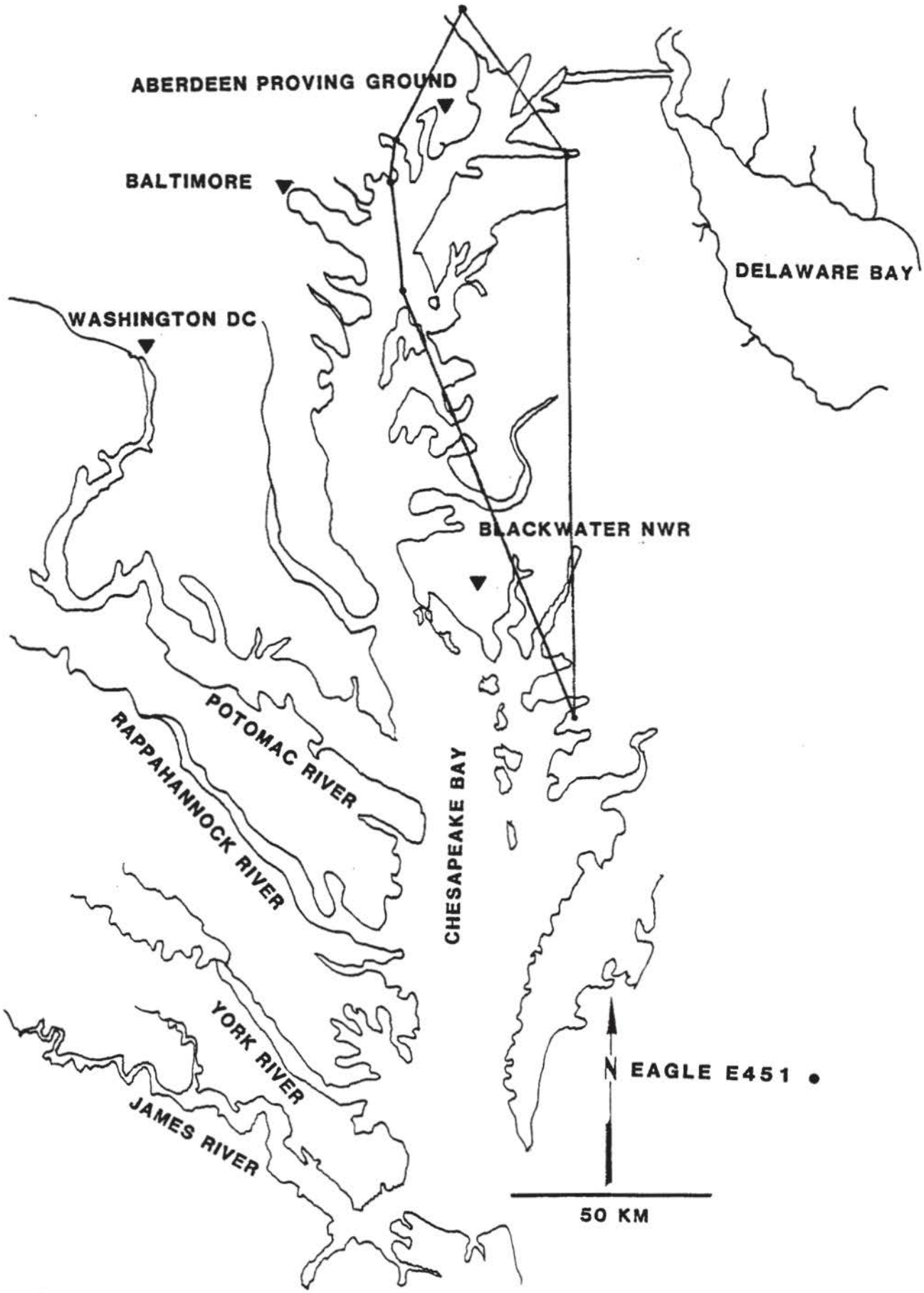


Figure 78. Locations and seasonal convex polygon home range of eagle E451 on the Northern Chesapeake Study Area during fall 1984.

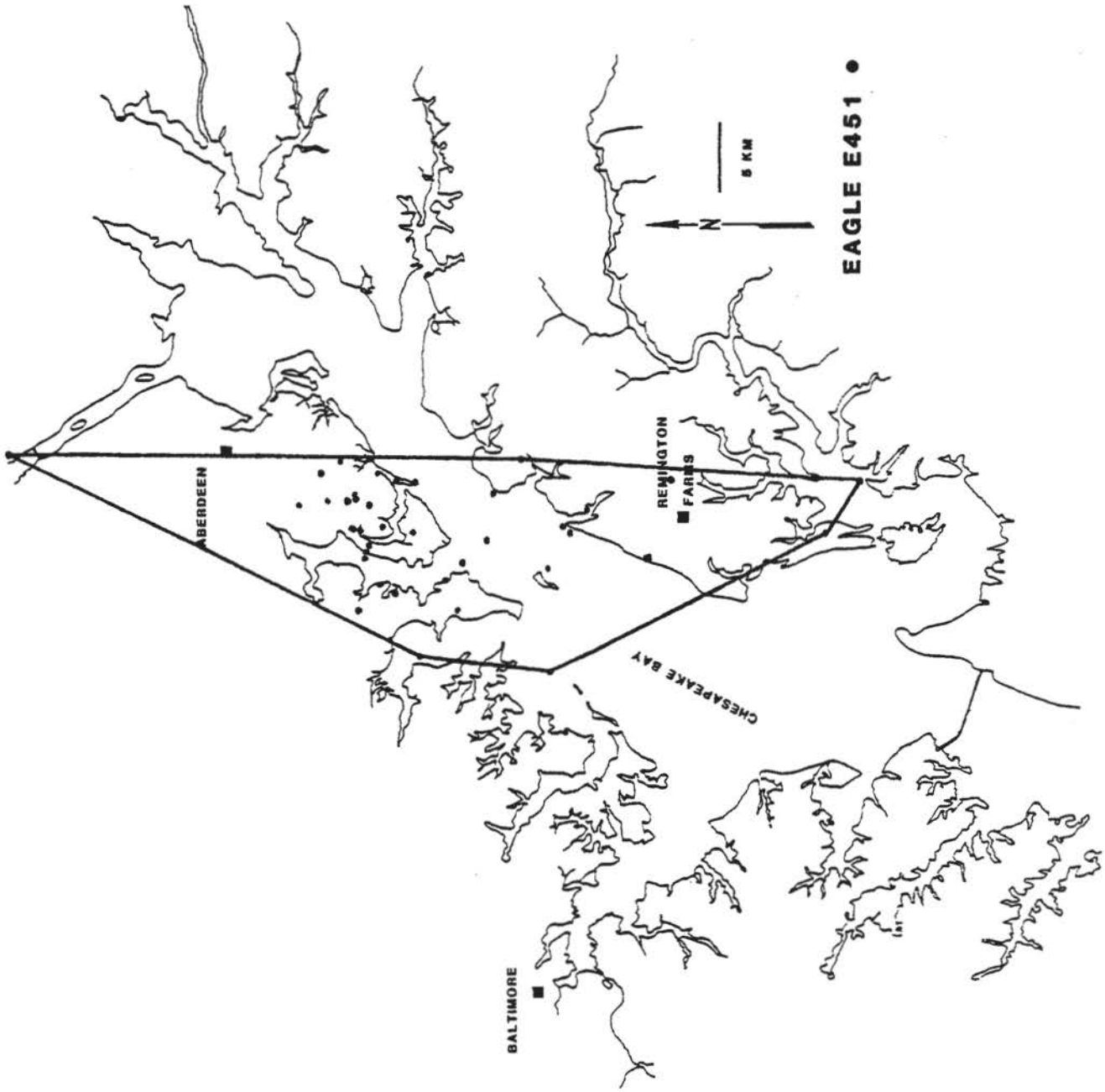


Figure 79. Locations and seasonal convex polygon home range of eagle E451 on the Northern Chesapeake Study Area during winter 1984-1985.

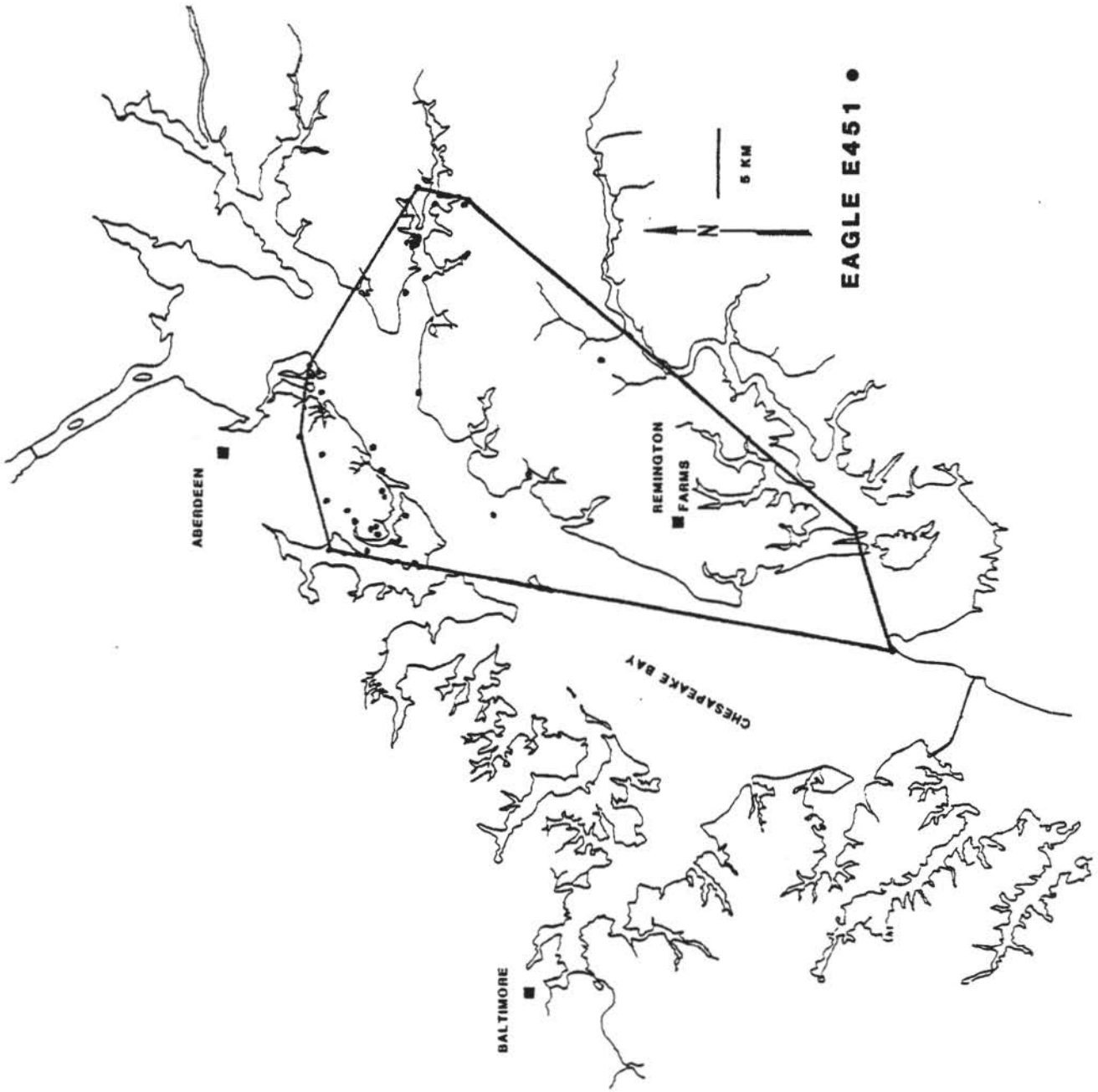


Figure 80. Locations and seasonal convex polygon home range of eagle E451 on the Northern Chesapeake Study Area during spring 1985.

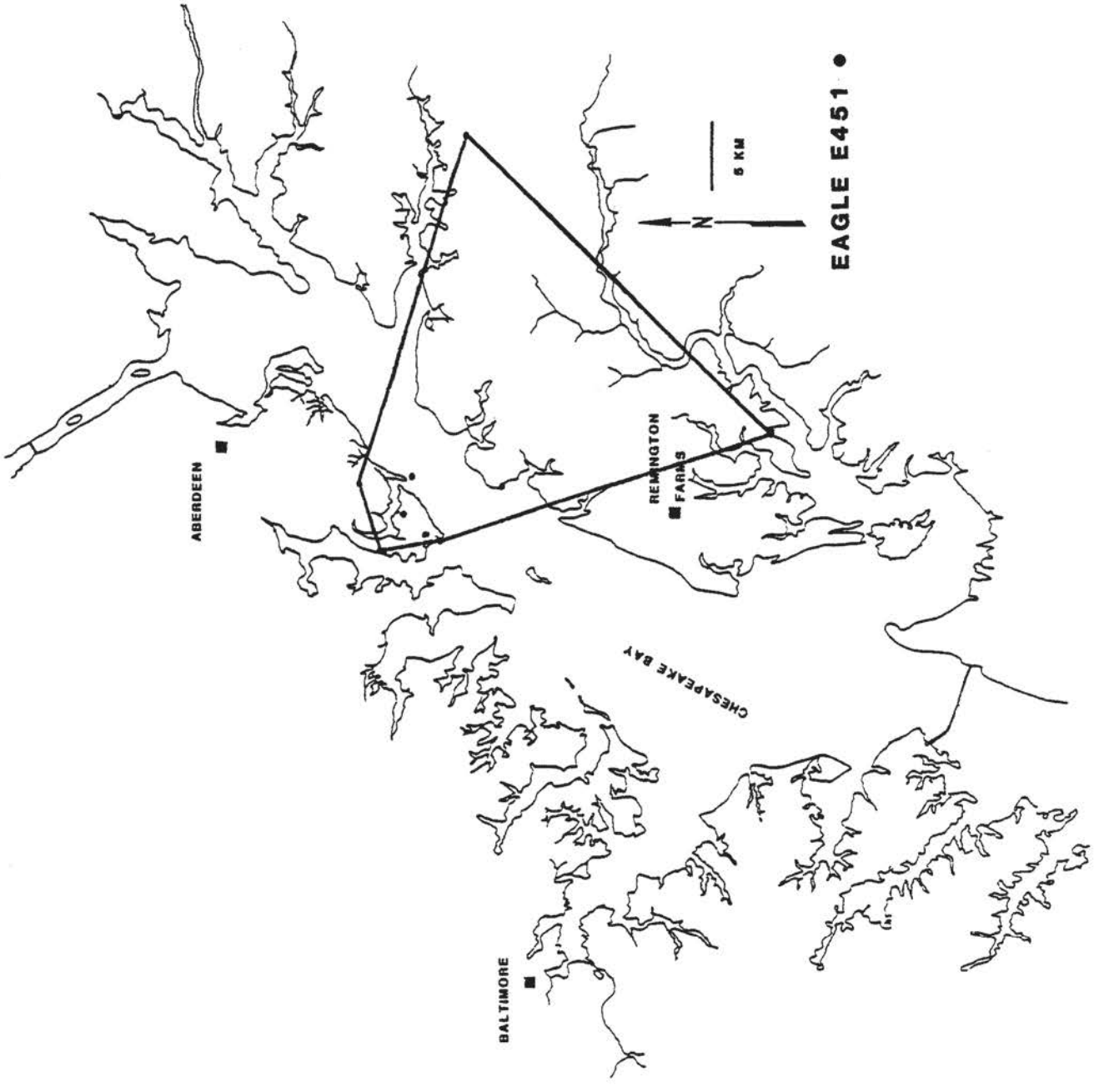


Figure 81. Total convex polygon home range of eagle E496 on the Chesapeake Bay from Sep 1984 - Apr 1985.

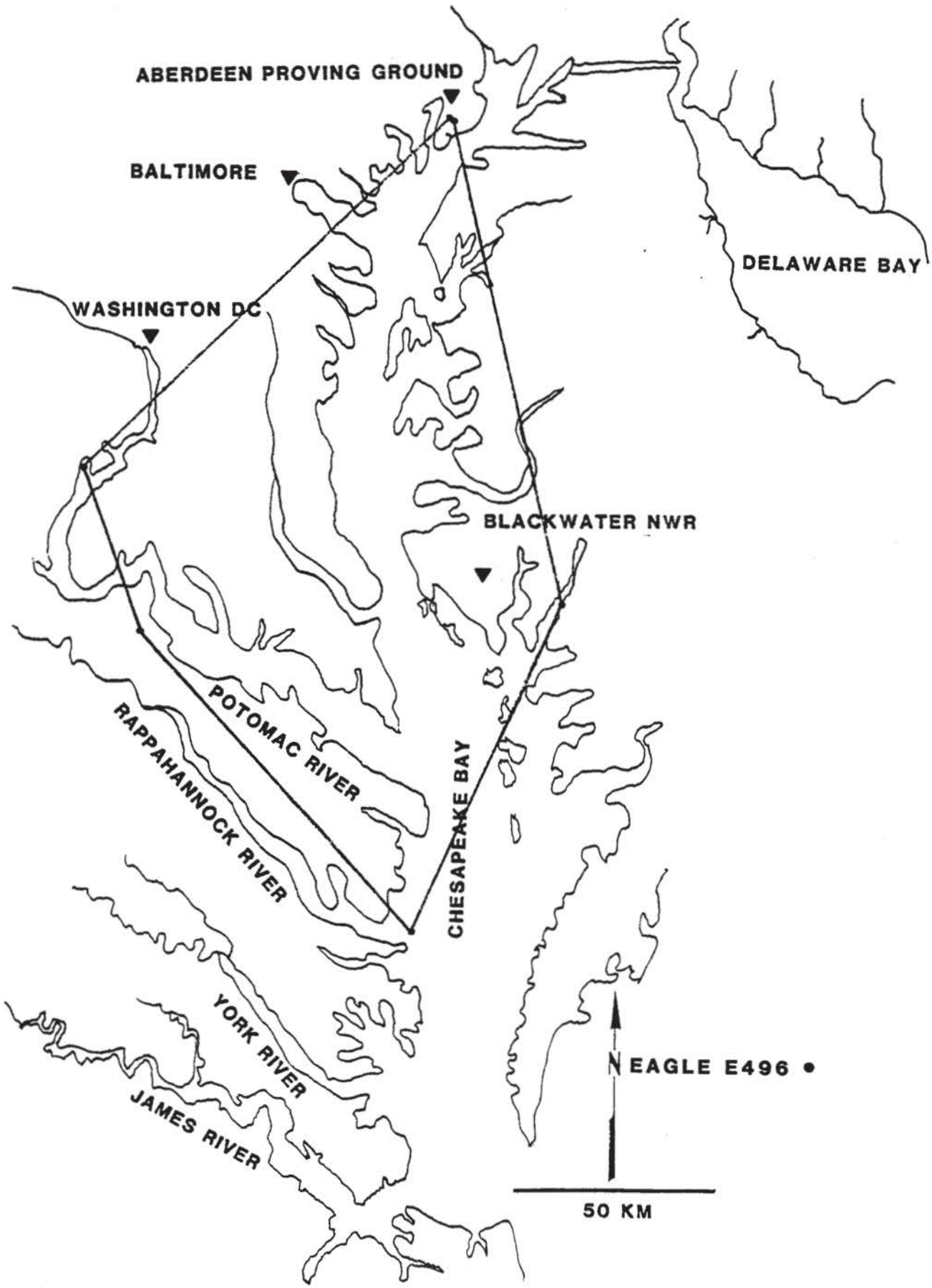


Figure 82. All locations and total convex polygon home range of eagle E522 on the Northern Chesapeake Study Area from Apr 1984 - Mar 1985.

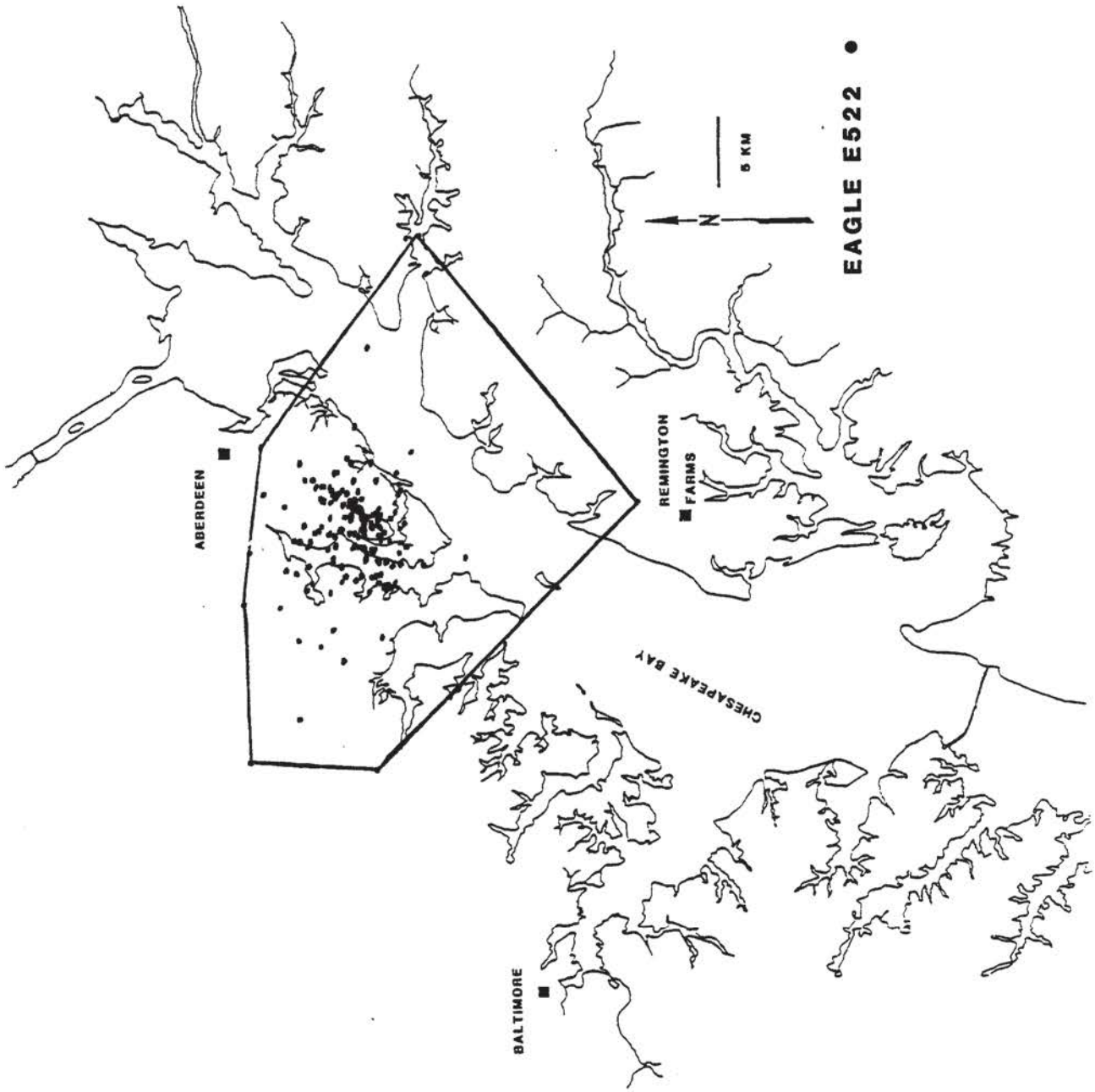


Figure 83. Locations and seasonal convex polygon home range of eagle E522 on the Aberdeen-Edgewood area during spring 1984.

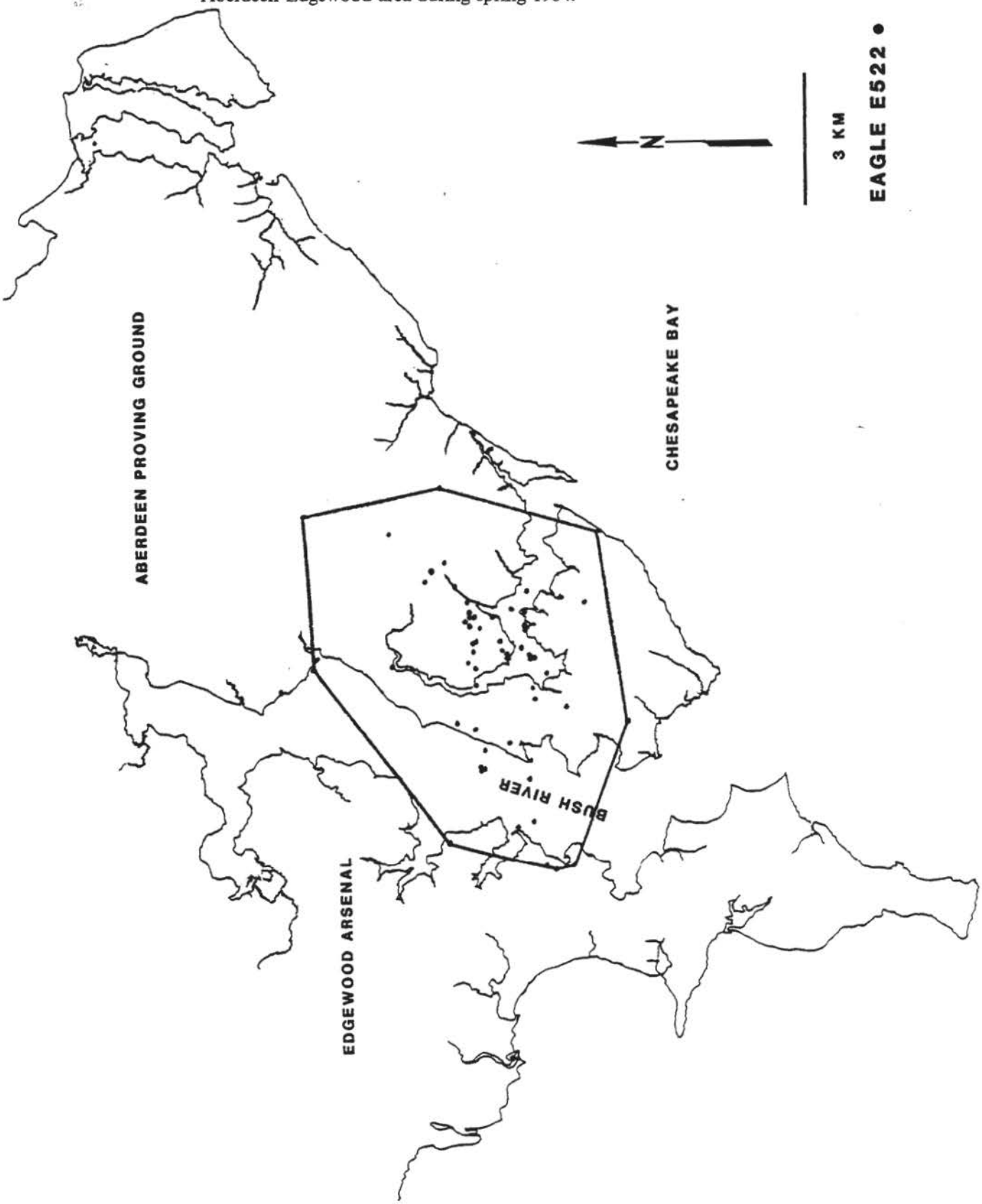


Figure 84. Locations and seasonal convex polygon home range of eagle E522 on the Northern Chesapeake Study Area during fall 1984.

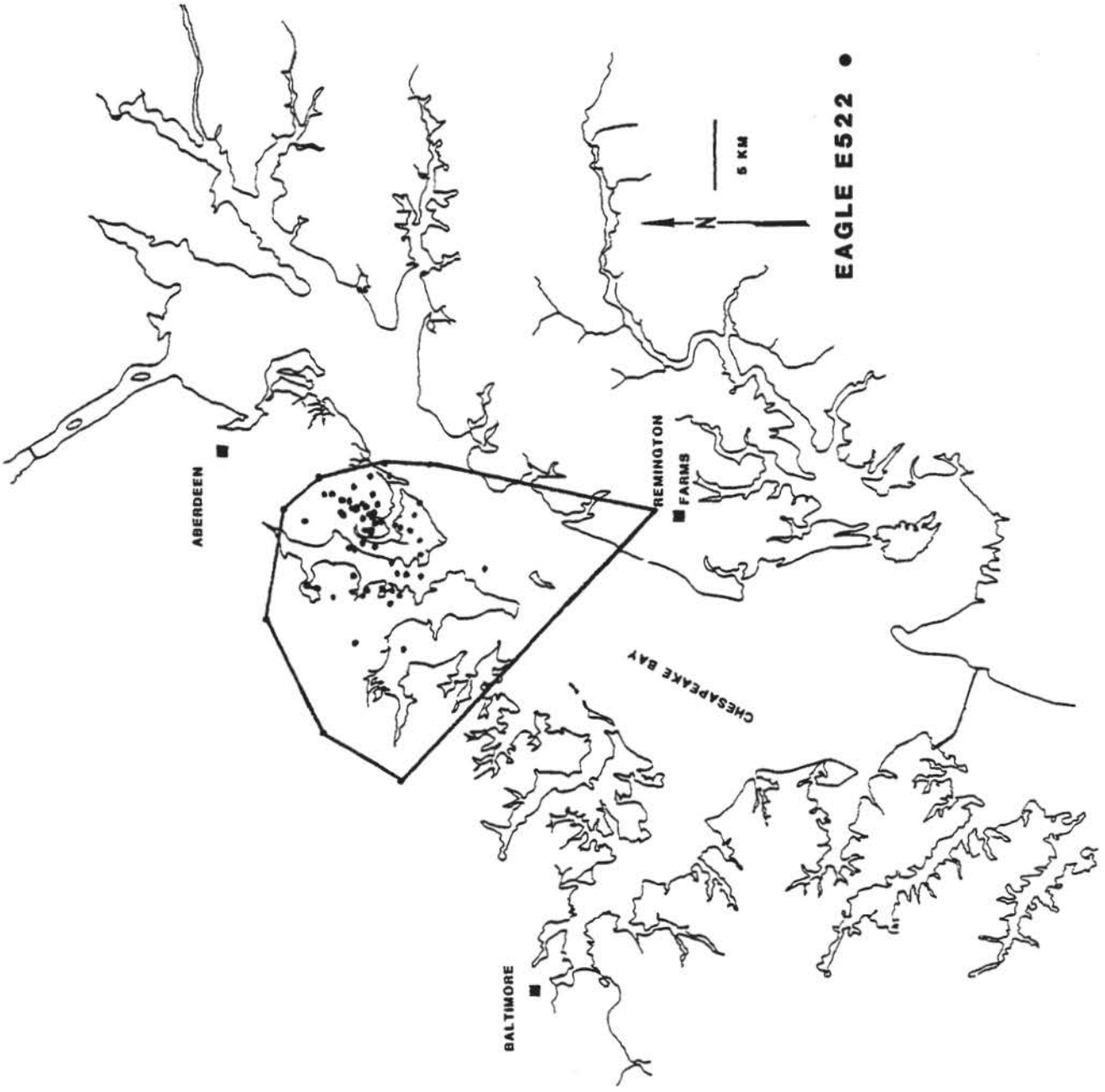


Figure 85. Locations and seasonal convex polygon home range of eagle E522 on the Northern Chesapeake Study Area during winter 1984-1985.

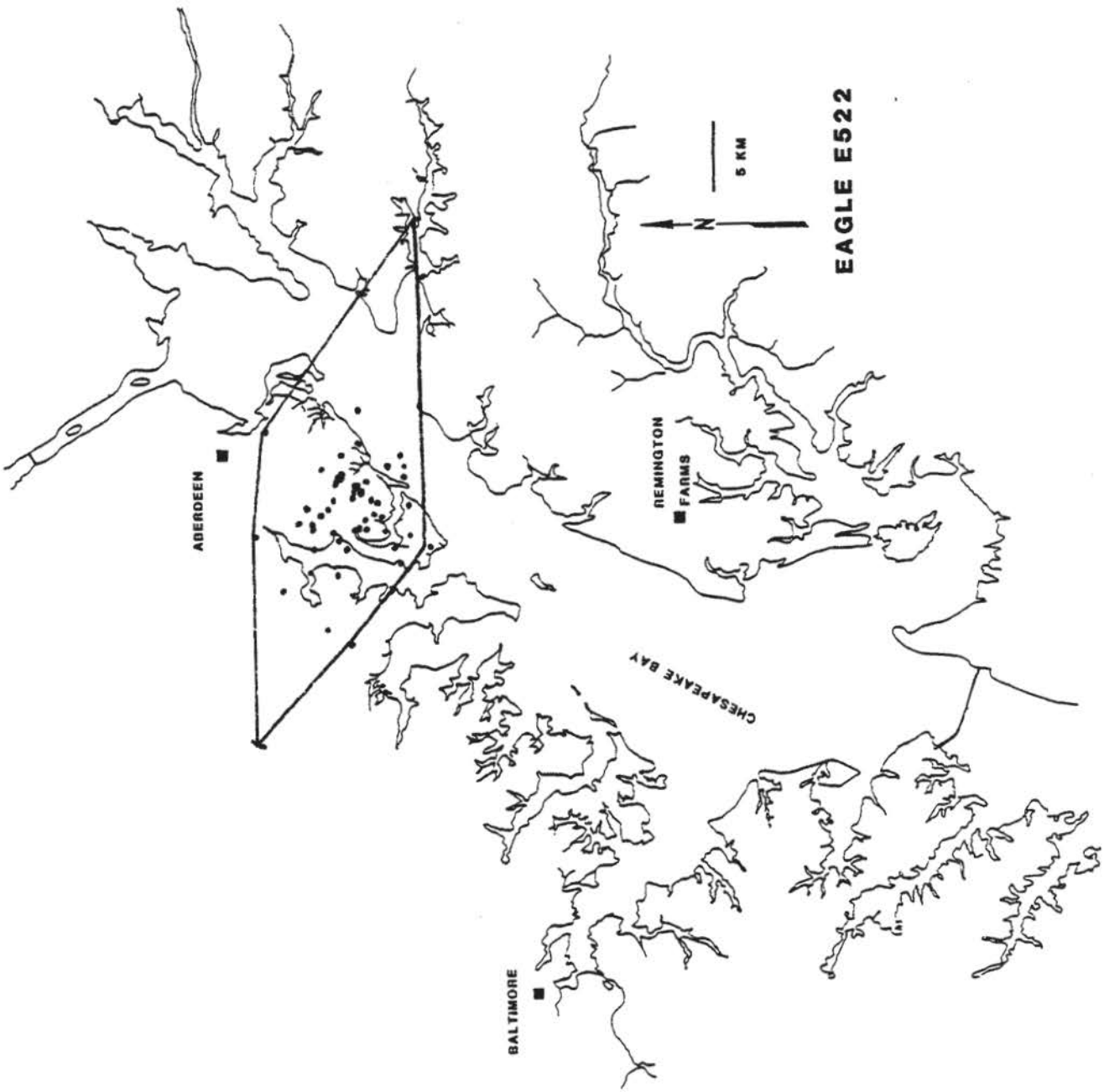


Figure 86. Locations and seasonal convex polygon home range of eagle E522 on the Northern Chesapeake Study Area during spring 1985.

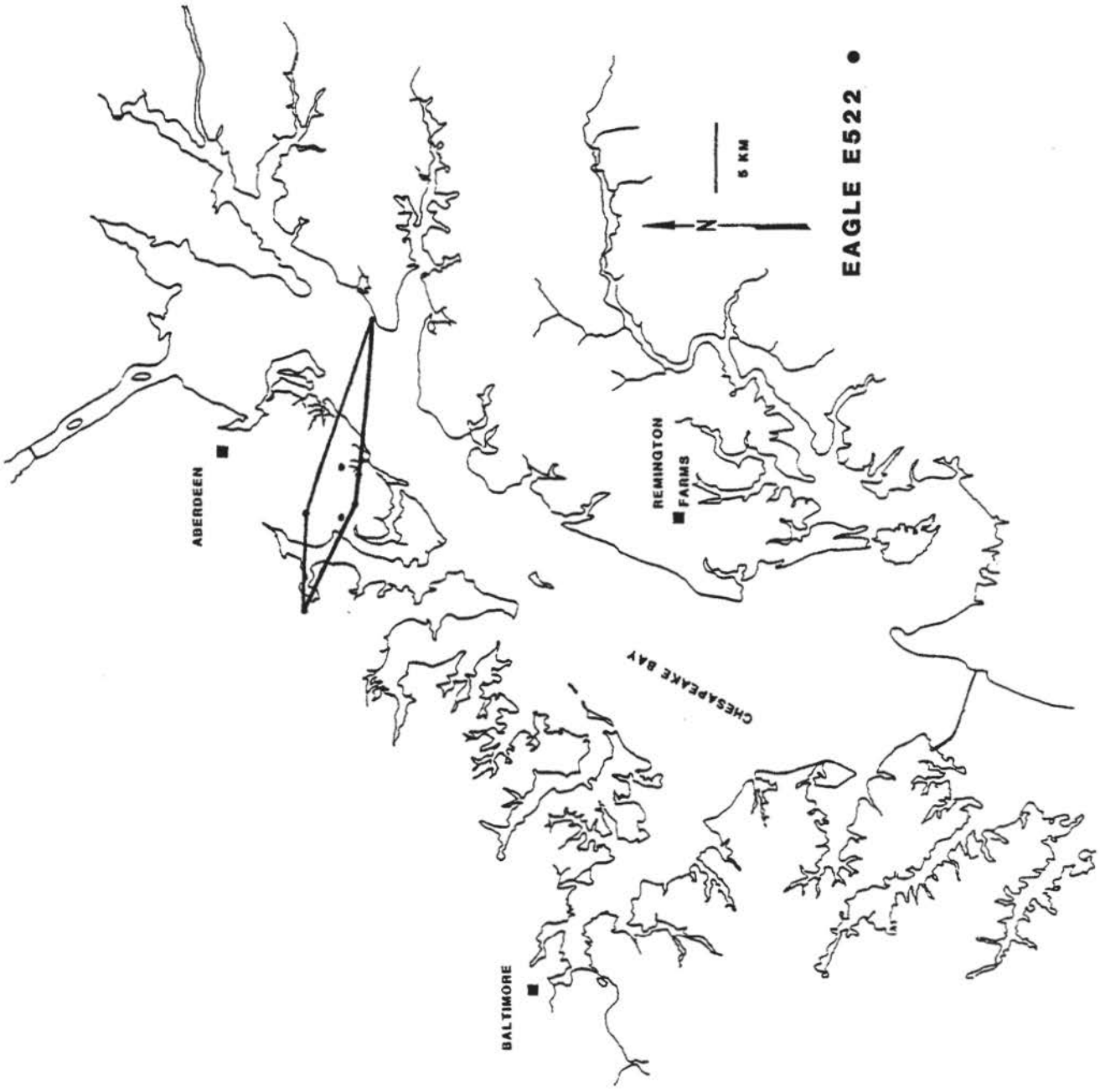


Figure 87. Total convex polygon home range of eagle E544 on the Chesapeake Bay from Jun 1984 - Mar 1985.

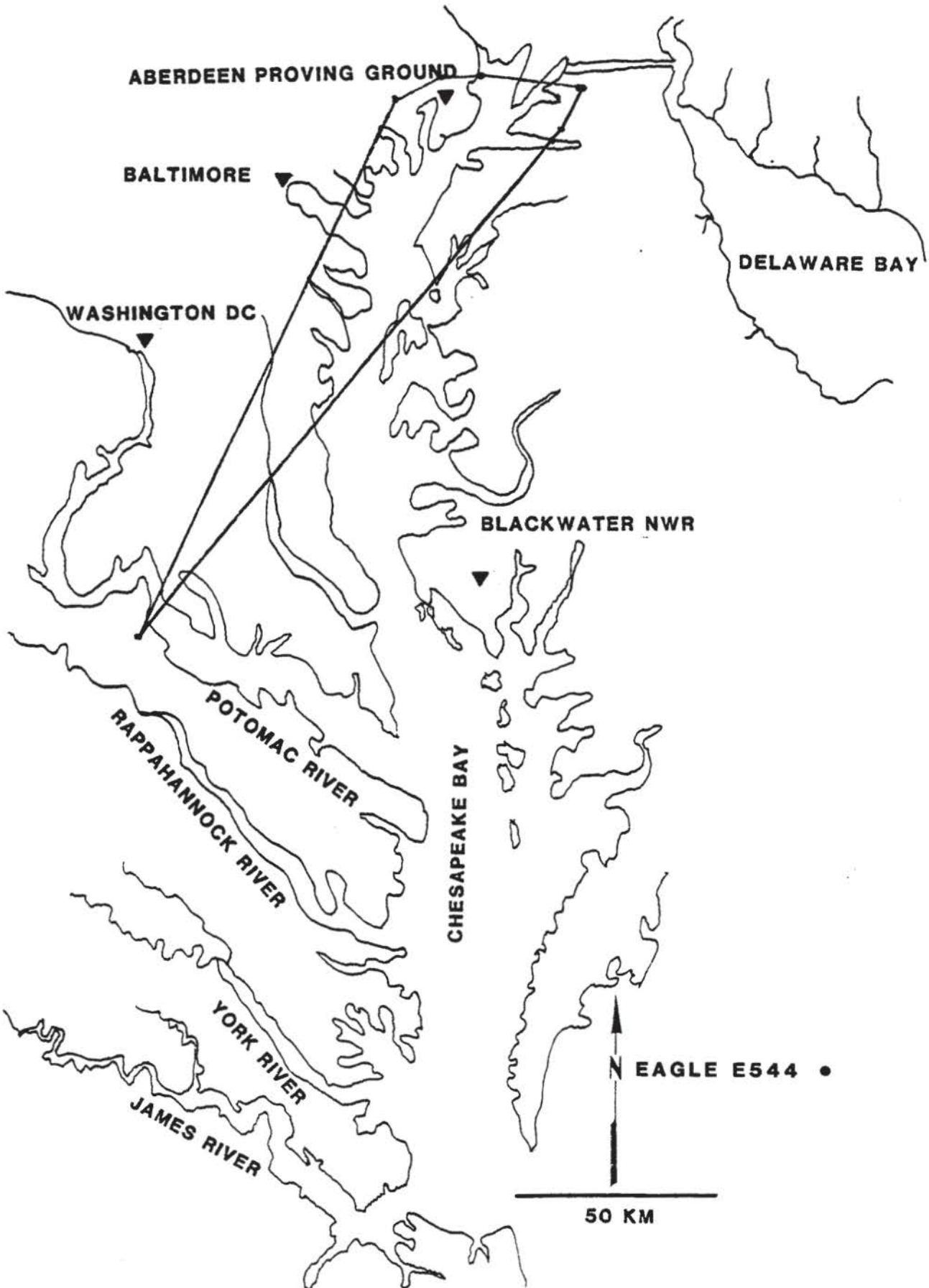


Figure 88. Locations and seasonal convex polygon home range of eagle E544 on the Aberdeen-Edgewood area during summer 1984.

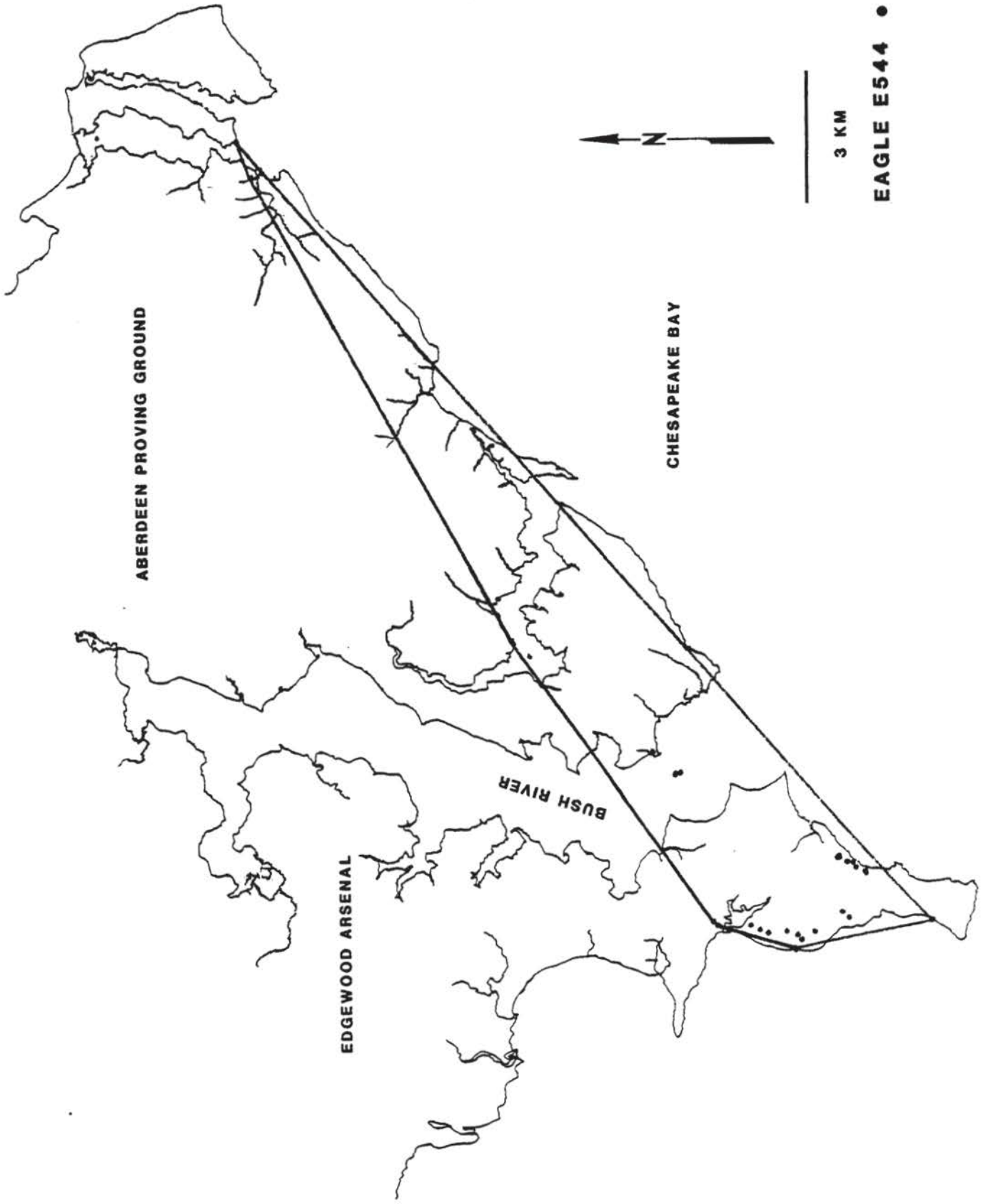


Figure 89. Locations and seasonal convex polygon home range of eagle E544 on the Northern Chesapeake Study Area during fall 1984.

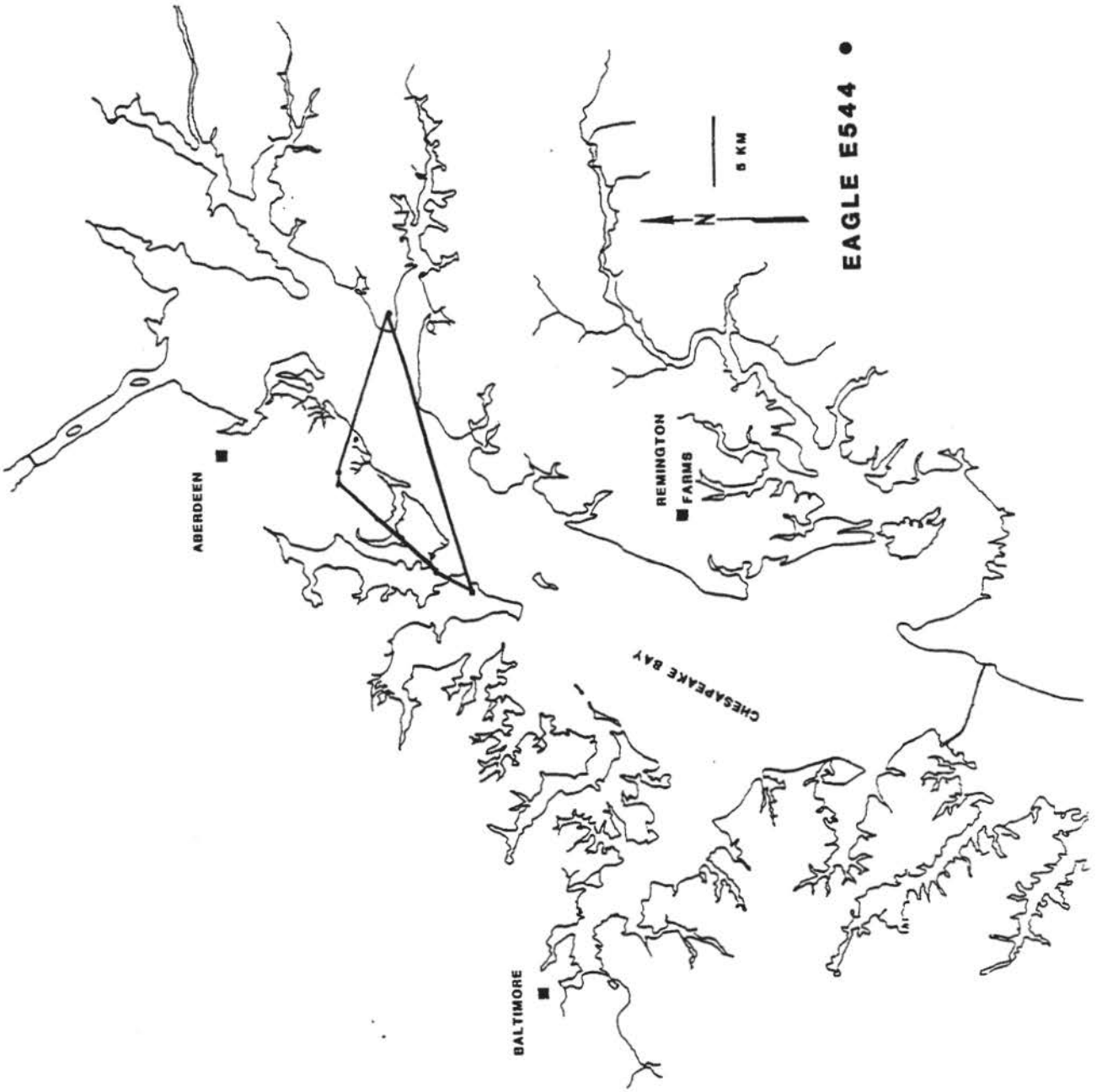


Figure 90. Locations and seasonal convex polygon home range of eagle E544 on the Northern Chesapeake Study Area during winter 1984-1985.

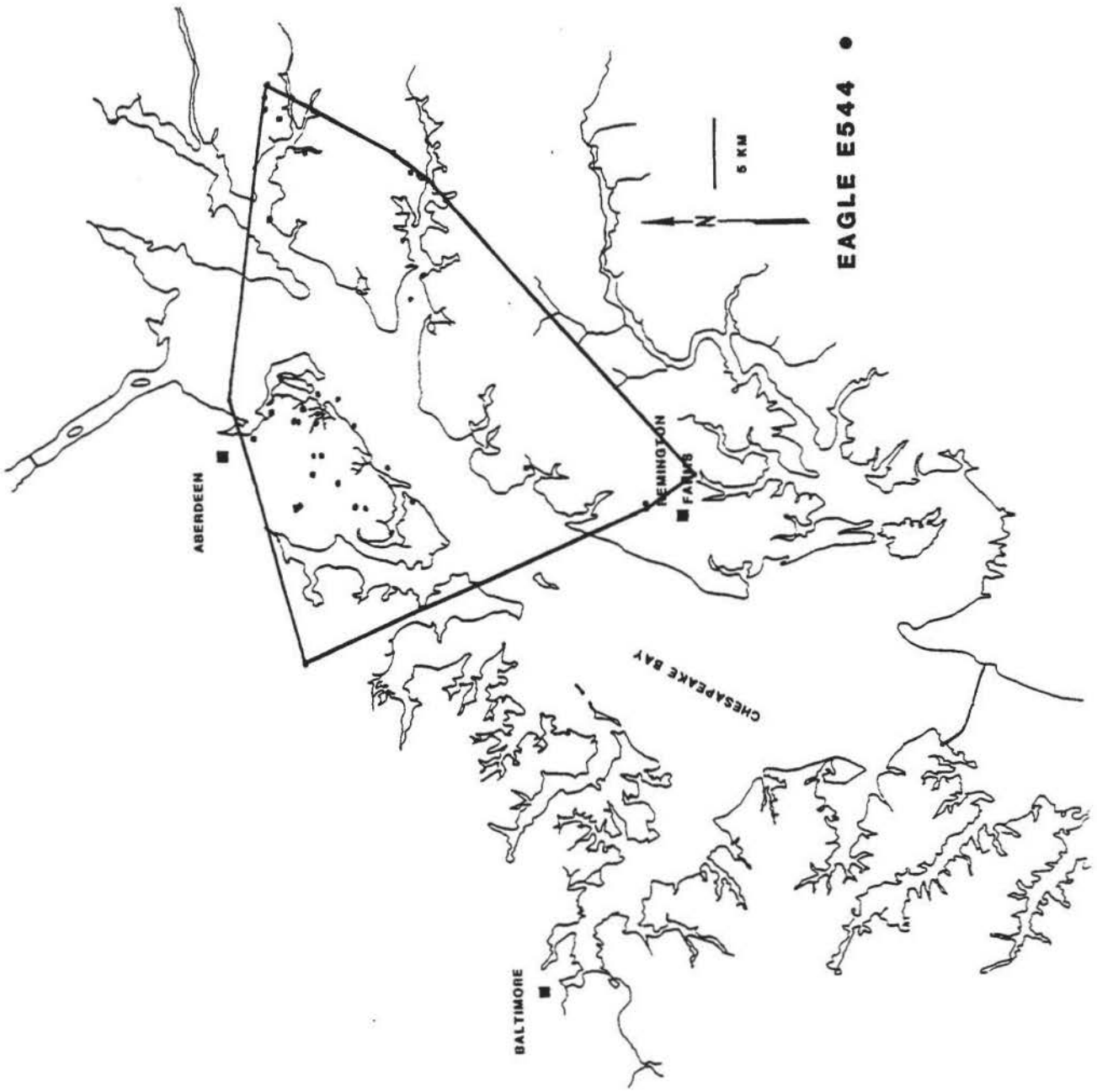


Figure 91. Locations and seasonal convex polygon home range of eagle E544 on the Northern Chesapeake Study Area during spring 1985.

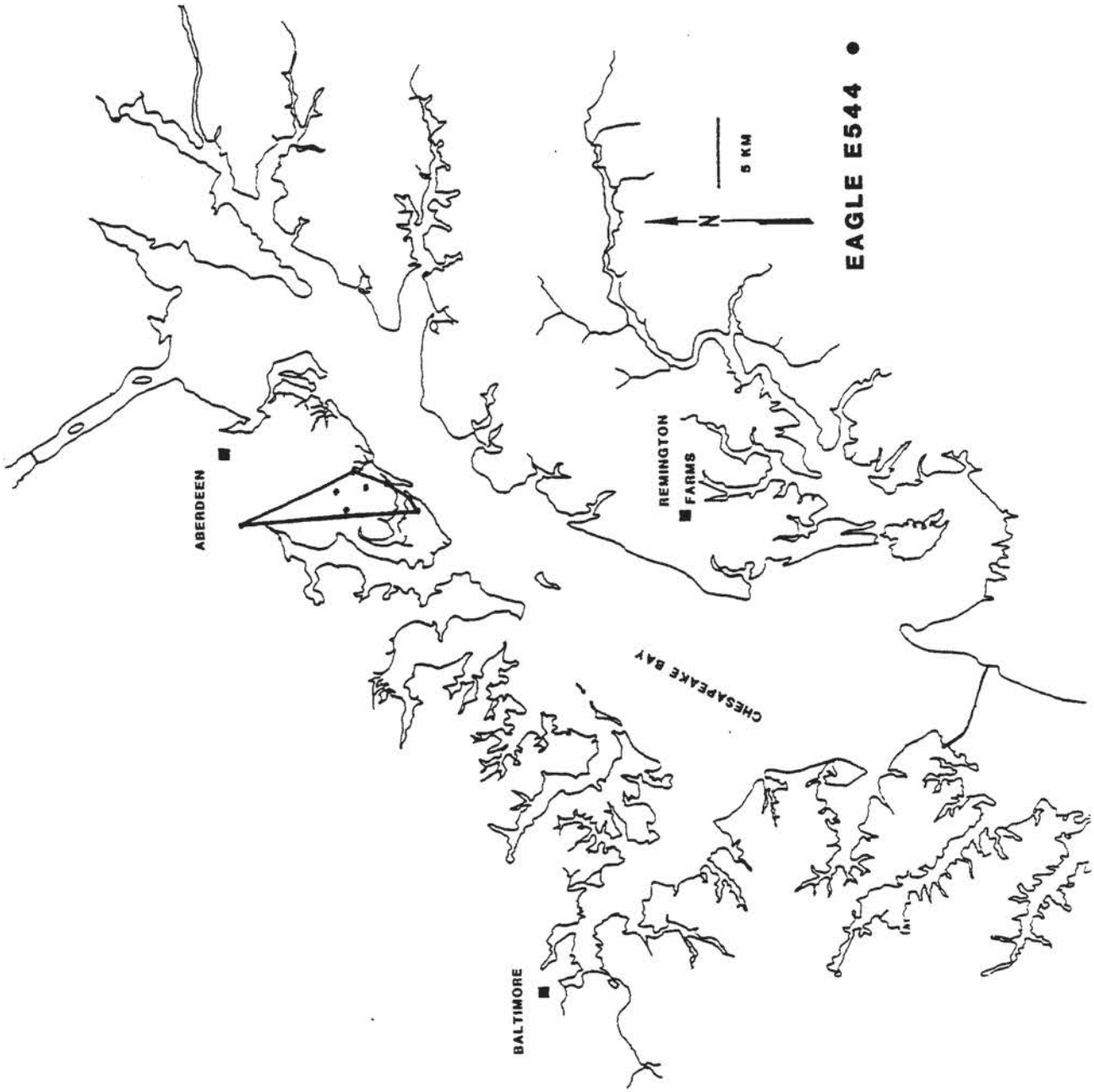


Figure 92. All locations and total convex polygon home range of eagle E552 on the Aberdeen-Edgewood area from Feb 1984 - Mar 1984.

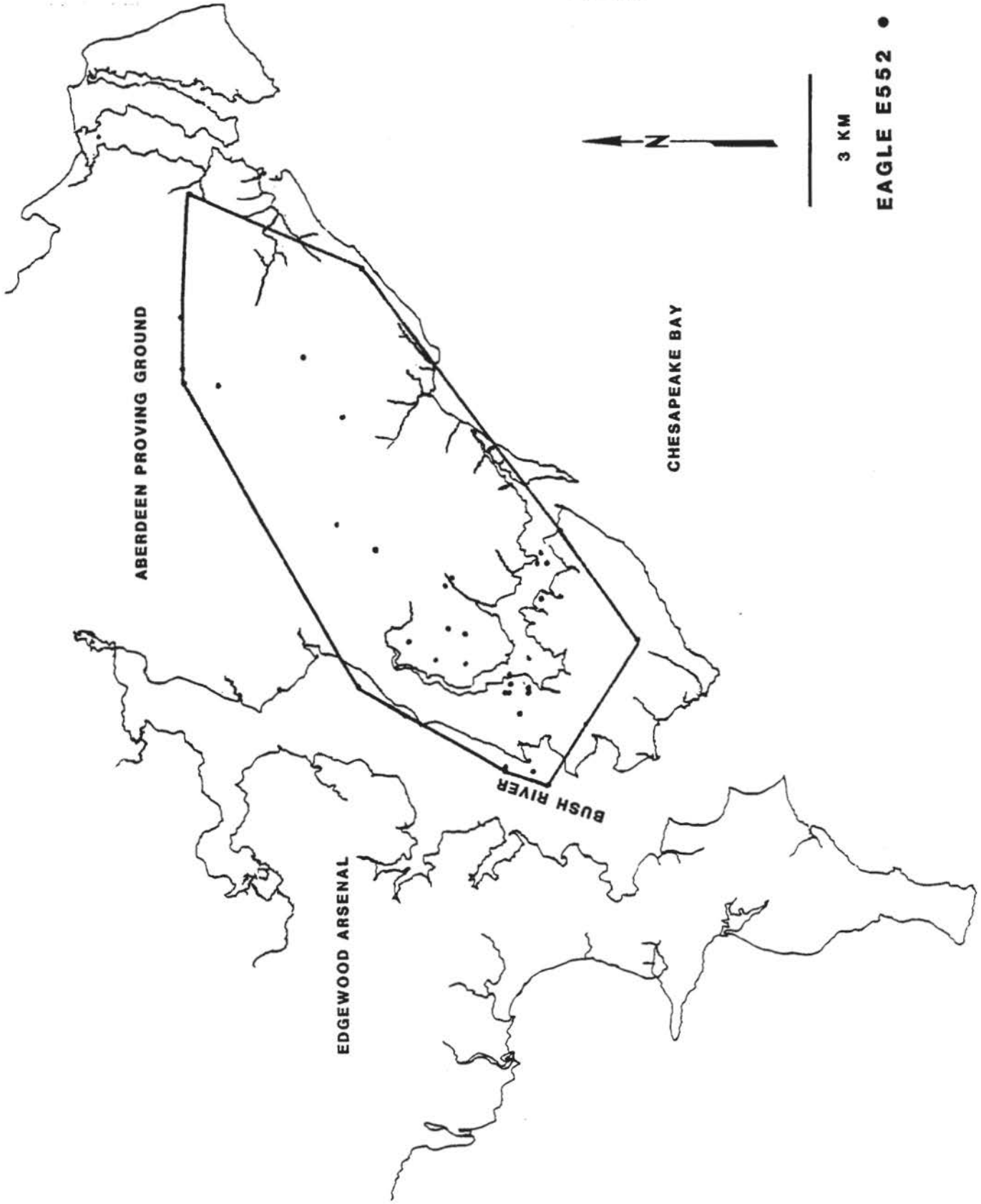


Figure 93. All locations and total convex polygon home range of eagle E573 on the Northern Chesapeake Study Area during Nov 1984.

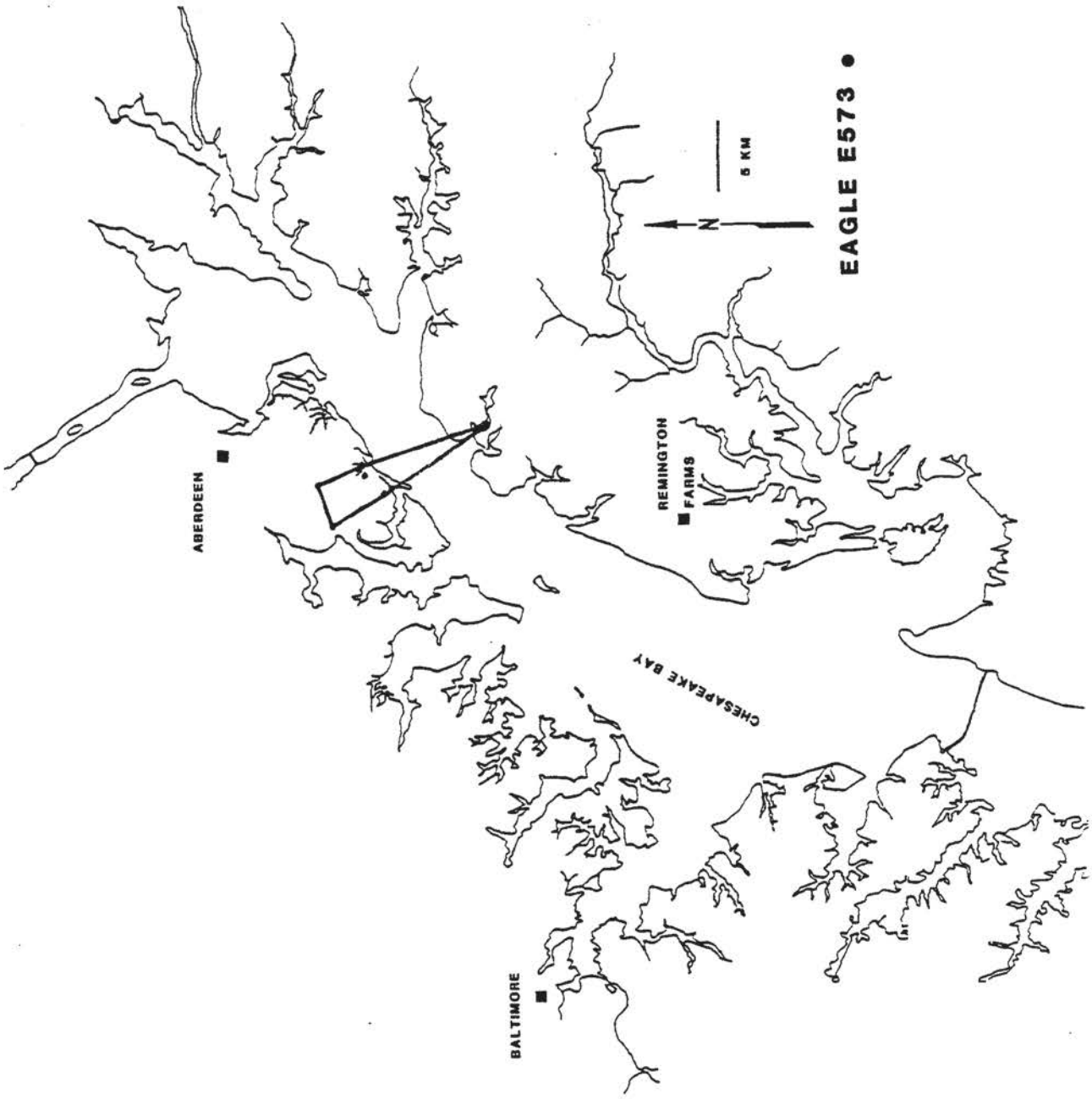


Figure 94. Total convex polygon home range of eagle E613 on the Chesapeake Bay from Jun 1984 - Jun 1985.

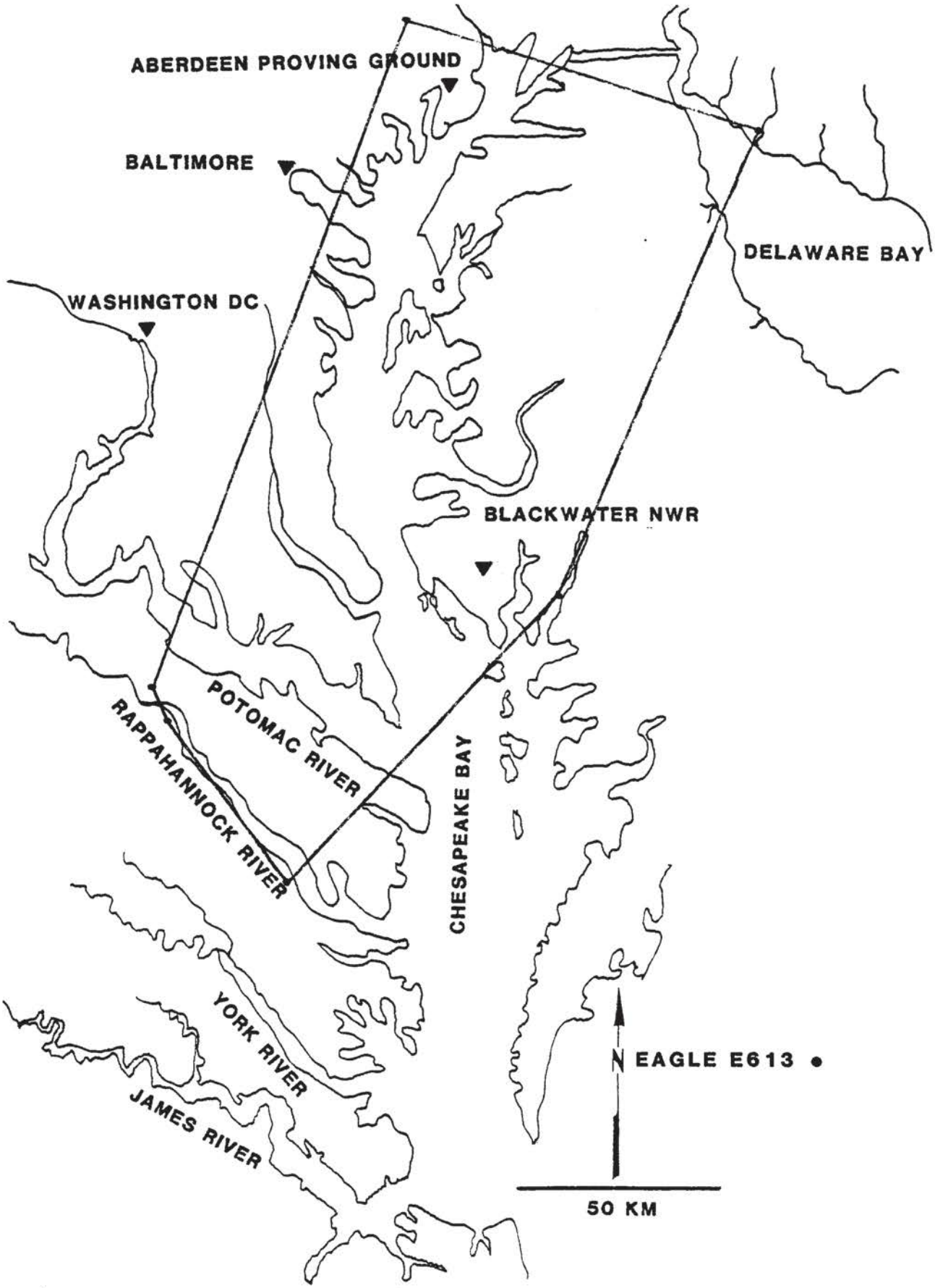


Figure 95. Locations and seasonal convex polygon home range of eagle E613 on the Aberdeen-Edgewood area during summer 1984.

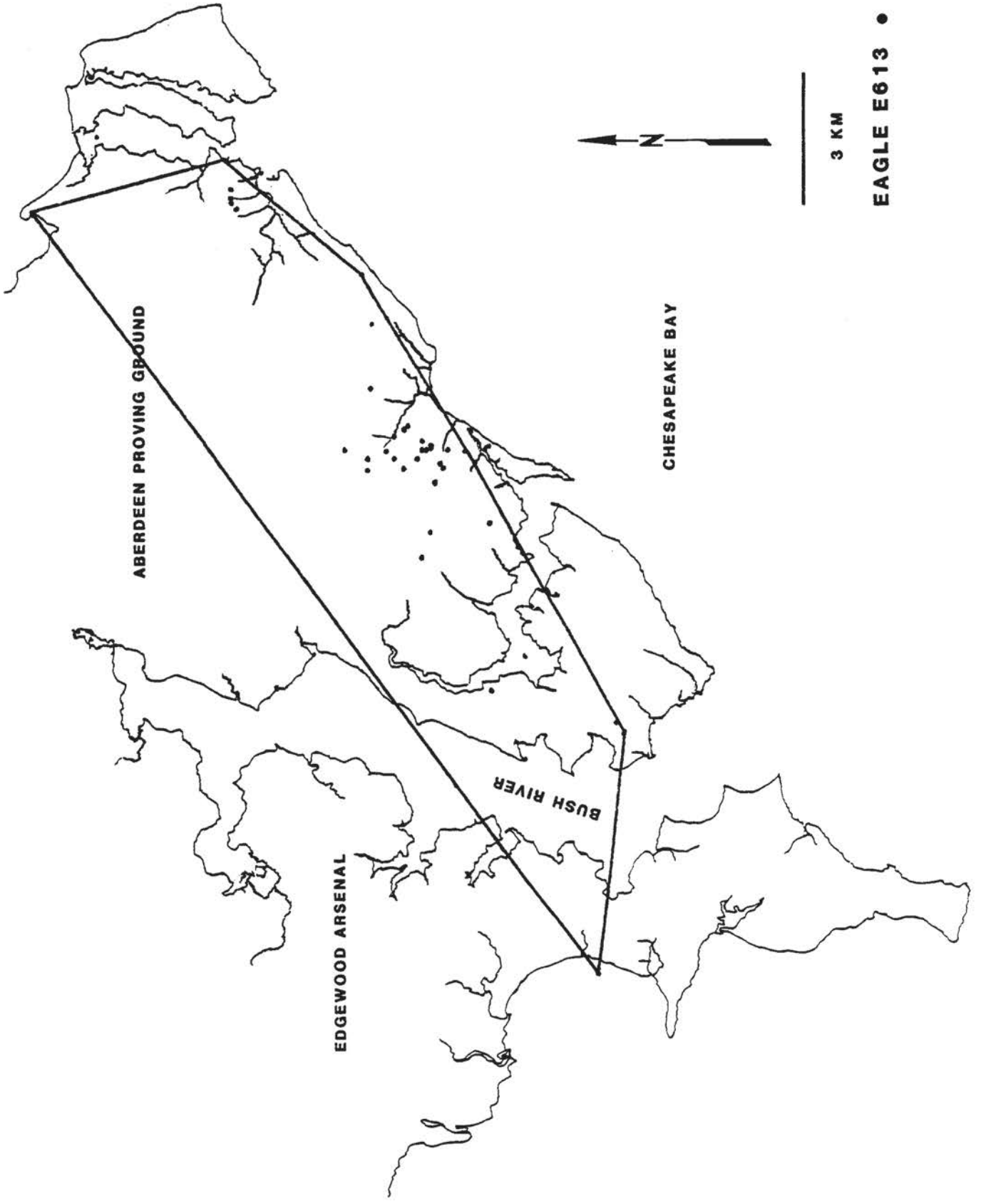


Figure 96. Locations and seasonal convex polygon home range of eagle E613 on the Northern Chesapeake Study Area during fall 1984.

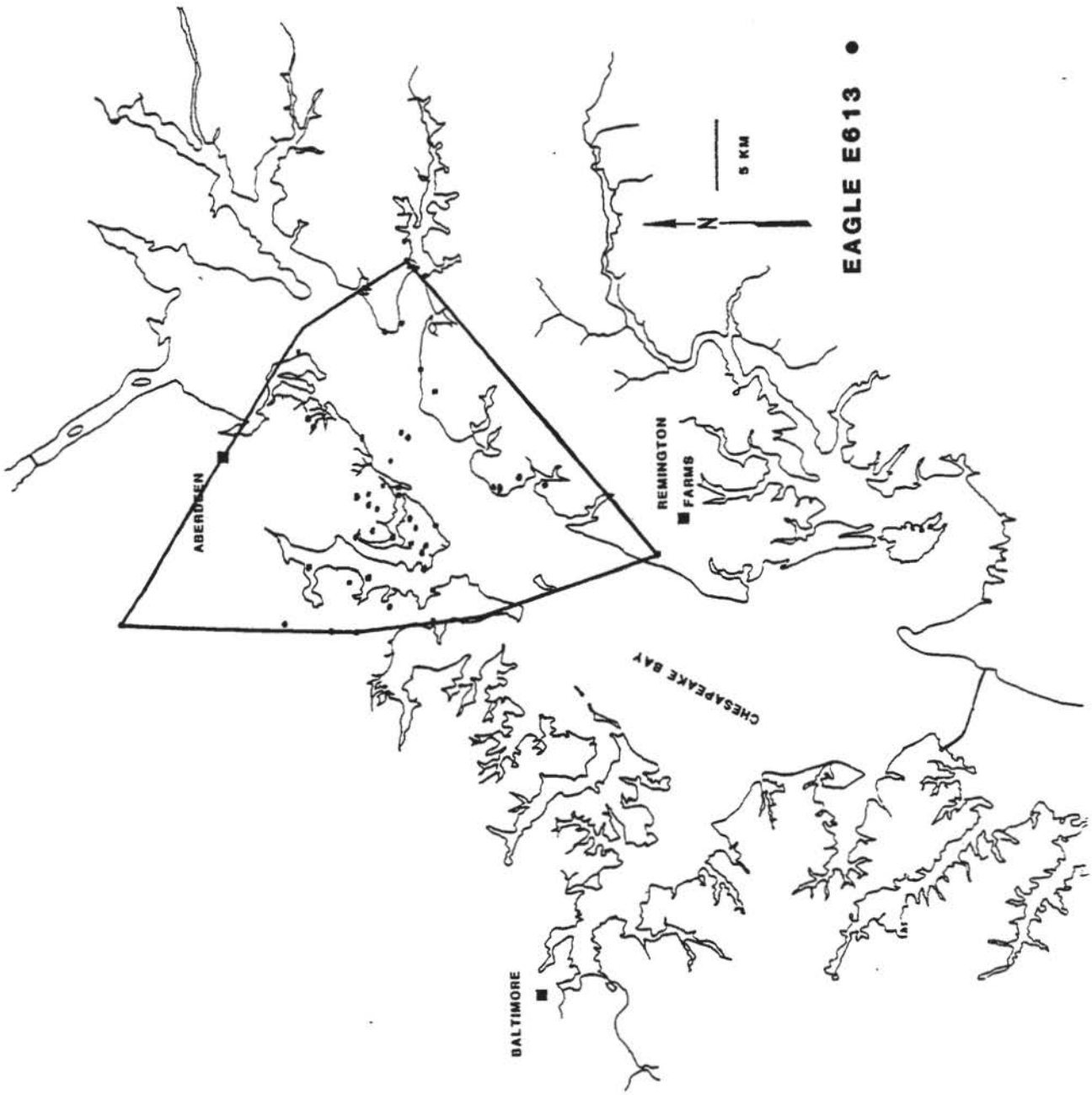


Figure 97. Locations and seasonal convex polygon home range of eagle E613 on the Northern Chesapeake Study Area during winter 1984-1985.

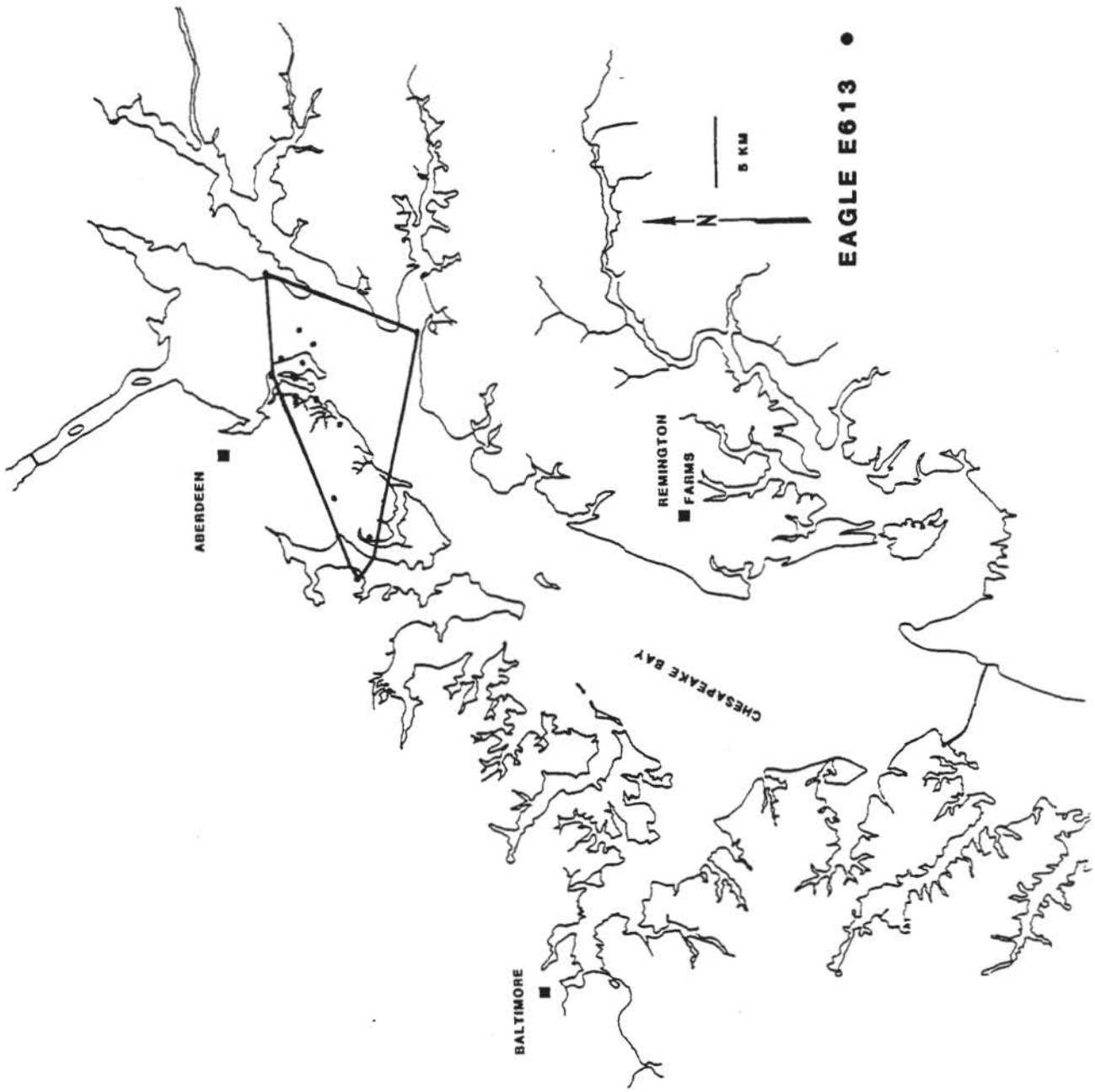


Figure 98. Locations and seasonal convex polygon home range of eagle E613 on the Northern Chesapeake Study Area during spring 1985.

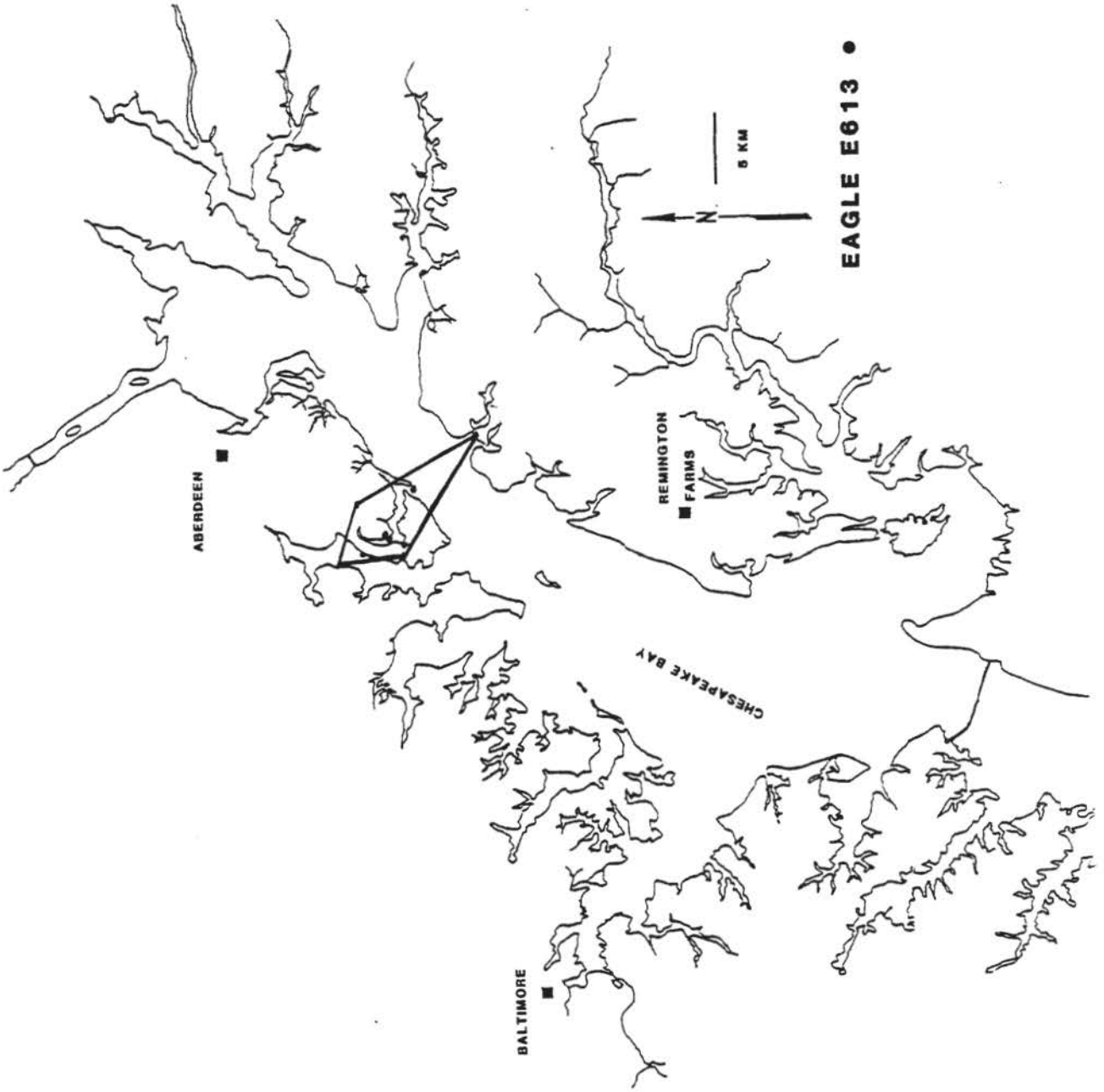


Figure 99. All locations and total convex polygon home range of eagle E641 on the Aberdeen-Edgewood area from Jun 1984 - Sep 1984.

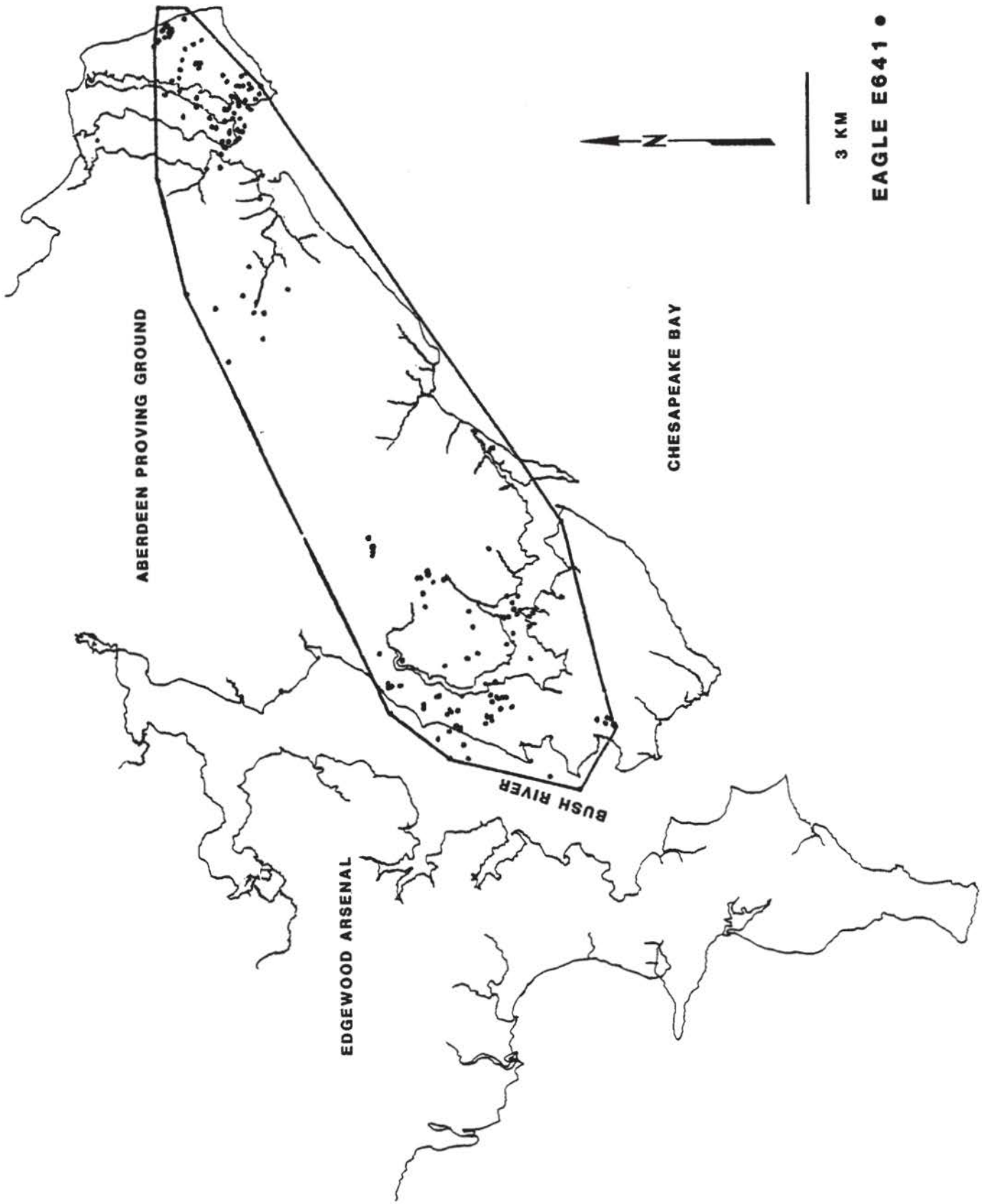


Figure 100. All locations and total convex polygon home range of eagle E700 on the Aberdeen-Edgewood area during Jun 1984

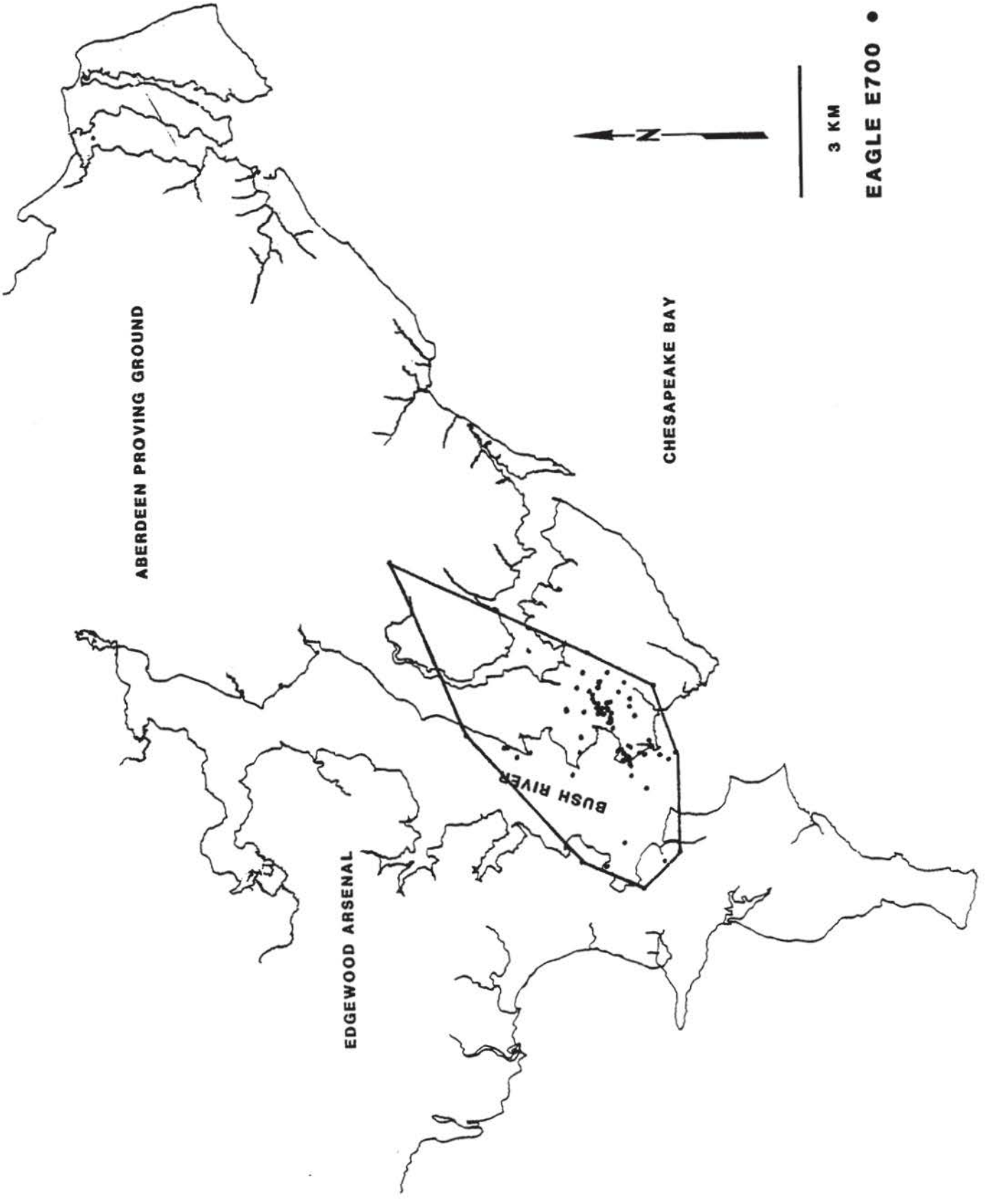


Figure 101. All locations and total convex polygon home range of eagle E842 on the Northern Chesapeake Study Area from Jul 1984 - Aug 1984.

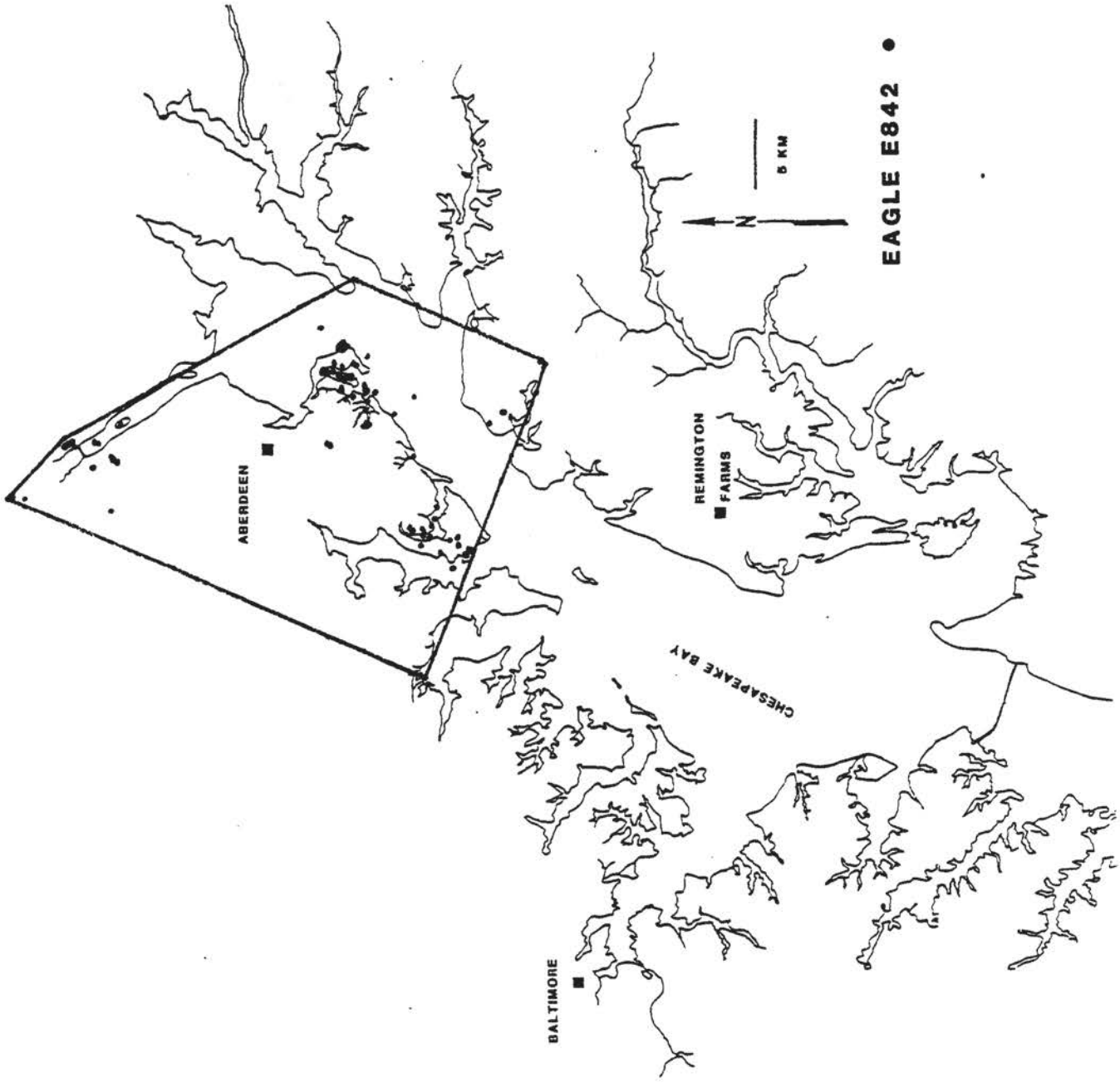


Figure 102. Locations of eagle E842 on the Susquehanna River during Aug 1984.

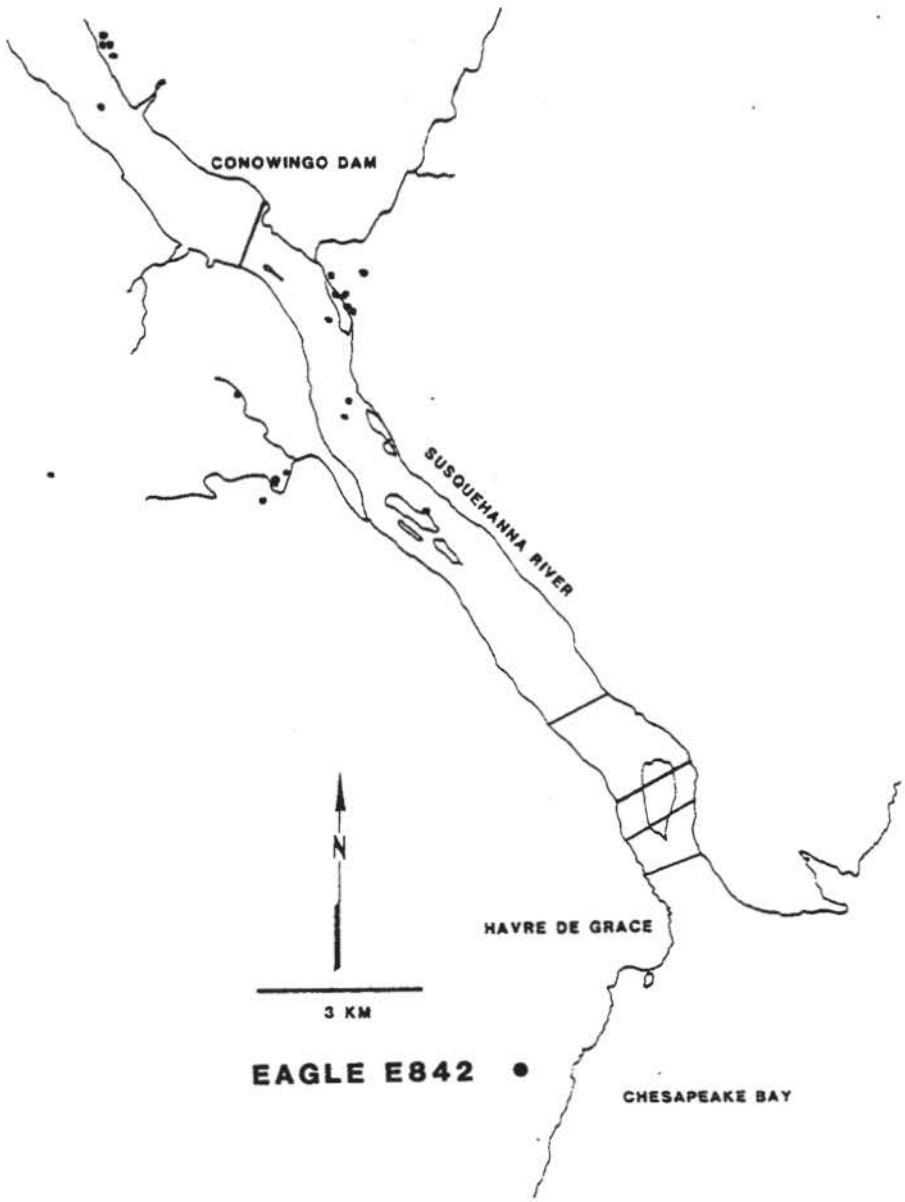


Figure 103. Total convex polygon home range of eagle A451 on the Chesapeake Bay from Dec 1984 - Feb 1985.

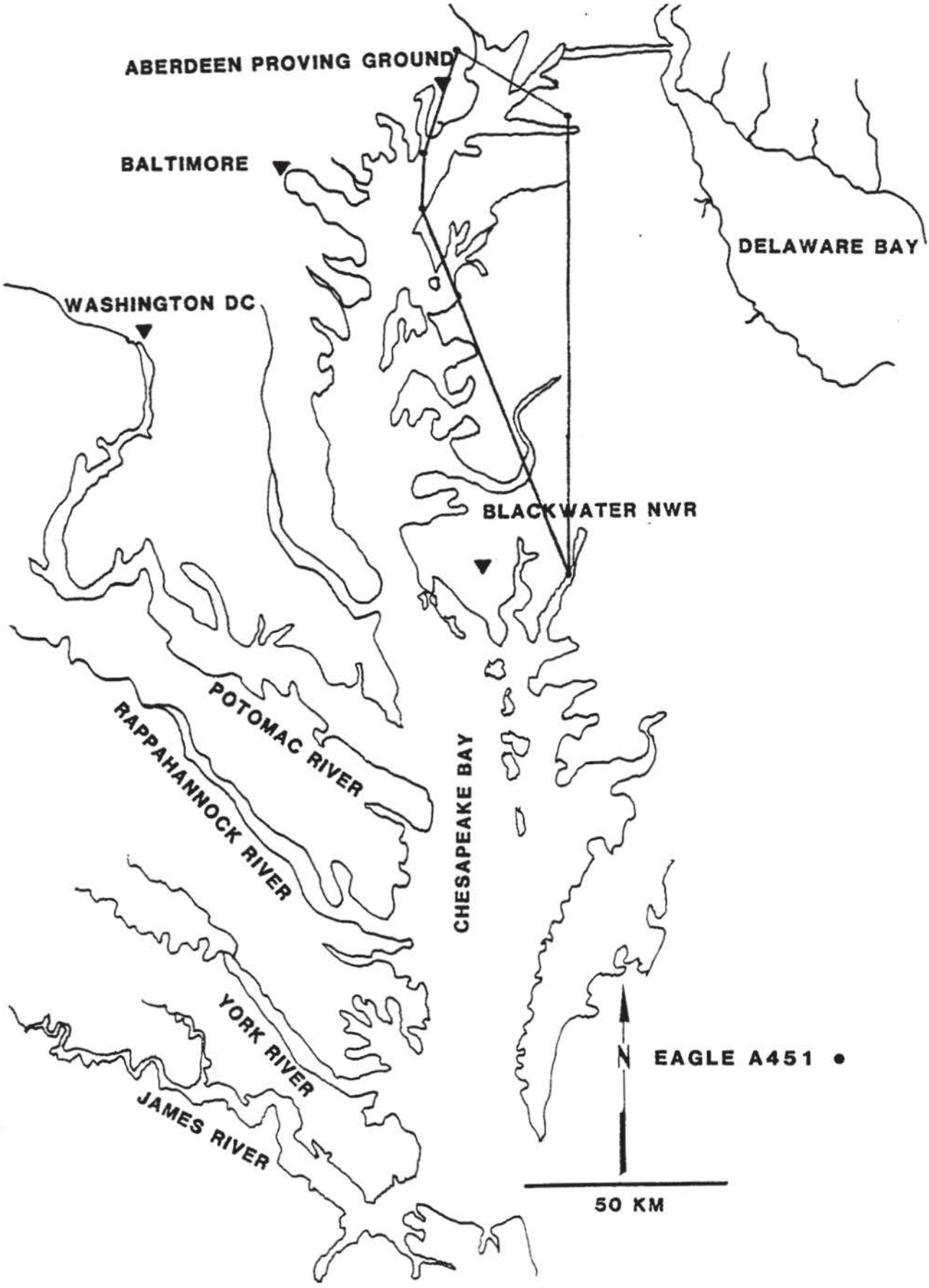


Figure 104. Locations and seasonal convex polygon home range of eagle A451 on the Northern Chesapeake Study Area during winter 1984-1985.

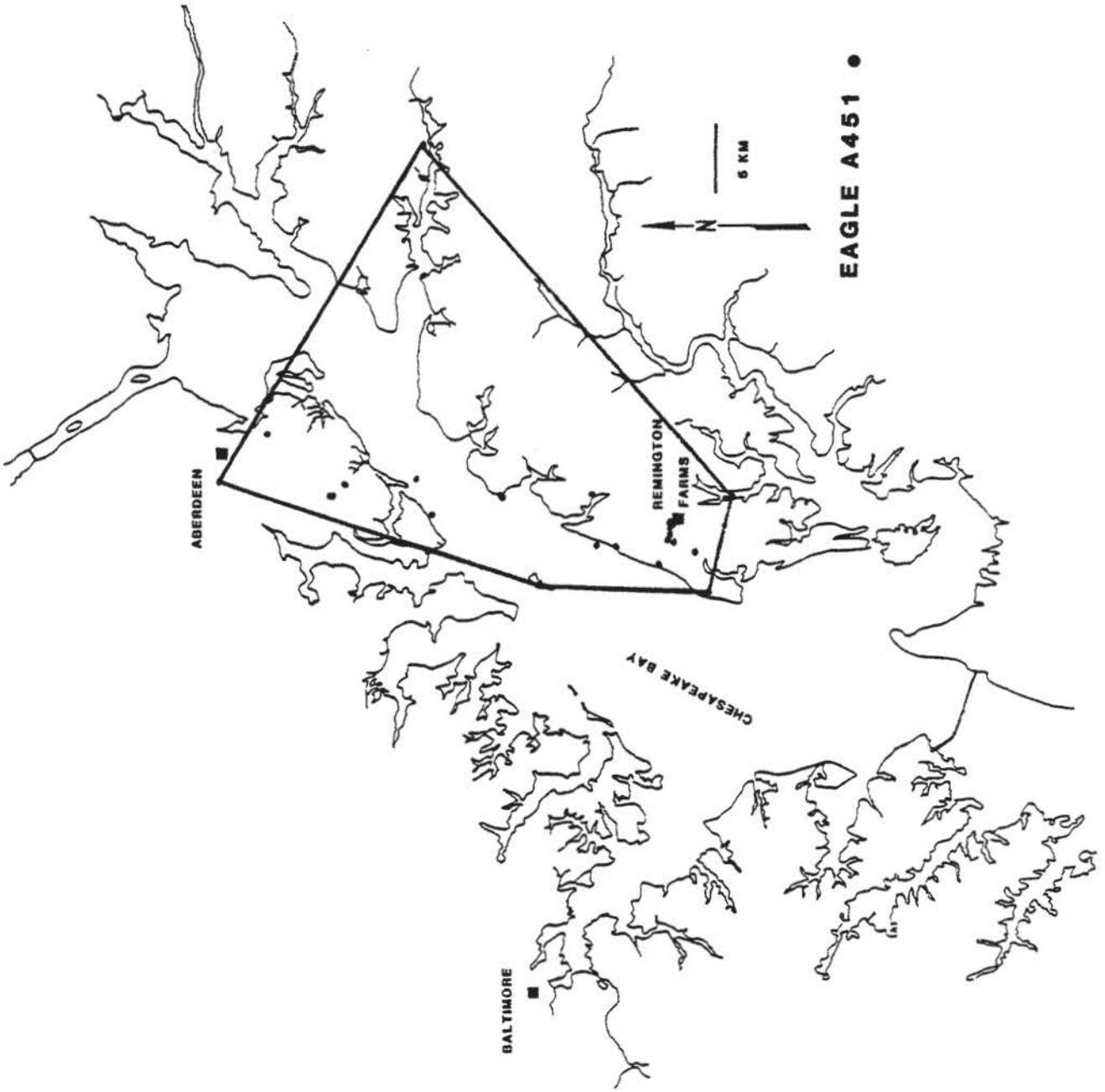


Figure 105. Total convex polygon home range of eagle A477 on the Chesapeake Bay from Dec 1984 - Feb 1985.

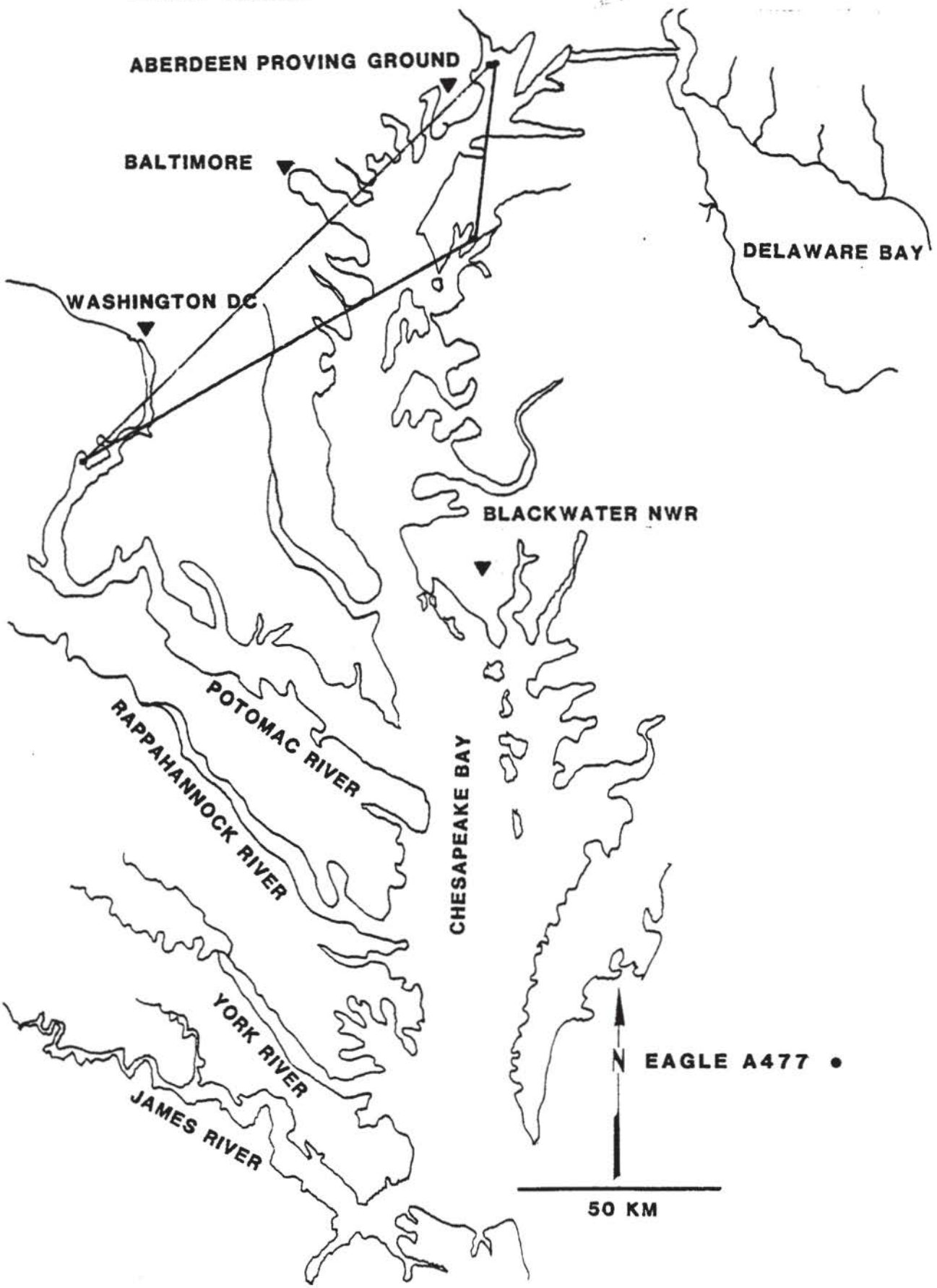


Figure 106. Locations and seasonal convex polygon home range of eagle A477 on the Northern Chesapeake Study Area during winter 1984-1985.

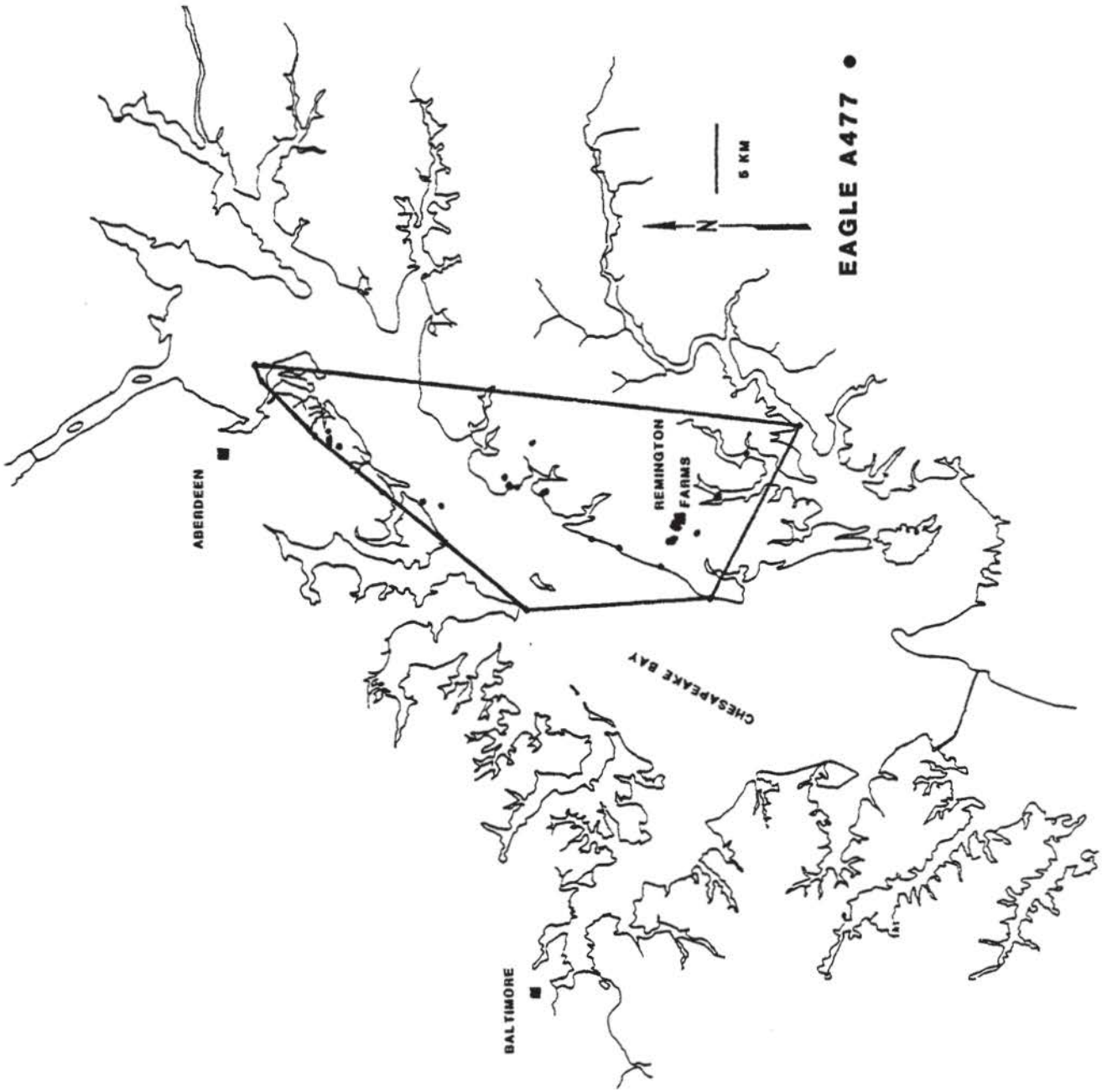


Figure 107. All locations of eagle A635 on the Northern Chesapeake Study Area during Dec 1984.

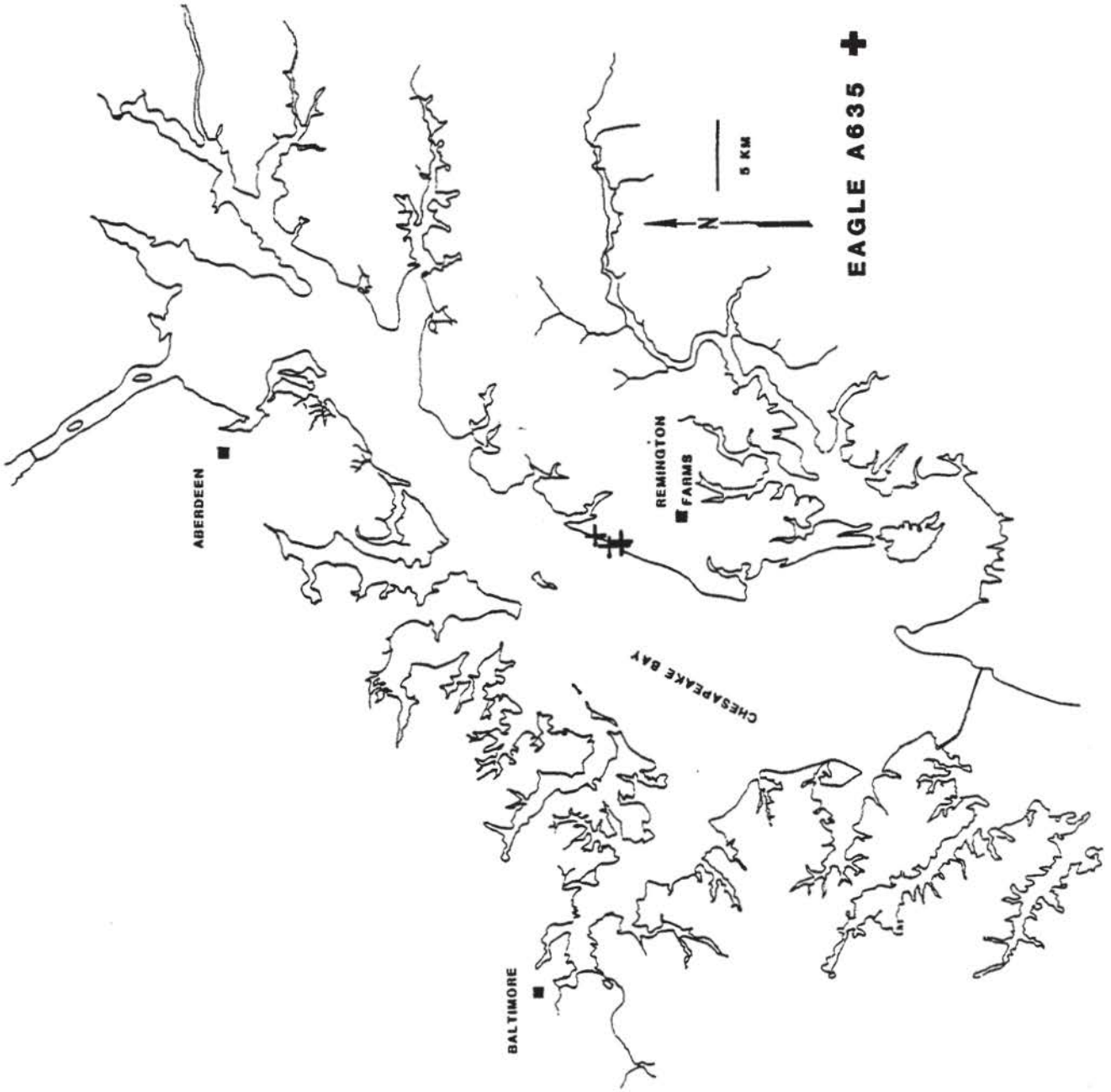


Figure 108. All locations and total convex polygon home range of eagle A734 on the Susquehanna River from Oct 1984 - Jan 1985.

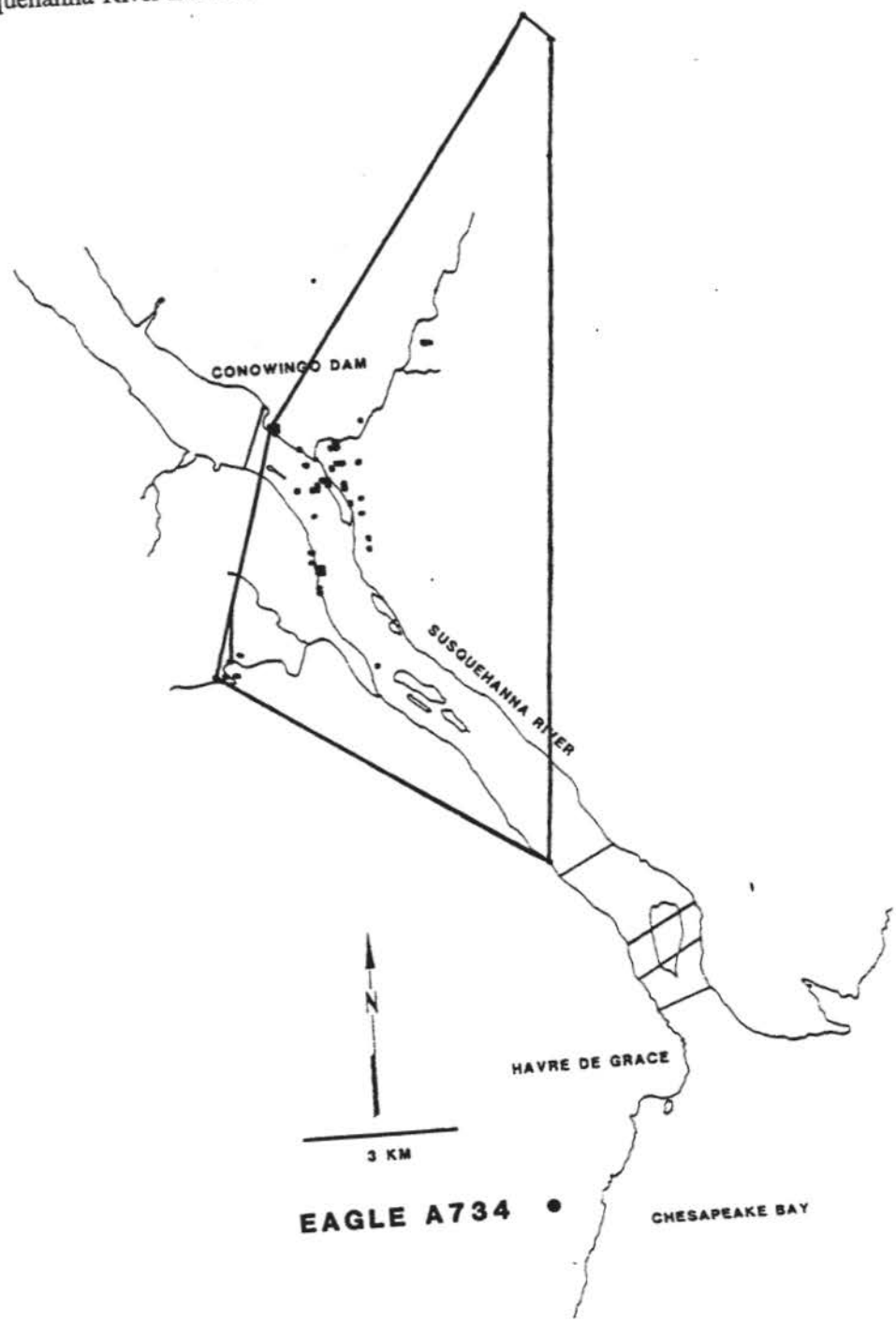


Figure 109. Locations and seasonal convex polygon home range of eagle A734 on the Susquehanna River during fall 1984.

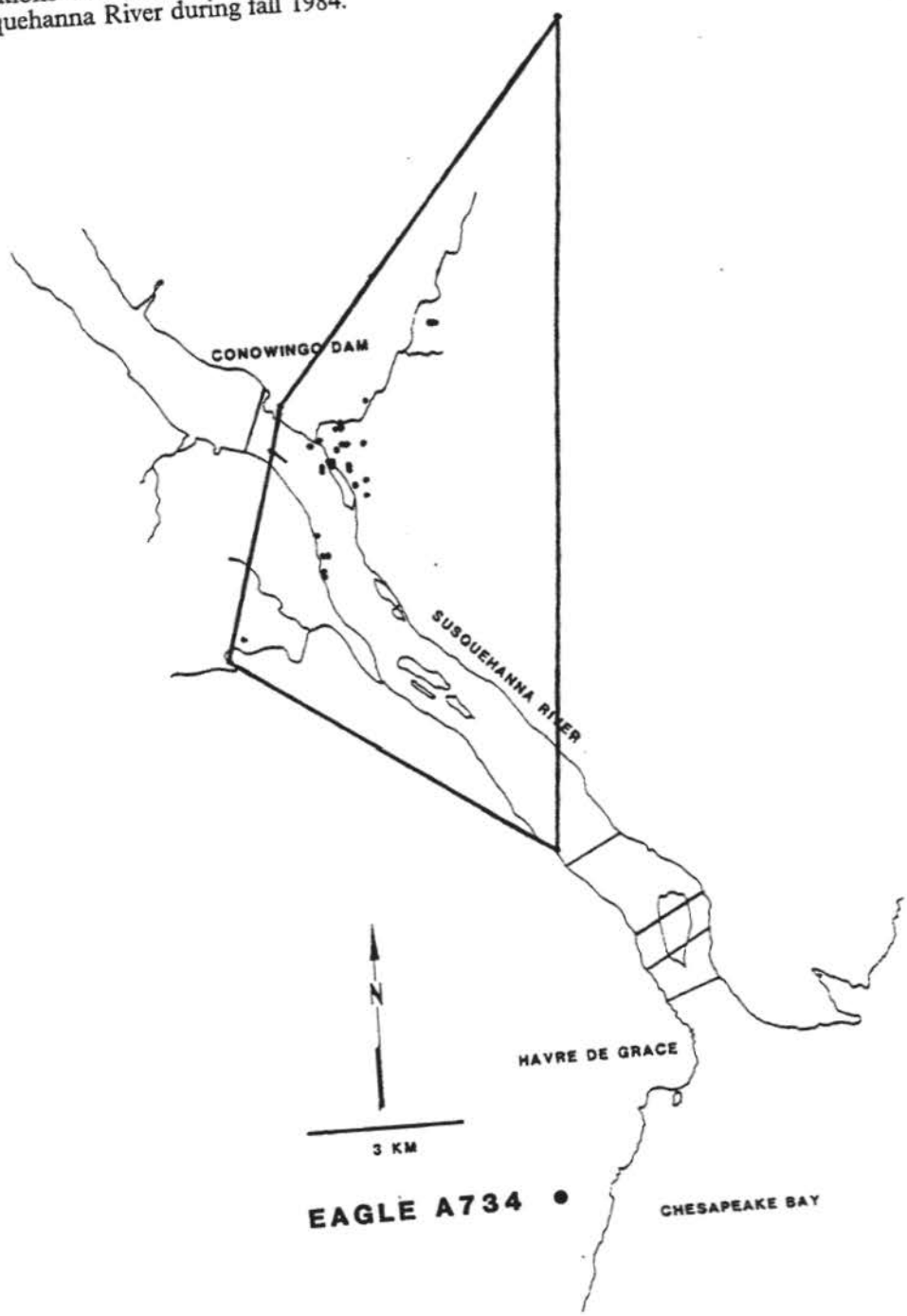


Figure 110. Locations and seasonal convex polygon home range of eagle A734 on the Susquehanna River during winter 1984-1985.

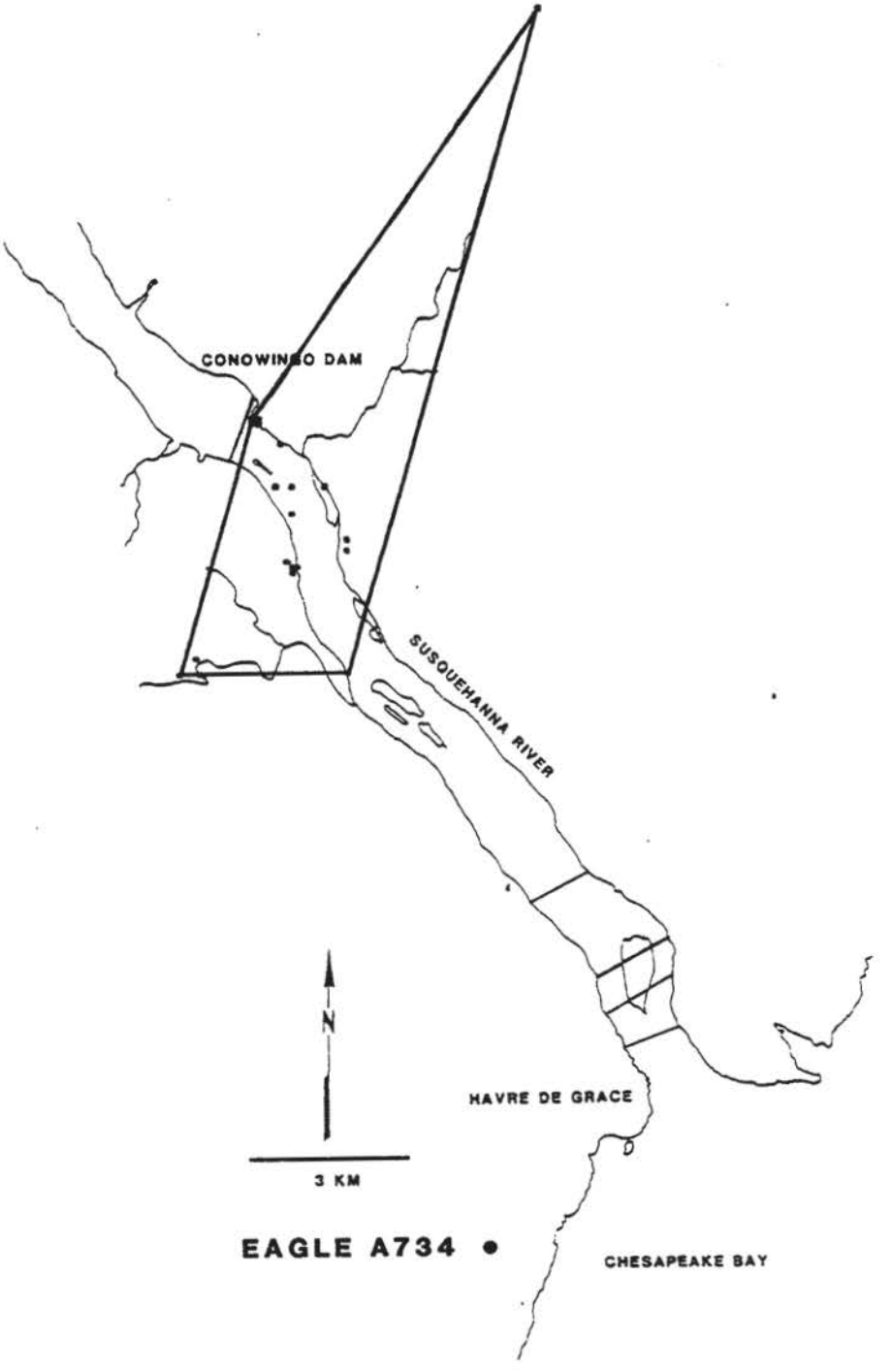


Figure 111. All locations of eagle A801 on the Northern Chesapeake Study Area during Dec 1984.

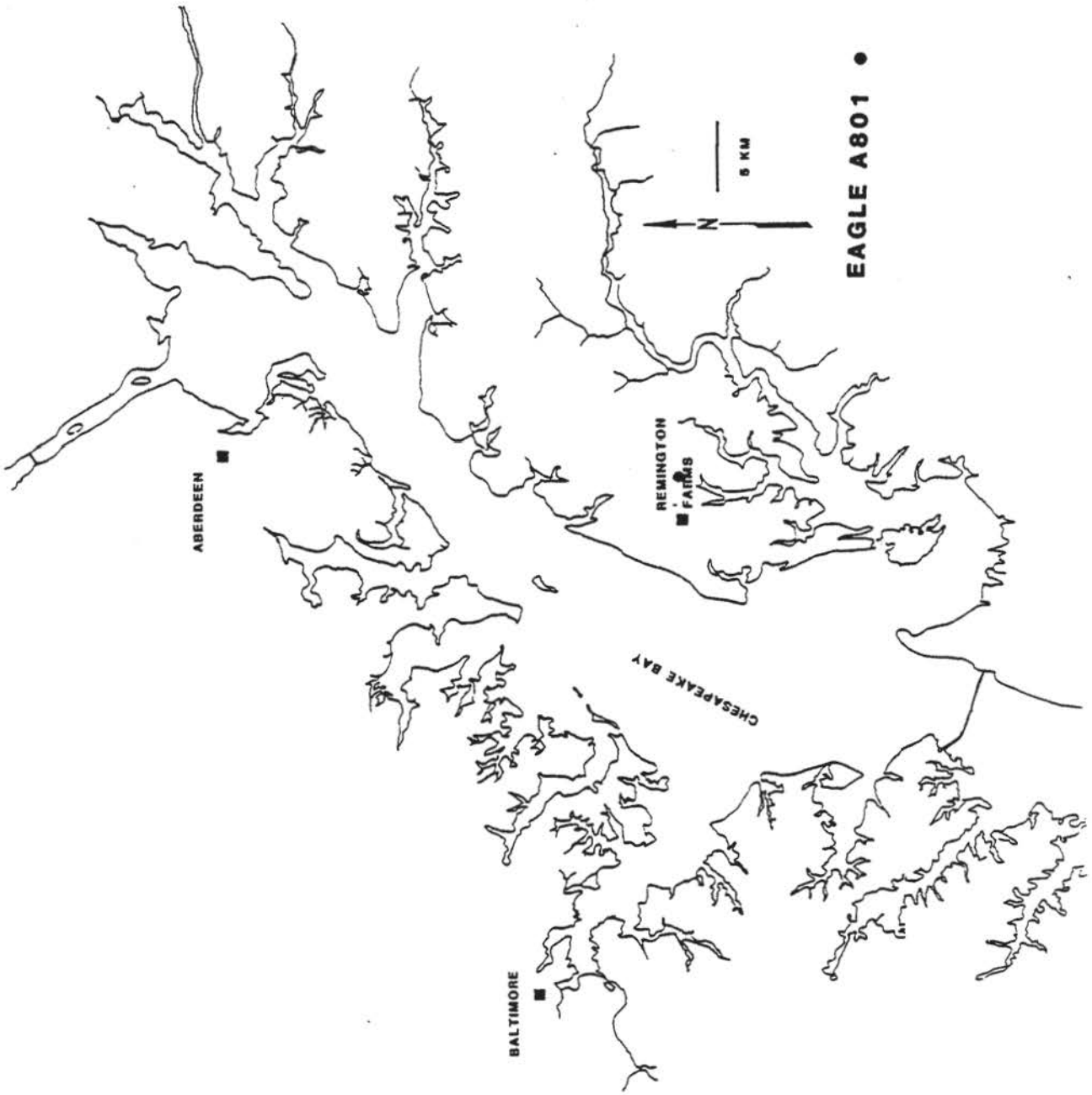


Figure 112. Total convex polygon home range of eagle A842 on the Chesapeake Bay from Dec 1984 - Mar 1985.

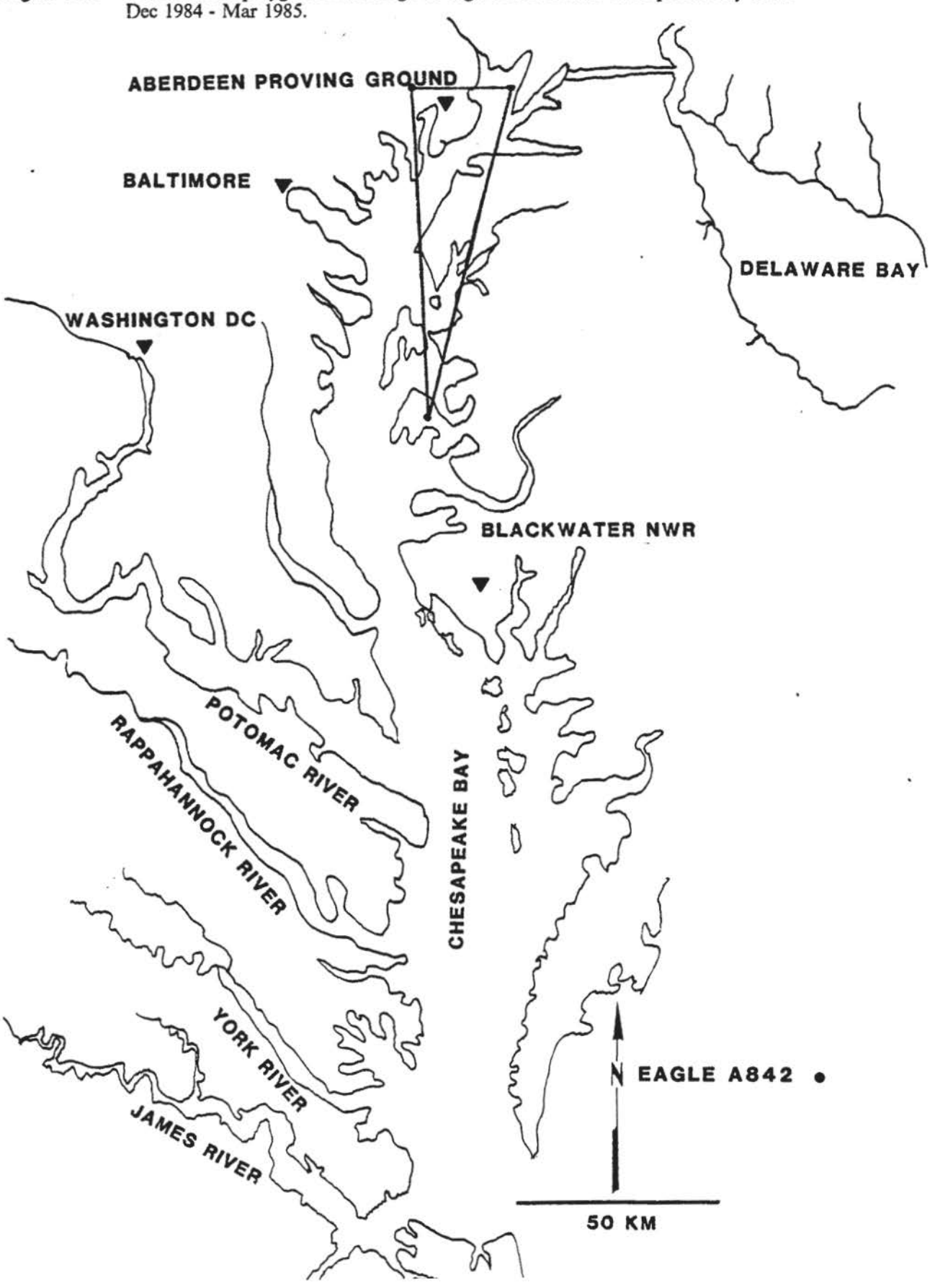


Figure 113. Locations and seasonal convex polygon home range of eagle A842 on the Northern Chesapeake Study Area during winter 1984-1985.

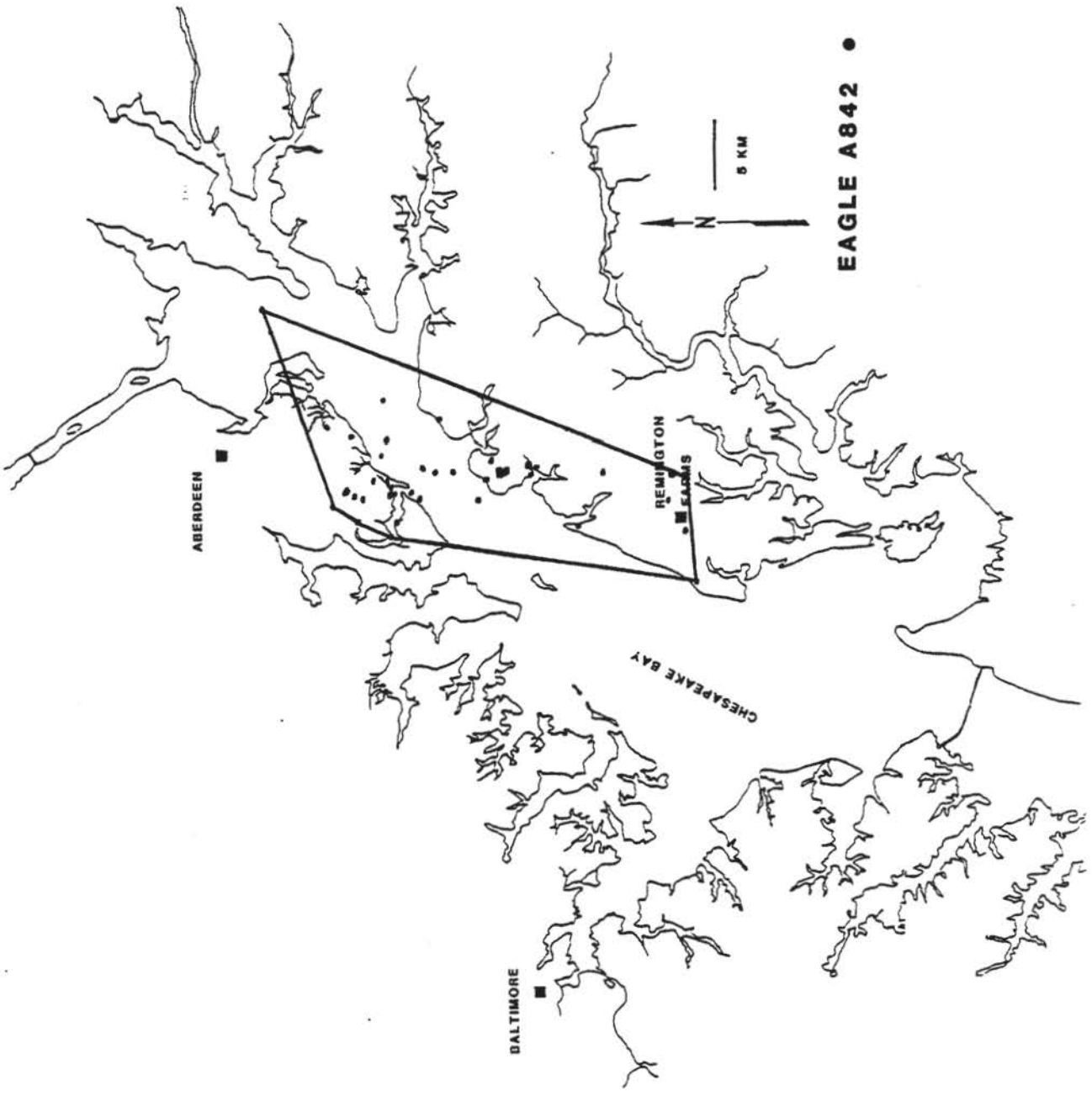


Figure 114. Locations and seasonal convex polygon home range of eagle A842 on the Northern Chesapeake Study Area during spring 1985.

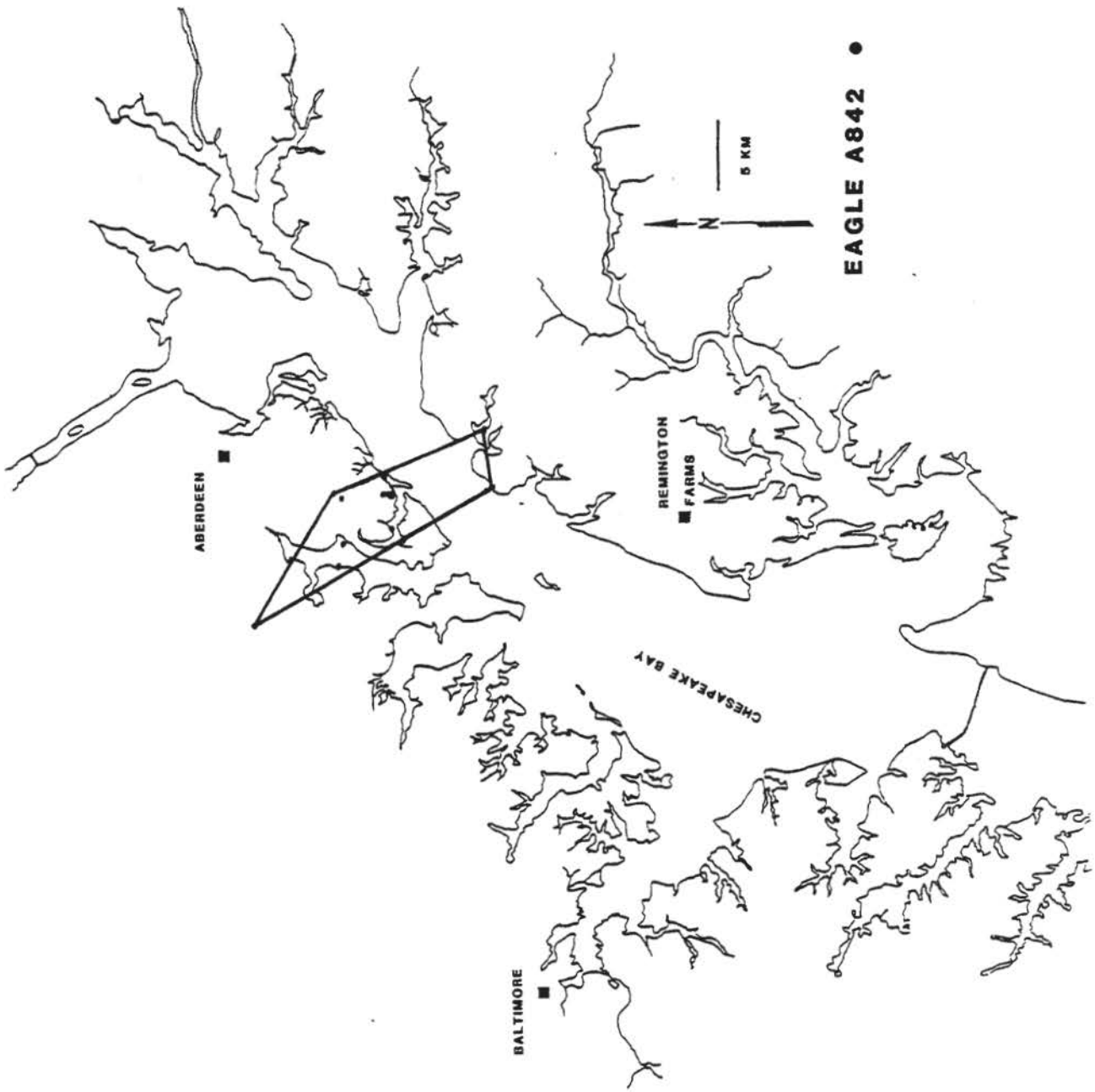


Figure 115. All locations and total convex polygon home range of eagle B292 on the Northern Chesapeake Study Area from Dec 1984 - Mar 1985.

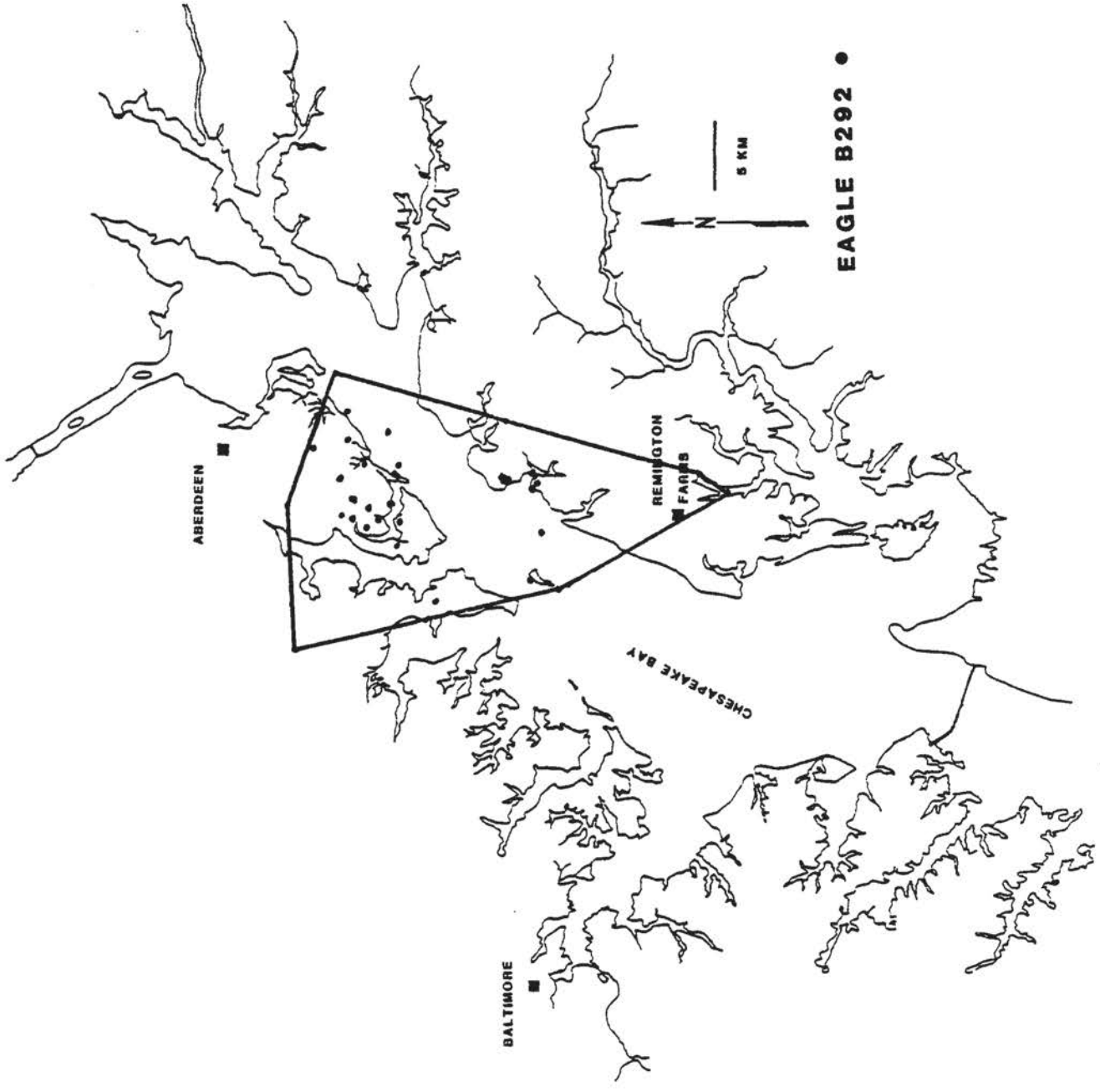
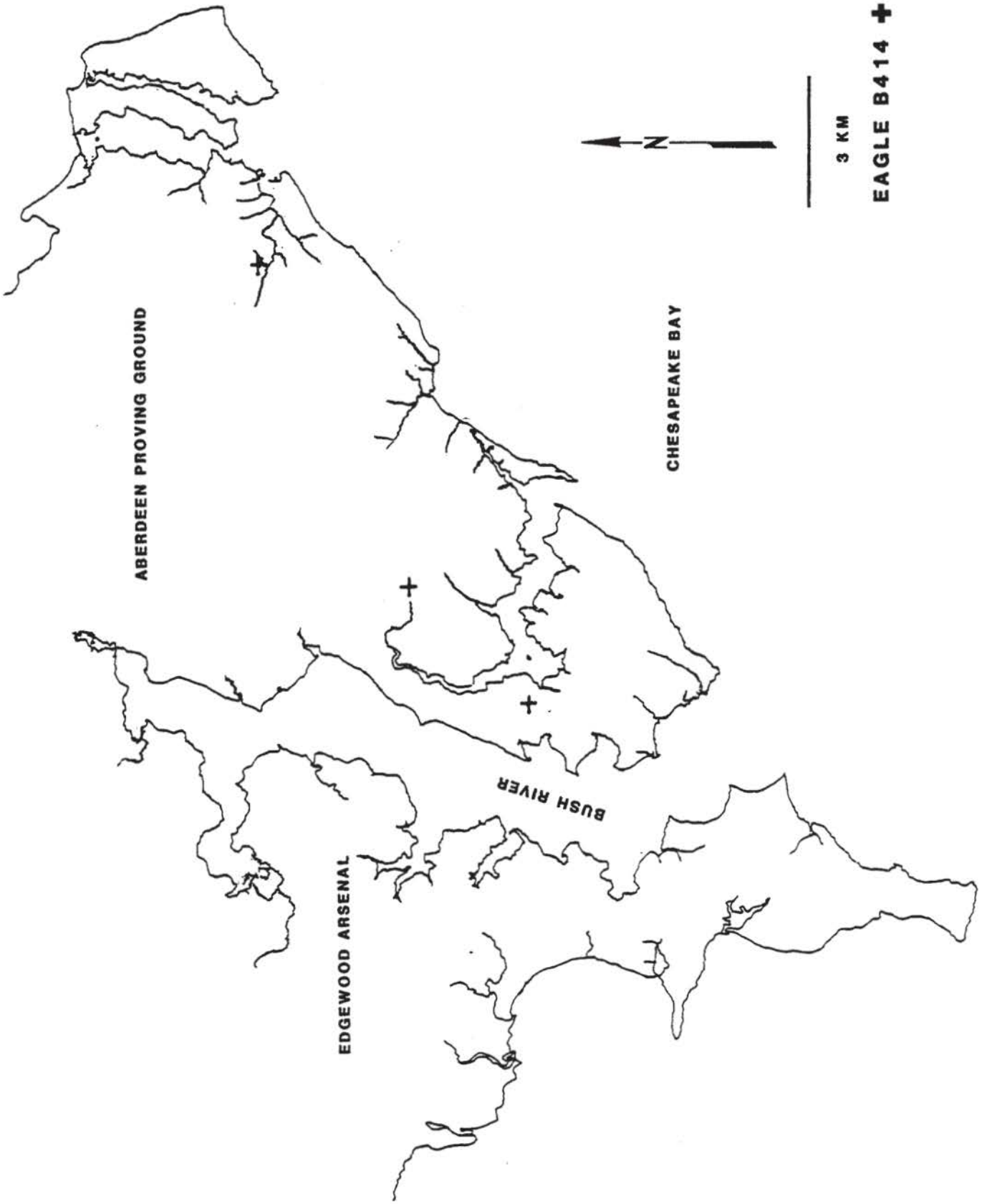



Figure 116. All locations and total convex polygon home range of eagle B414 on the Aberdeen-Edgewood area during Mar 1984.