

**FINAL REPORT**

**RECONNAISSANCE AND ASSESSMENT OF THE NEED, IMPORTANCE,  
AND COST OF CONDUCTING BAT INVENTORIES AT THOMAS  
STONE NATIONAL HISTORIC SITE, GEORGE WASHINGTON  
BIRTHPLACE NATIONAL MONUMENT, AND COLONIAL NATIONAL  
HISTORICAL PARK**

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### Abstract

Bat inventories are recommended for Colonial National Historical Park (COLO), George Washington Birthplace National Monument (GEWA), and Thomas Stone National Historic Site (THST) to identify species occurrence in these parks. In order to avoid potential future conflicts among alternative uses within the parks, it is important that resource managers know which bat species are present and their ecology. Bat species assemblages at COLO, GEWA, and THST would be comparable to those found on the Coastal Plain of the southeastern United States. Although it is unlikely, but not certain, that any federally listed endangered bat species occur at COLO, GEWA, or THST, several southeastern species, including some of special concern, have geographic ranges with northern limits in southeastern Virginia. Because of its geographic location and diversity of cover types, COLO probably has the highest bat species richness and highest potential for species of special concern of the 3 parks and should receive priority for bat inventories. There are 8 bat species that probably occur at COLO, including Rafinesque's big-eared bat (*Corynorhinus rafinesquii macrotis*), which is a species of special concern throughout its range and is state-endangered in Virginia. There probably are 7 common bat species that occur at THST and GEWA. Cover types at GEWA are similar to those at COLO. However, GEWA is approximately 95 km north of COLO and bat species more restricted to the southeastern United States probably do not occur there. The bat community at THST probably is similar to the community at GEWA. However, the number of bats occurring at THST may be less than at GEWA because THST is smaller in size and has fewer permanent water sources. A baseline inventory of bat species commonly occurring within these parks could be accomplished during 1 summer (i.e., 11 weeks); 6 weeks at COLO, 3 weeks at GEWA, and 2 weeks at THST.

for an estimated cost of \$68,310. GEWA and THST, if done without COLO, could be done for an estimated cost of \$39,534.

### **Introduction**

Approximately 1,000 bat species occur worldwide on every continent except Antarctica. Bats represent about 25% of all mammalian species. In the United States, 45 bat species representing 4 families and 19 genera occur. Of these, 6 are either endangered species or subspecies. Additionally, 20 are considered species of special concern. Population declines typically are attributed to habitat loss or colony disturbance (Harvey et al. 1999). In the mid-Atlantic region, 17 bat species occur, 6 of which are federally listed endangered or of special concern.

All bat species occurring in the mid-Atlantic region are insectivorous. Bats consume a wide variety of insects including harmful forest and crop pests. Bats may consume over half their body weight in insects each night (Harvey et al. 1999). Bats in the mid-Atlantic region are nocturnal and use ultrasonic echolocation to navigate and locate food.

During summer, most bat species are segregated sexually. Moreover, different bat species typically do not roost together in summer. The females of some species form maternity colonies and others roost singly. Males of most species roost singly or in small groups. Bats roost in caves, mines, tunnels, buildings, bridges, hollow trees, tree foliage, and under leaf litter and exfoliating bark (Barbour and Davis 1969, Appendix I). Some bat species in the mid-Atlantic region migrate hundreds of kilometers between summer roosts and winter hibernacula (Barbour and Davis 1969, Harvey et al. 1999).

Much recent attention has focused on the conservation and management of bats because of their role in the ecosystem and as possible indicator species (Fenton 2003, Miller et al. 2003).

For example, bats fill a variety of trophic roles and are vulnerable to land use impacts such as deforestation, urbanization, and environmental contamination (Fenton 1997, Pierson 1998, O'Shea et al. 2003). However, to make informed management decisions regarding bats, collecting baseline inventory data is an important and necessary initial undertaking. Although a general sense of bat species composition for a given area can be determined by examining geographic ranges, verifying the presence of species through an inventory process facilitates more informed and accurate management decisions.

Many bat species that are of special concern, threatened, or endangered occur on Federal lands, including those administered by the National Park Service (NPS) (Johnson et al. 2003b, 2005). We met with Charles D. Rafkind, Natural Resource Manager, Colonial National Historical Park (COLO); and Rijk Morawe, Natural Resource Manager, George Washington Birthplace National Monument (GEWA) and Thomas Stone National Historic Site (THST) on 27–28 April 2005 to discuss bat inventories and inspect the various habitats within the parks to determine potential bat use and to estimate efforts required to inventory bat communities. During our meetings, we obtained Geographic Information System (GIS) layers to assist our inventory effort approximations.

### **Preliminary assessment of parks**

We examined potential bat habitat and inventory sites during our tours throughout COLO, GEWA, and THST. Based on our previous experiences conducting bat inventories on State and Federal lands, we were able to determine potential bat habitat and inventory sites in each park. All 3 parks contained suitable roosting sites (e.g., trees, structures), foraging areas (e.g., fields, forests, waterways), and water sources (e.g., streams, rivers, ponds) for bats. Food resources (i.e., insects) are generally abundant and diverse because of the diversity of cover types

and water sources in the parks. We identified inventory sites for mist net and acoustic surveys in each park.

### *Colonial National Historical Park*

Colonial National Historical Park is located in James City, Surry, Williamsburg City, and York counties, Virginia. It contains >3,800 ha of wetlands, forests, shorelines, and fields. The Yorktown tract consisted of fields, mature mixed forests, and water sources including the York River, Wormley Pond, and several small streams. These water sources not only provide bats with water, but also are habitat for insects. Some of these aquatic insects become volant during the adult stage of their life cycle and are a food source for bats. The Jamestown tract is located on Jamestown Island, which is surrounded by the James and Back rivers. The mature forests, marshes, and swamps that occur on the island provide habitat for bats. Historic and modern structures exist at the Jamestown and Yorktown tracts, but there were no reports of bats roosting in them.

At COLO, the mosaic of cover types likely provides roosting and foraging habitat for a variety of bat species. Moreover, bat species richness at COLO likely is higher than at GEWA or THST (Appendix II). Many bat species in the southeastern United States have geographic ranges with northern limits in southeastern Virginia. COLO is the southernmost of the 3 parks, and therefore is most likely to provide habitat for these southeastern bat species. Some species of concern that occur in the southeastern United States and potentially occur at COLO include Rafinesque's big-eared bats (*Corynorhinus rafinesquii*), southeastern myotis (*Myotis austroriparius*), and northern yellow bats (*Lasiurus intermedius*). Bat inventory efforts at COLO would include acoustic monitoring with Anabat II bat detectors, mist netting, harp trapping, and visually inspecting various cover types and potential roosts. A reasonable assessment of bat

species commonly occurring at COLO could be completed in about 6 weeks (Appendix III). The Jamestown and Yorktown tracts would receive the most intense inventory efforts within COLO because they are the largest, most contiguous tracts with numerous survey opportunities. At Jamestown, we located 4 potential mist net sites and 7 acoustic monitoring sites (Figures 1 and 2). At Yorktown, we located 8 potential mist net sites and 14 acoustic monitoring sites (Figure 3). We located few potential mist net sites and acoustic monitoring sites along the Colonial National Historical Parkway because it is a narrow public roadway with few adjacent tracts to survey (Figure 4).

#### *George Washington Birthplace National Monument*

The George Washington Birthplace National Monument is located in Westmoreland County, Virginia, and contains about 270 ha of wetlands, forests, shorelines, and fields. The park is bordered on the north by the Potomac River and on the east by Popes Creek. Within the park, there are several water sources including Dancing Marsh, Ice Pond, and other marshes and ponds. The mature mixed forests throughout the park surely provide roosting sites for many bat species. There are historic and modern structures at GEWA, but there were no reports of bats using them as roost sites.

The mosaic of cover types likely provides roosting and foraging habitat for a variety of bat species. However, the bat community at GEWA probably lacks species restricted to the southeastern United States (Appendix II). It is unlikely that any bat species of special concern occur at GEWA. Bat inventory efforts at GEWA would include acoustic monitoring with Anabat II bat detectors, mist netting, harp trapping, and visually inspecting various cover types and potential roosts. A reasonable assessment of bat species commonly occurring at GEWA could be completed in about 3 weeks (Appendices III and IV). We located 7 potential mist net

sites at creeks, ponds, wooded roads, and hiking trails. We located 13 potential acoustic monitoring sites scattered throughout the park in various cover types (Figure 5).

#### *Thomas Stone National Historic Site*

The Thomas Stone National Historic Site is located in Charles County, Maryland and contains about 110 ha of streams, forests, and fields. The mature forests at THST would provide roosting sites for bats. Within the park, there are a few water sources including 2 small ponds and a small stream, Hoghole Run.

The mosaic of cover types would provide roosting and foraging habitat for a variety of bat species. Similar to GEWA, the bat community at THST probably lacks species restricted to the southeastern United States (Appendix II). It is unlikely that any bat species of special concern occur at THST. Bat inventory efforts at THST would include acoustic monitoring with Anabat II bat detectors, mist netting, harp trapping, and visually inspecting various cover types and potential roosts. A reasonable assessment of bat species commonly occurring at THST could be completed in about 2 weeks (Appendices III and IV). We located 4 potential mist net sites at creeks, ponds, wooded corridors, and hiking trails. We located 7 potential acoustic monitoring sites scattered throughout the park in various cover types (Figure 6).

#### *Bat species occurrences*

We predicted bat species occurrences in each park using geographic ranges and Virginia county records. We determined if geographic ranges (NAUS 2006) of bat species overlapped park boundaries. We obtained Virginia county records (VADGIF 2005) for each species and determined if they occurred in the same counties as the parks. Although Thomas Stone National Historic Site is located in Maryland, it is close enough to Virginia (<13 km) to assume bats occurring in the nearest Virginia counties probably also occur in Charles County, Maryland.

In Maryland, 10 bat species have been documented (Appendix II, Paradiso 1969). In Virginia, 17 bat species have been documented, including all those that occur in Maryland (Appendix II, VADGIF 2005). The bat communities at COLO, GEWA, and THST are probably similar in species composition to those found on the Coastal Plain of the southeastern United States (Menzel et al. 2000a, 2003). At COLO, GEWA, and THST, we could reasonably expect to document big brown bats (*Eptesicus fuscus*), eastern red bats (*Lasiurus borealis*), hoary bats (*L. cinereus*), little brown myotis (*Myotis lucifugus*), evening bats (*Nycticeius humeralis*), and eastern pipistrelles (*Pipistrellus subflavus*). All are considered common species throughout their respective ranges. Some bat species including Seminole bats (*L. seminolus*), northern yellow bats, Rafinesque's big-eared bats, Brazilian free-tailed bats (*Tadarida brasiliensis*), and southeastern myotis reach the northern periphery of their respective geographic ranges in southeastern Virginia (Figures 7–19; Barbour and Davis 1969). It is unlikely that any federally listed endangered bat species occur at COLO, GEWA, and THST. Endangered Virginia big-eared bats (*Corynorhinus townsendii virginianus*), Indiana myotis (*Myotis sodalis*), and gray myotis (*M. grisescens*) have been documented in Virginia, but in the western, mountainous portion of the state (VADGIF 2005). The summer ranges of Indiana myotis that hibernate in the Appalachian Mountains remain unclear. Indiana myotis begin to emerge from hibernation in mid-April (Cope and Humphrey 1977) and migrate long distances, sometimes >500 km, to their summer ranges (Kurta and Murray 2002). Virginia big-eared bats and gray bats are year round cave obligates (Barbour and Davis 1969). There are no cave resources within COLO, GEWA, or THST. Of the bat species that are more restricted to the southeastern United States, Rafinesque's big-eared bat and southeastern myotis are the only species of special concern that may occur at COLO, GEWA, and THST (Harvey et al. 1999). Although these species could occur at all 3

parks, realistically, COLO probably is the only park in which they may occur. Both subspecies of Rafinesque's big-eared bat occur in Virginia, but only *C. r. macrotis* potentially occurs at COLO, GEWA, and THST. *Corynorhinus r. rafinesquii* occurs in southwestern Virginia. *Corynorhinus r. macrotis* is state-endangered in Virginia. The northern limit of its geographic range is in southeastern Virginia, and it has been documented in counties surrounding COLO. It is possible that this subspecies occurs at COLO, but probably not at GEWA or THST. The southeastern myotis is a Virginia state-rare species that is known from 4 Virginia counties southeast of COLO. If present at COLO, their numbers would likely be small. It probably does not occur at GEWA or THST. Other common southeastern United States bat species that have a low probability of occurring at COLO, GEWA, or THST, include northern yellow bats, Seminole bats, and Brazilian free-tailed bats. There are incidental records of these species from southeastern Virginia. Therefore, if present, they would be most likely to occur at COLO. Only 2 incidental occurrences of northern yellow bats are known north of its contiguous range along the coast of the southeastern United States; 1 at Willoughby Beach, Virginia (Rageot 1955) and 1 at Westfield, New Jersey (Koopman 1965). Their geographic range coincides with the range of Spanish moss (*Tillandsia usneoides*). We did not observe Spanish moss at any of the parks. That is not to say that it does not occur there. Spanish moss is known to occur in Northampton County and near Virginia Beach. Similar to northern yellow bats, Seminole bats have a remote possibility of occurring at COLO. However, few records of Seminole bats have been documented north of North Carolina (Poole 1932, Layne 1955). Only 1 occurrence of the Brazilian free-tailed bat has been documented in Virginia, from a house in Suffolk (City) County (VADGIF 2005).

Because of its geographic location and diversity of cover types, COLO probably has the highest bat species richness and highest potential for species of special concern of the 3 parks. GEWA is approximately 95 km north of COLO and bat species more restricted to the southeastern United States probably do not occur there. The bat community at THST probably is similar to the community at GEWA.

### **Bat inventory methods**

To accomplish a baseline inventory of bat species occurring at COLO, GEWA, and THST, we would use standard approved bat inventory methods, including capturing bats in mist nets and harp traps, acoustic monitoring for bat echolocation calls with Anabat II bat detectors, and visual observations at bat roosts. There are advantages and disadvantages to each method. Acoustic monitoring is a non-intrusive method of quickly documenting bat species within an area. More locations can be sampled during a night using acoustic monitoring than mist netting because it is a handheld device that is easy to move among sample sites. Acoustic monitoring can be used to identify potential mist netting sites. Acoustic monitoring can be conducted at fewer sites for longer periods of time to obtain information, including migration data and long-term activity trends. Some bat species are more readily documented with acoustic means than with capture techniques (O'Farrell and Gannon 1999). Currently, acoustic monitoring provides no data on sex, age, or reproductive condition of recorded bats. Moreover, there is some skepticism surrounding the accuracy of bat identification using acoustic methods (Barclay 1999). Mist netting and harp trapping provide definite identification of bat species as well as information including sex, age, and reproductive condition, which is important in evaluating the status of the bat community in an area.

*Mist netting and harp trapping*

To capture bats, we would use 50-denier, 2-ply, 38 mm-mesh mist nets (Avinet, Dryden, New York, USA) measuring 2.6 m high and 6, 9, or 12 m long. Mist nets typically are erected over stream corridors, small pools, hiking trails, and service roads. We use 1-tier and 3-tier mist net arrangements. A 3-tier mist net arrangement consists of 3 mist nets stacked vertically and suspended between a rope and pulley system on 2 10-m telescoping poles (Gardner et al. 1989). We may use a harp trap (1 × 1 m; Bat Conservation and Management, Carlisle, Pennsylvania, USA) in unique situations, including at roost sites in trees or buildings, to determine species. We would conduct mist netting and harp trapping every weeknight for 5 hours following sunset, i.e., until 0200 hours. We would not conduct bat inventories during periods of heavy rain, high wind ( $\geq 20$  kph), or cold temperatures ( $< 0^{\circ}$  C). We check mist nets and harp traps for captured bats at least every 20 minutes, and more frequently when bat activity is high. We would collect standard data from each captured individual including the species (Menzel et al. 2002b) as well as its weight, forearm length, sex, age, and reproductive condition before being released. We determine weight (g) with a spring scale (Pesola, Switzerland). Forearm length is measured to the nearest 0.5 mm. We determine age (i.e., adult or juvenile) by examining the level of epiphyseal-diaphyseal fusion in finger bones (Kunz and Anthony 1982). We determine the reproductive condition of female bats by palpating the abdomen and inspecting mammary glands (Racey 1988).

We use an Olympus Camedia C-5050 digital camera (New York, New York, USA) to create voucher photographs of every species captured at every park. As some southeastern bat species may be at the limits of their northern range, we may seek to acquire tissue (wing punch) or hair samples of such species for genetic analysis in order to avoid any questions concerning

their identification. For example, several bat biologists have raised questions over whether Seminole bats can be distinguished visually from dark-morphed red bats. Bat biologists have worked out protocols for these types of sampling procedures. In view of the fact that hair regrows and the tiny hole made in the wing membrane heals over quickly, bats are only affected temporarily by these procedures.

### *Acoustic monitoring*

To some extent, bat species can be distinguished by characteristics of their echolocation calls (Fenton and Bell 1981). We use Anabat II (Titley Electronics, Ballina, Australia) broadband, frequency-division, bat detectors to acoustically monitor for bat echolocation calls. We acoustically monitor at multiple sites within various land covers and vegetative structures at each park to take advantage of the various foraging strategies exhibited by bat species that potentially occur in the parks (Menzel 2003, Ford et al. 2004, 2005). We conduct acoustic monitoring for 20 minutes at each site between sunset and 0200 hours. Each acoustic monitoring site may be sampled up to 2 times on the same night or different nights, depending on logistics. Echolocation calls are recorded to an Anabat CompactFlash storage Zero-Crossing Analysis Interface Module. Echolocation calls are later downloaded to a computer and analyzed using Analook 4.8p software (Corben 2001). We use qualitative and quantitative echolocation call identification methods (Fenton and Bell 1981, O'Farrell et al. 1999, Murray et al. 2001). We identify echolocation calls of species by comparing our unknowns to a library comprised of echolocation calls collected from hand-released bats marked with chemiluminescent tags collected throughout the southeastern United States (Menzel et al. 2002a). We only identify echolocation call sequences containing  $\geq 3$  pulses. Currently, no techniques exist to reliably distinguish male/female or adult/juvenile bat echolocation calls.

*Summer roost evaluations*

Mist net and acoustic surveys would provide information on bat species composition and foraging areas at COLO, GEWA, and THST. However, roosting site information in forests can be determined by attaching radio transmitters to bats or by serendipitous observations. If we used radio transmitters, we would follow accepted procedures for determining roosting sites and foraging areas of bats (Samuel and Fuller 1994, Menzel et al. 2002c, Owen et al. 2003). Roosting sites would be located during the day and compared with random roosting sites (Menzel et al. 1998). Foraging areas would be located via simultaneous triangulation of bat locations throughout the night (Owen et al. 2003). Home ranges and habitat use also could be obtained from foraging data (Aebischer et al. 1993, Owen et al. 2003). Specifics of a radio telemetry aspect to the inventory would be discussed with NPS prior to initiation of the inventory. Bats may use structures (e.g., buildings and bridges) within parks as roost sites. Bat roosts assessment in COLO, GEWA, and THST structures can be verified by visual observation. However, a more efficient assessment could be made with input from NPS staff regarding locations of known or suspected bat roosts. During summer, when possible, emergence counts of colonies would be conducted. We would determine species through daytime observations, capture of individuals, or identification of recorded echolocation calls.

*Global Positioning System data*

The geographic locations of our acoustic monitoring, mist net, harp trap, and roost inventory sites would be determined with Thales MobileMapper (Santa Clara, California, USA) global positioning systems or hand-digitized in ArcMap (ESRI, Redlands, California, USA) using digital orthophoto quarter quadrangles provided by the National Park Service. We would use Thales MobileMapper software to conduct differential correction of position data using base

station data from nearby continuously operating reference stations (e.g., Richmond, VA or U.S. Naval Observatory, Washington, D.C.). We would note the location of our inventory sites in relation to recognizable park features (e.g., trails, roads, streams).

### *Bat inventory schedule*

Logistically, it would be more efficient to complete inventories at one park before commencing inventories at another park. We would conduct bat inventories during summer months (15 May – 15 August). During summer, we would assess parks for reproductively active female bats. Parturition for most female bats in the region occurs in June (Barbour and Davis 1969). In July, juvenile bats become volant. Inventories could begin earlier than May or later than August, but this would depend on availability of technicians, budget conditions, and if additional inventory efforts were needed to make a more complete assessment of the bat community. Bat inventory efforts in spring and fall may have a higher probability of detecting silver-haired bats (*Lasionycteris noctivagans*) and hoary bats (*Lasiurus cinereus*), which are considered common migratory species. Bat activity may occur at COLO, GEWA, and THST during warm winter days, but likely would be lower than during summer (Whitaker et al. 1997).

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Figure 1. Potential mist net and acoustic (Anabat) monitoring sites at Colonial National Historical Park, Virginia.

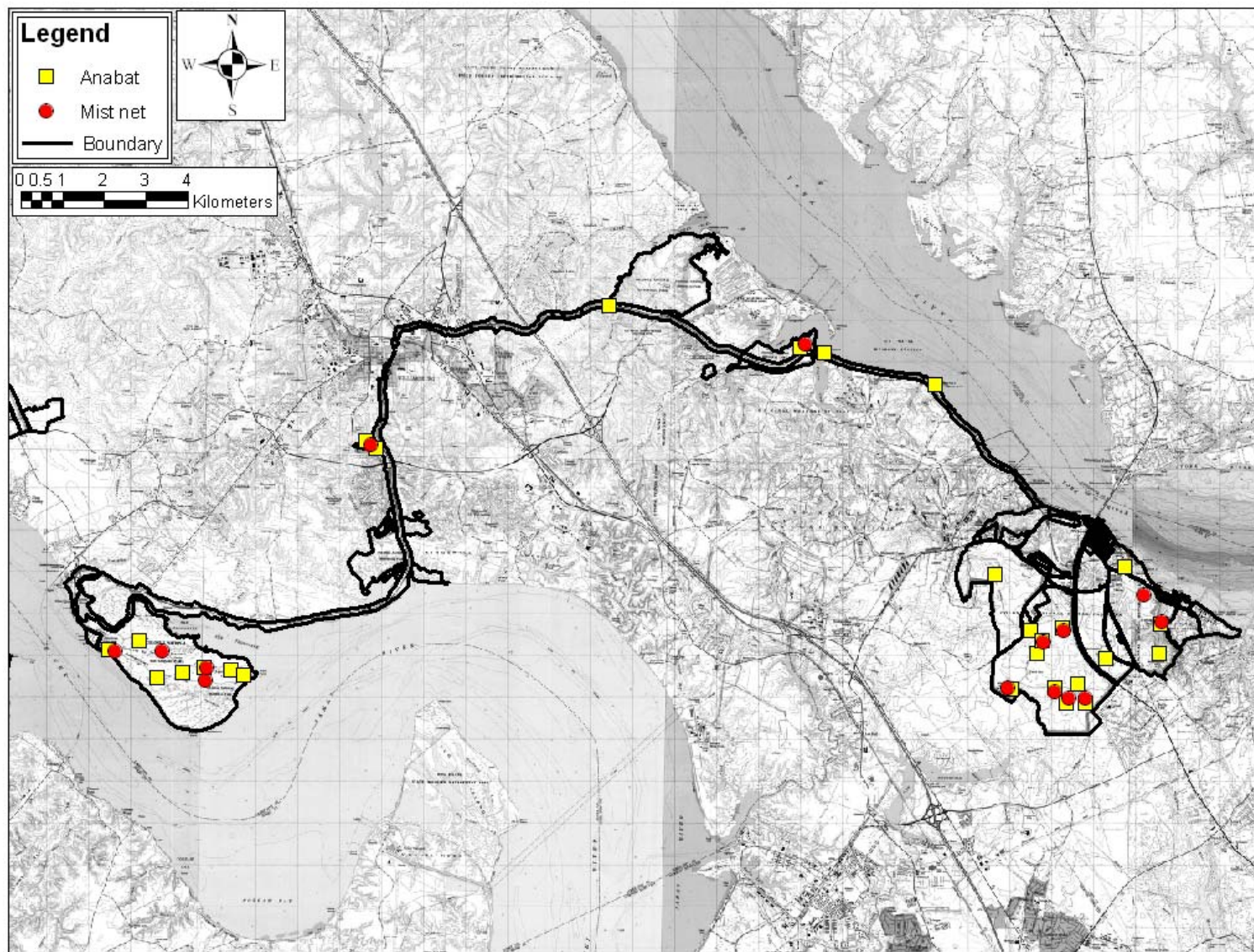


Fig. 1

Figure 2. Potential mist net and acoustic (Anabat) monitoring sites at Jamestown, Colonial National Historical Park, Virginia.

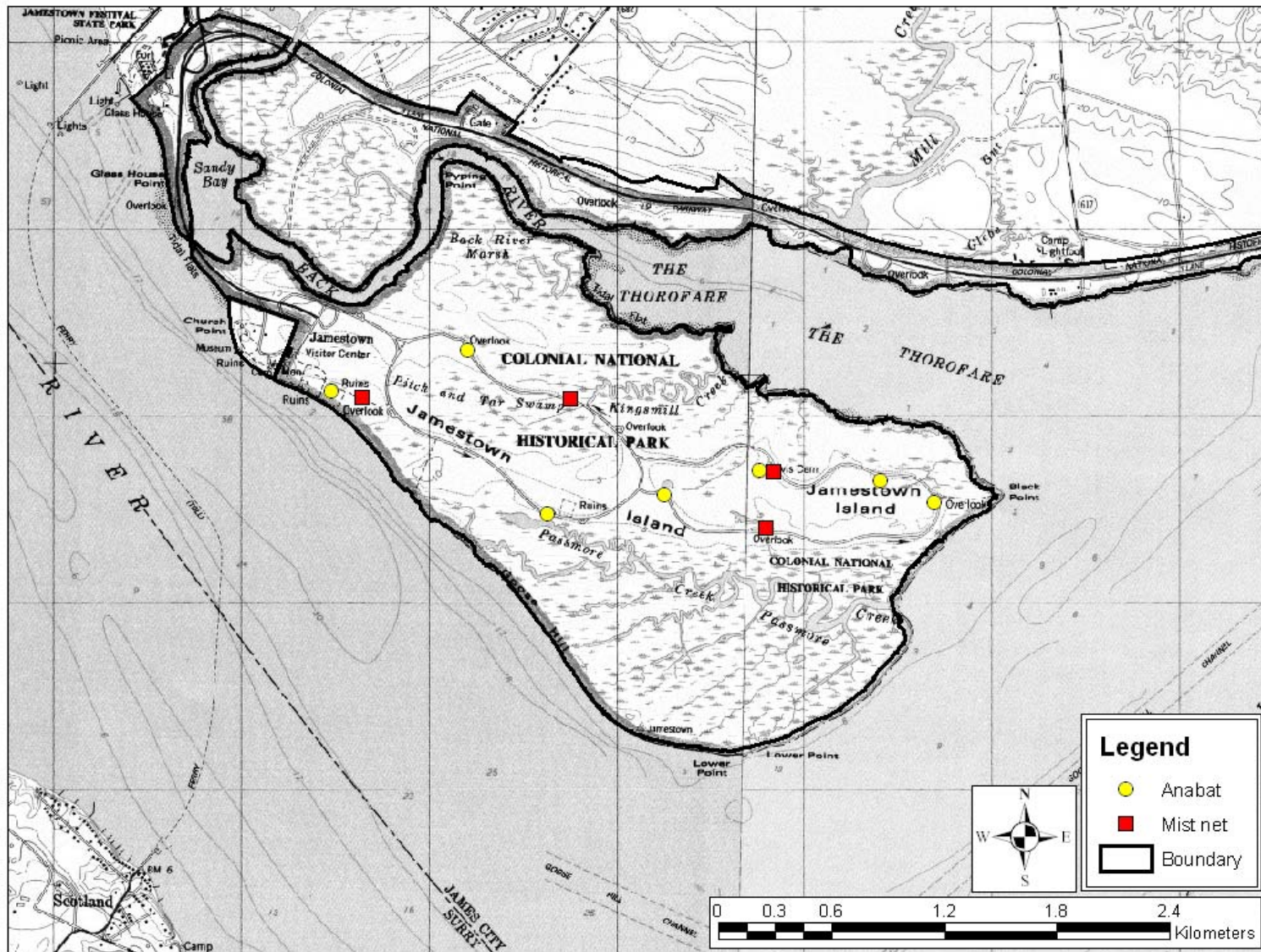


Fig. 2

Figure 3. Potential mist net and acoustic (Anabat) monitoring sites at Yorktown, Colonial National Historical Park, Virginia.

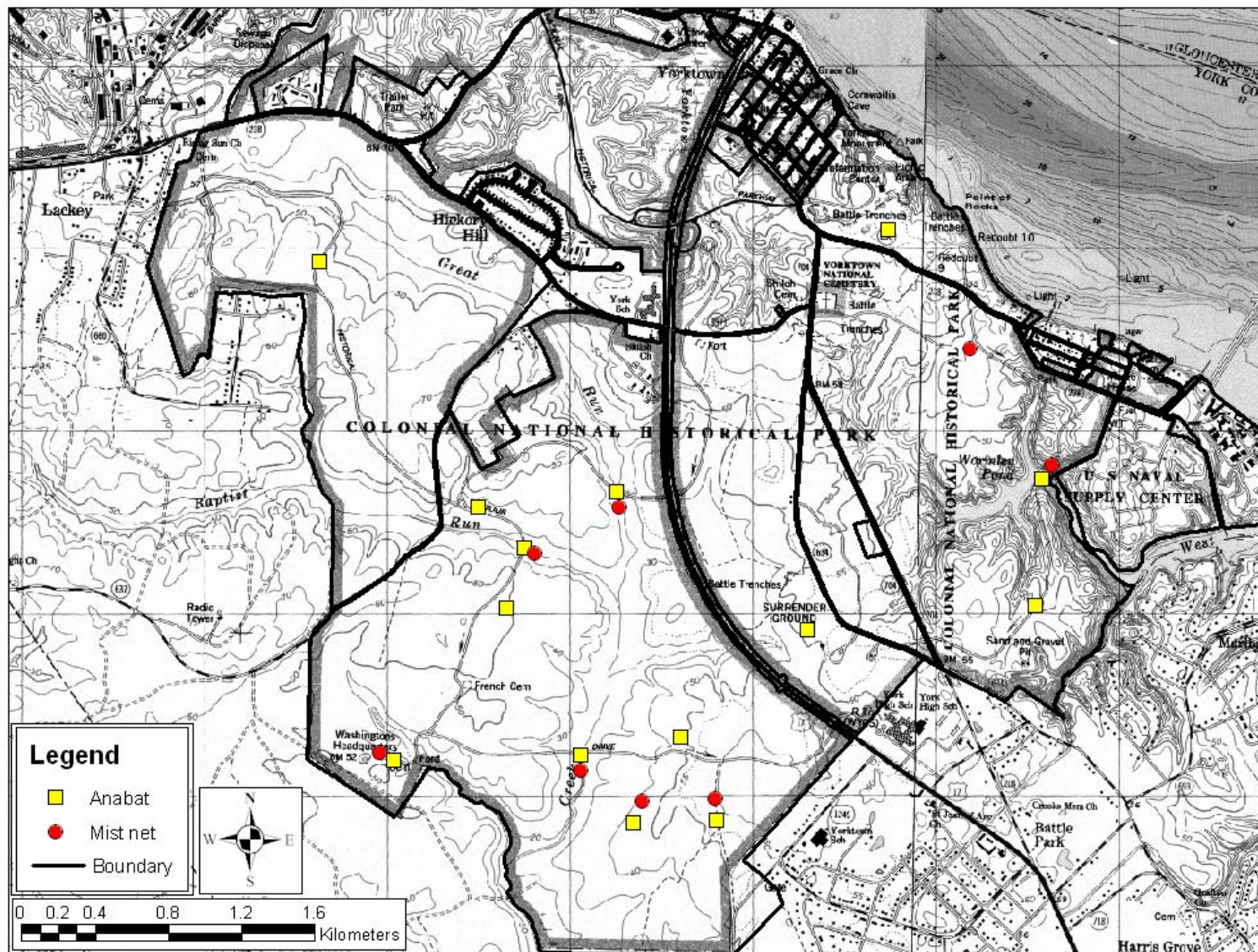


Fig. 3

Figure 4. Potential mist net and acoustic (Anabat) monitoring sites at Colonial National Historical Parkway, Colonial National Historical Park, Virginia.

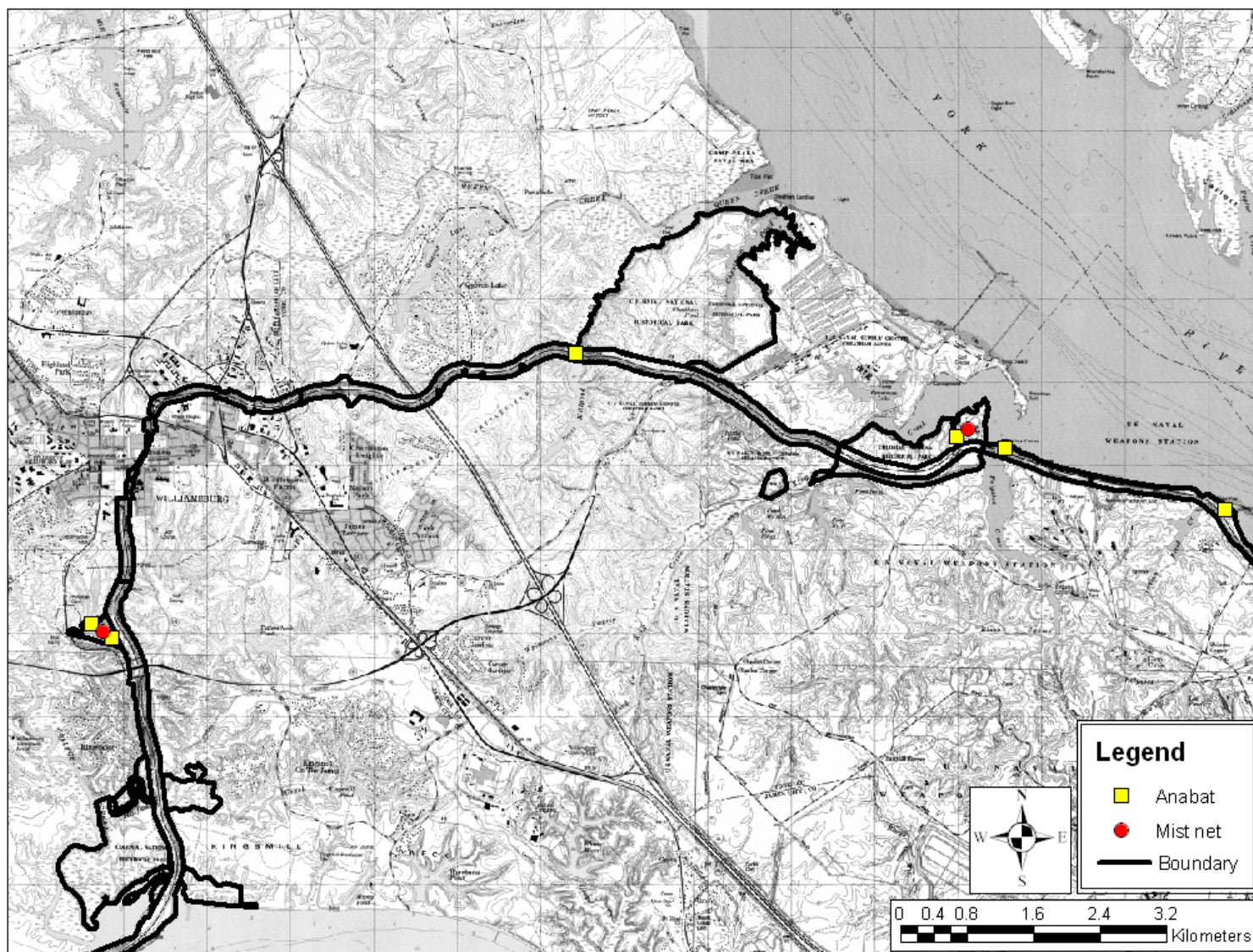


Fig. 4

Figure 5. Potential mist net and acoustic (Anabat) monitoring sites at George Washington Birthplace National Monument, Virginia.

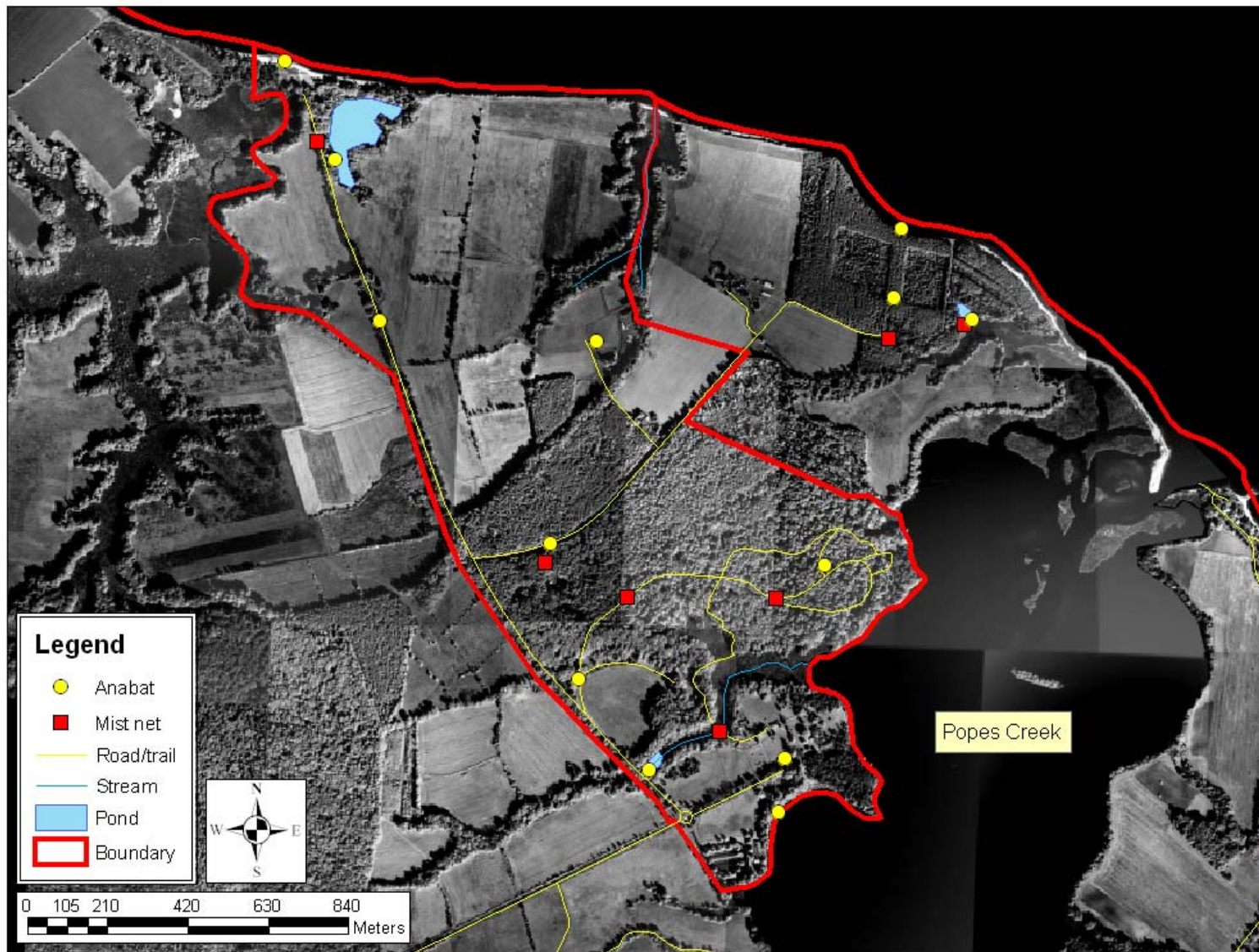


Fig. 5

Figure 6. Potential mist net and acoustic (Anabat) monitoring sites at Thomas Stone National Historic Site, Maryland.

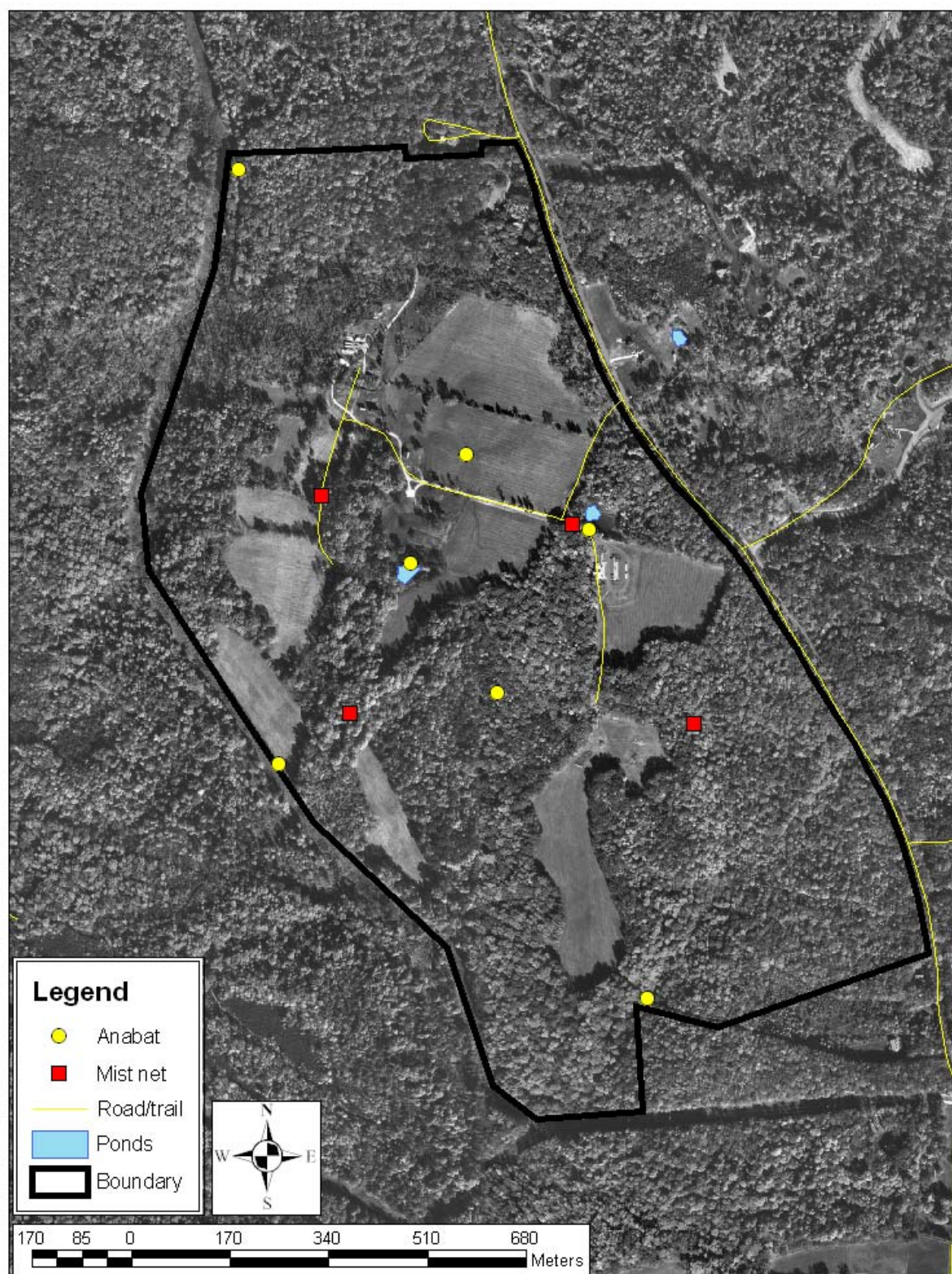


Fig. 6

Figure 7. Geographic and state range of *Corynorhinus rafinesquii macrotis* in Virginia.

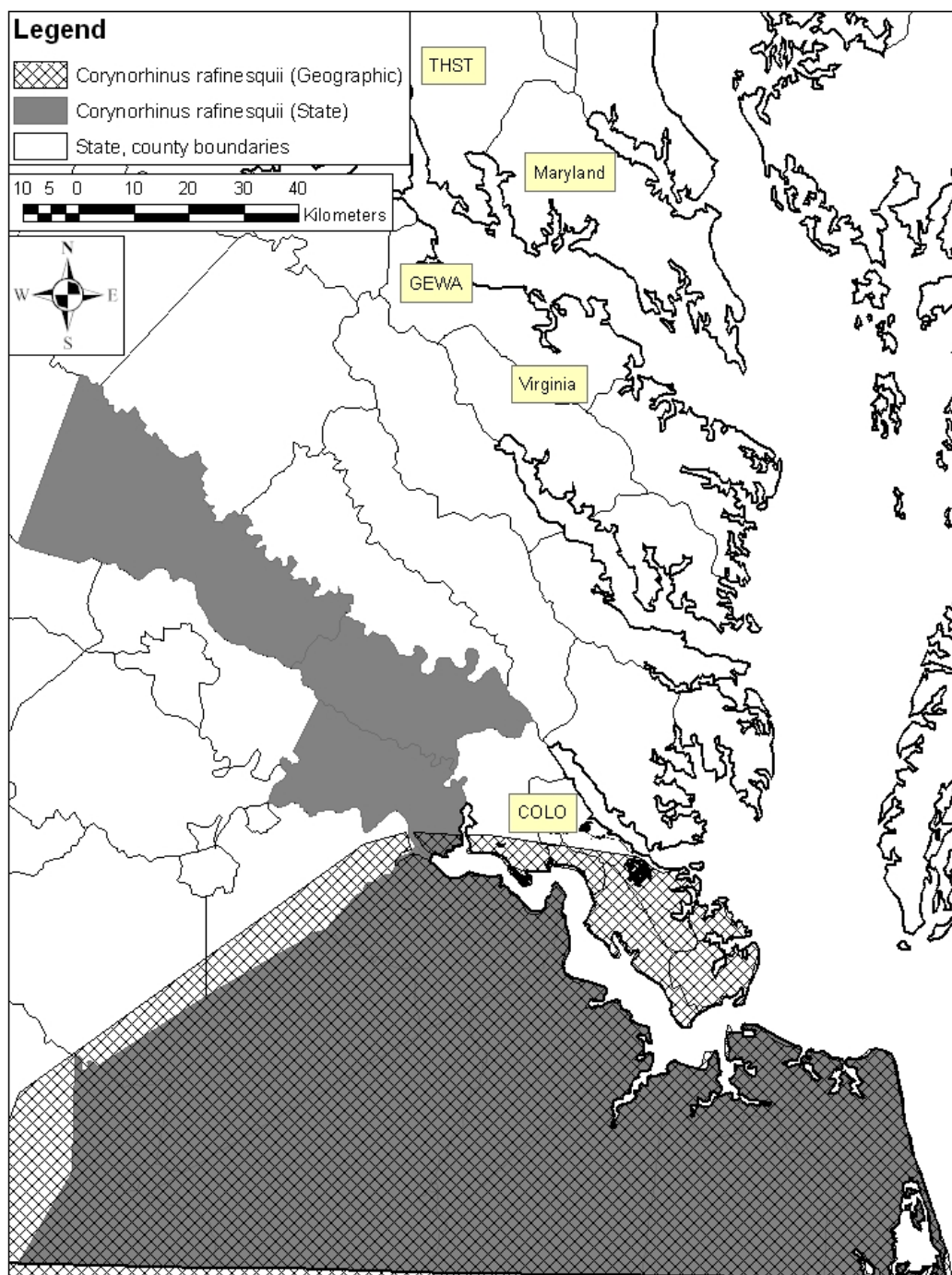


Figure 8. Geographic and state range of *Eptesicus fuscus* in Maryland and Virginia.

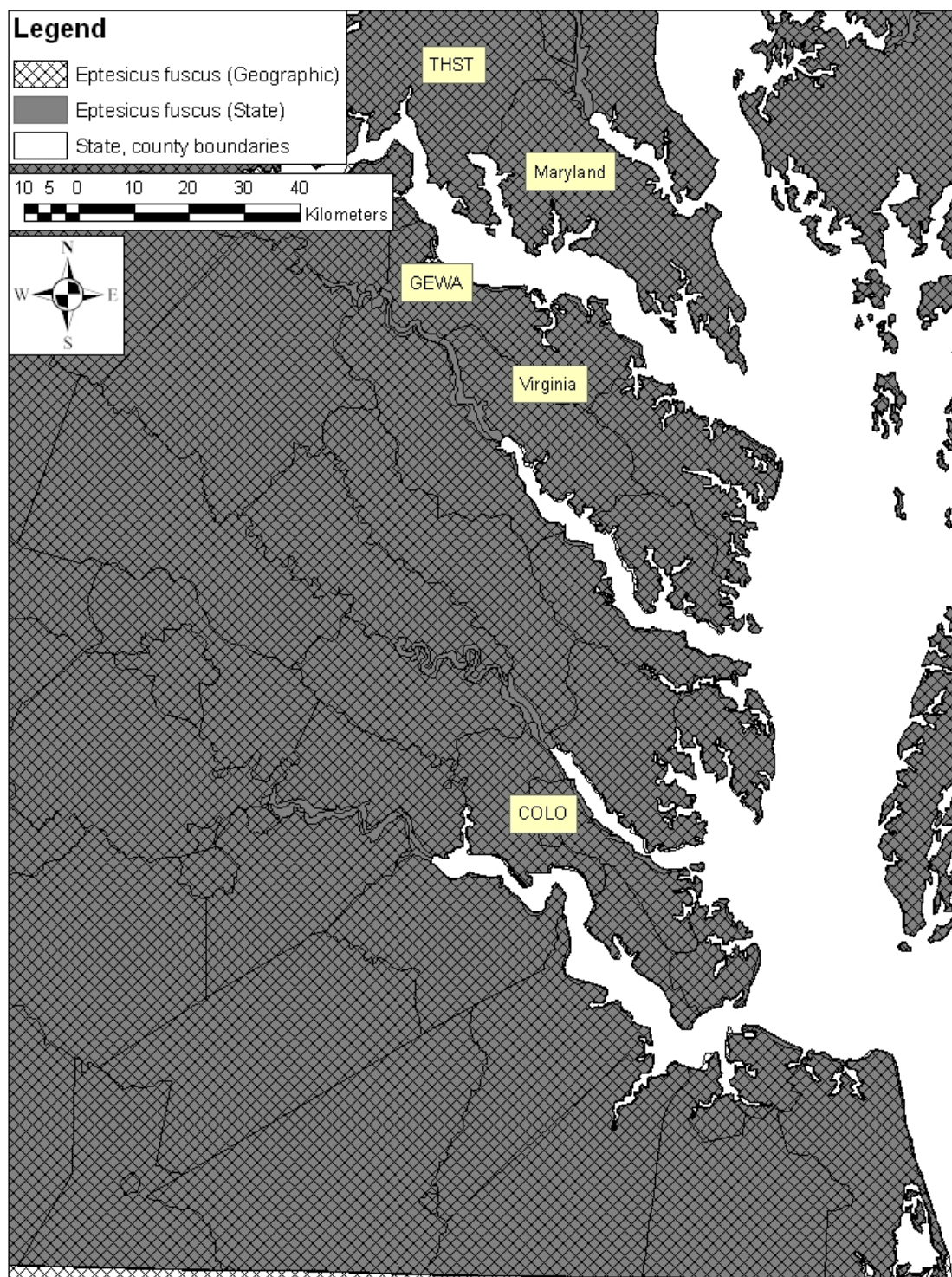


Figure 9. Geographic and state range of *Lasionycteris noctivagans* in Maryland and Virginia.

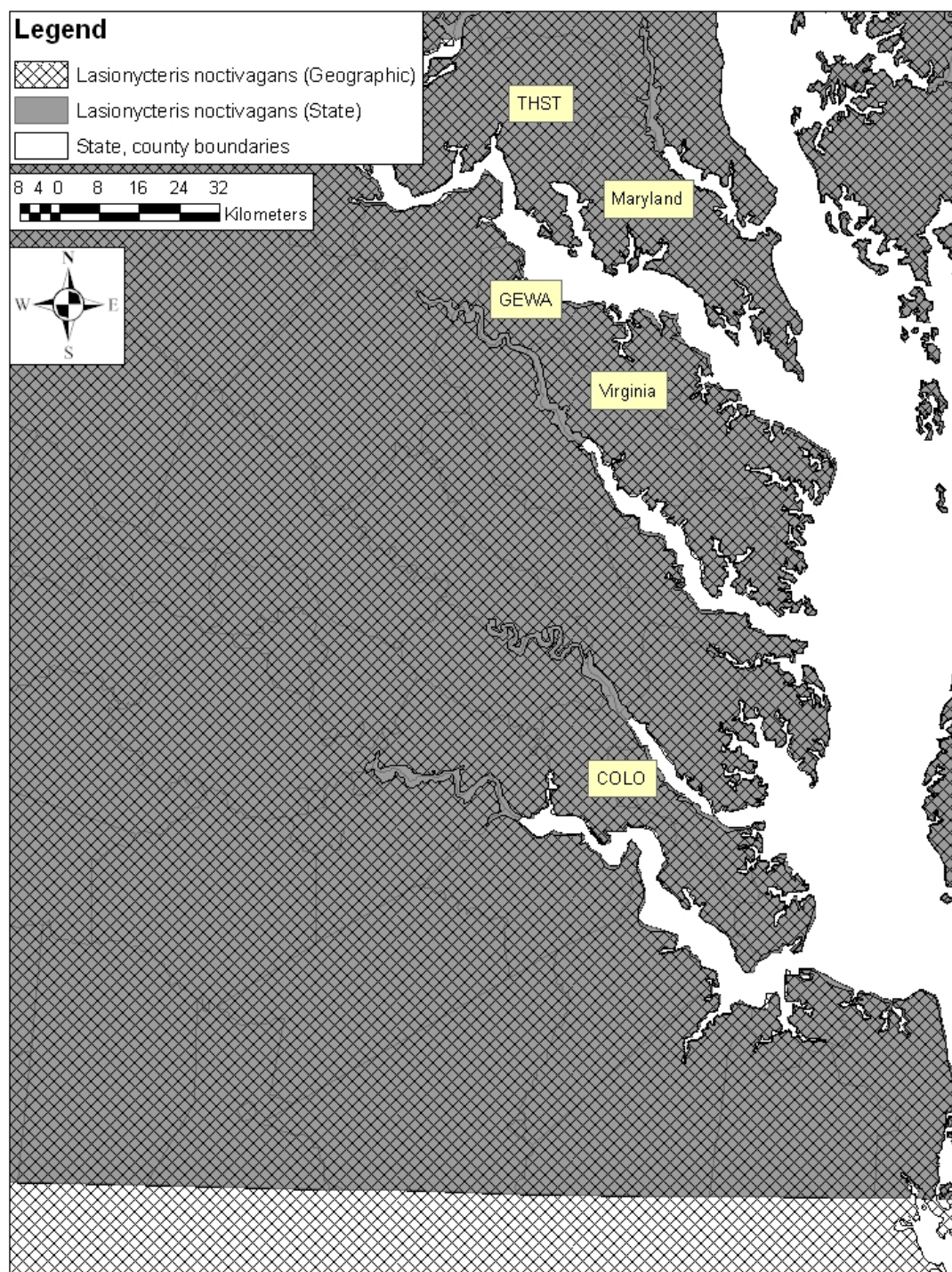


Figure 10. Geographic and state range of *Lasiurus borealis* in Maryland and Virginia.

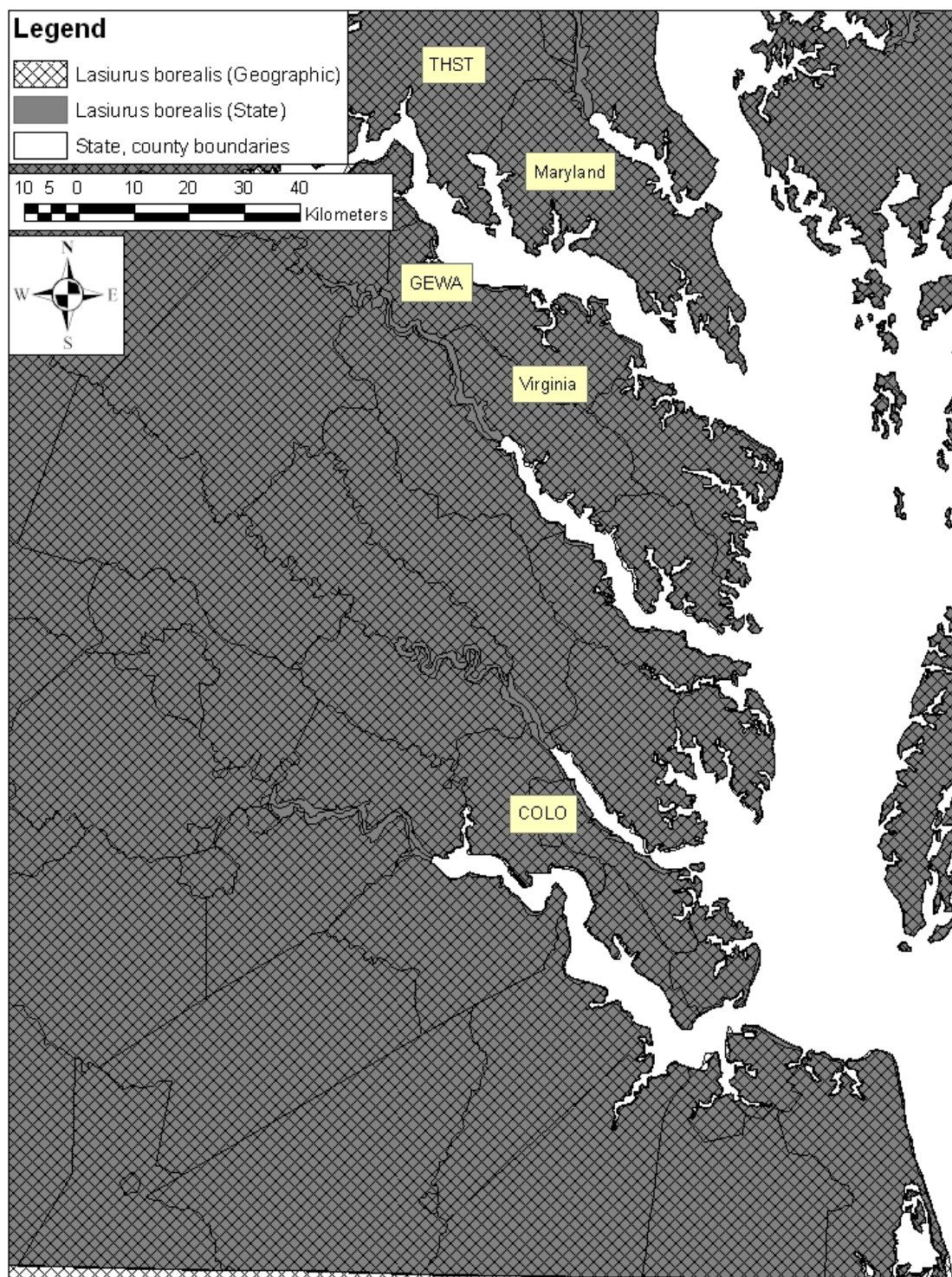


Figure 11. Geographic and state range of *Lasiurus cinereus* in Maryland and Virginia.

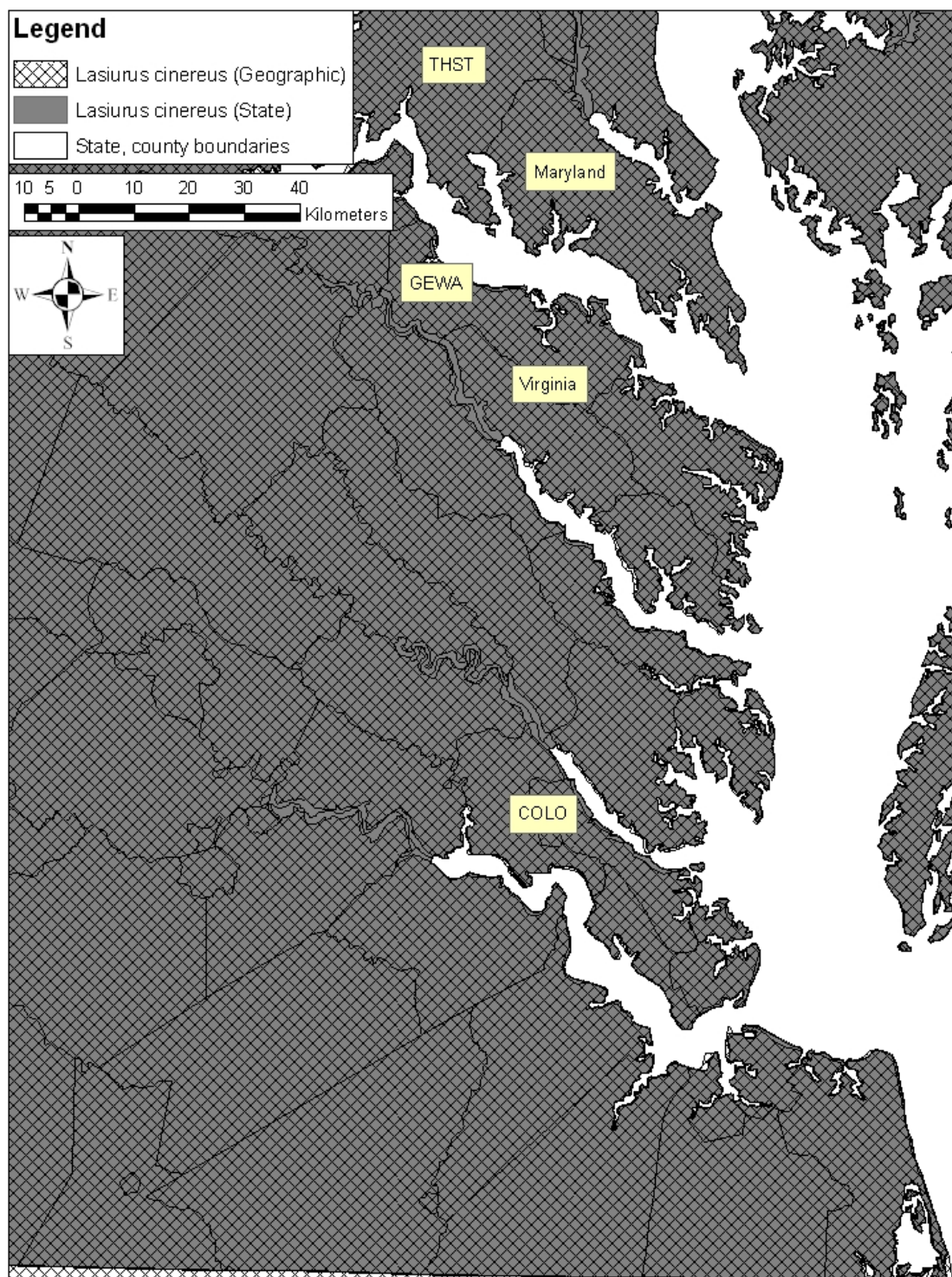


Figure 12. State range of *Lasiurus intermedius* in Virginia. Note: Northeastern limit of geographic range ends near border of South Carolina and North Carolina.

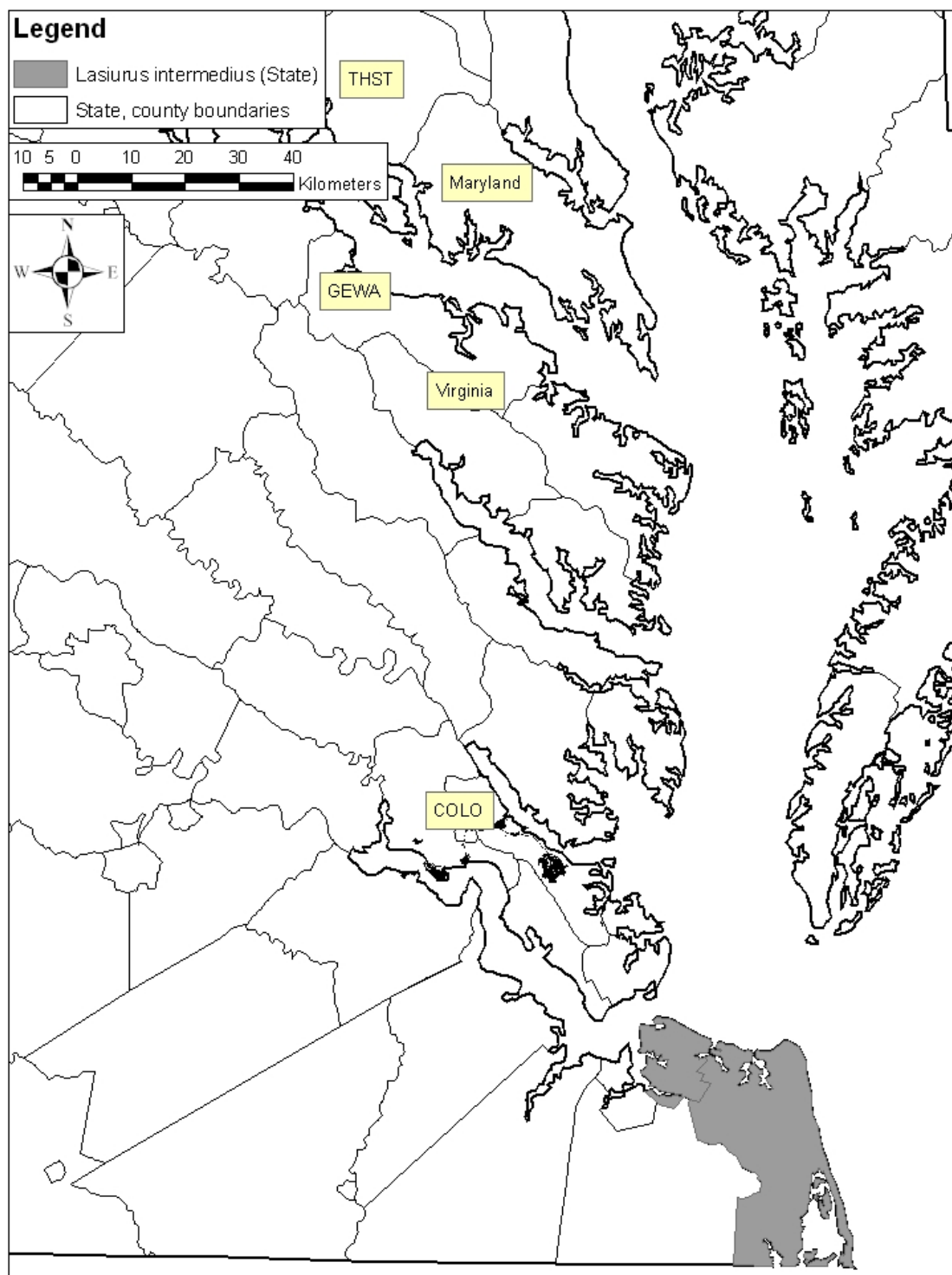


Figure 13. Geographic and state range of *Lasiurus seminolus* in Virginia.

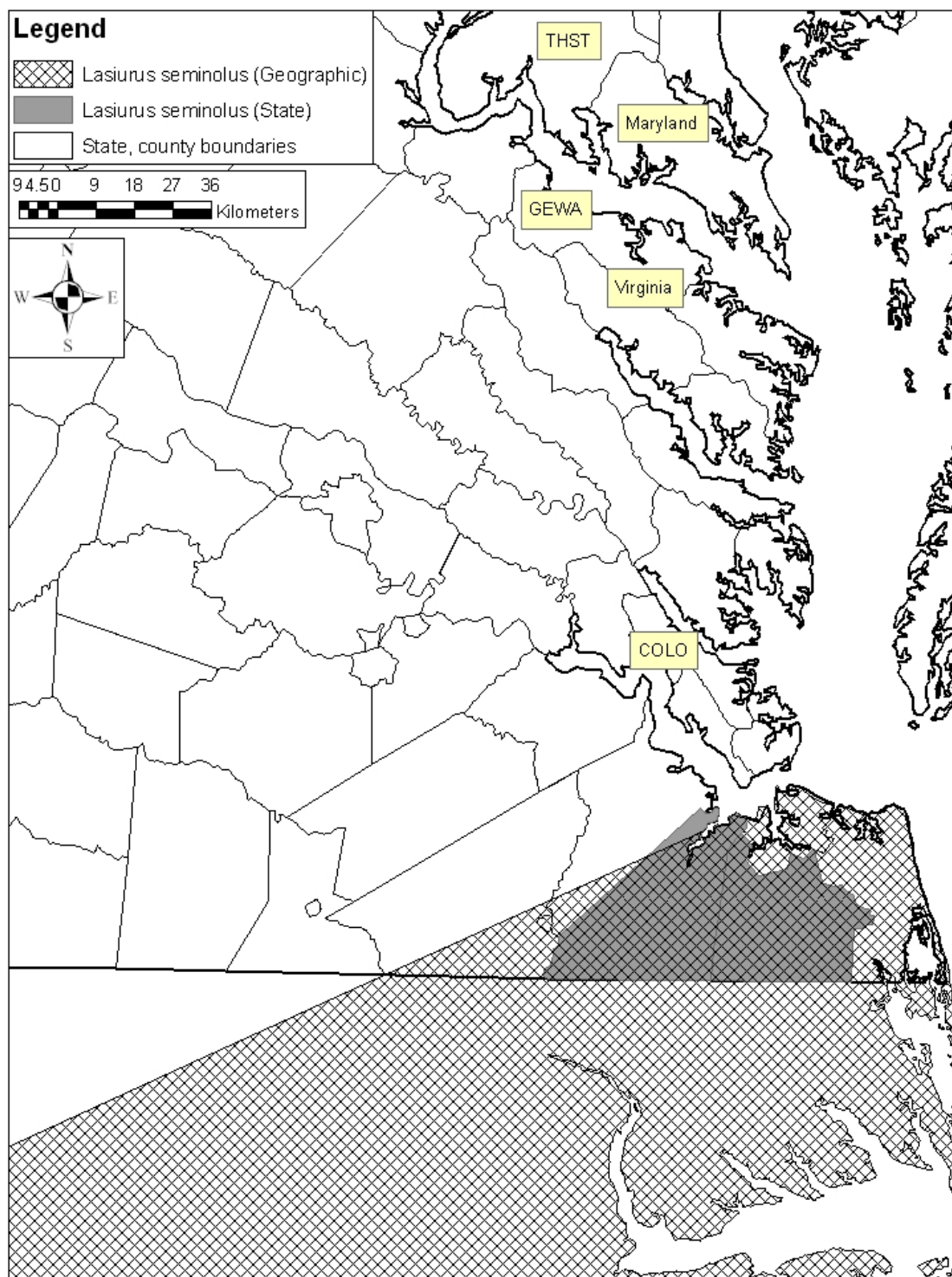


Figure 14. Geographic and state range of *Myotis austroriparius* in Virginia.

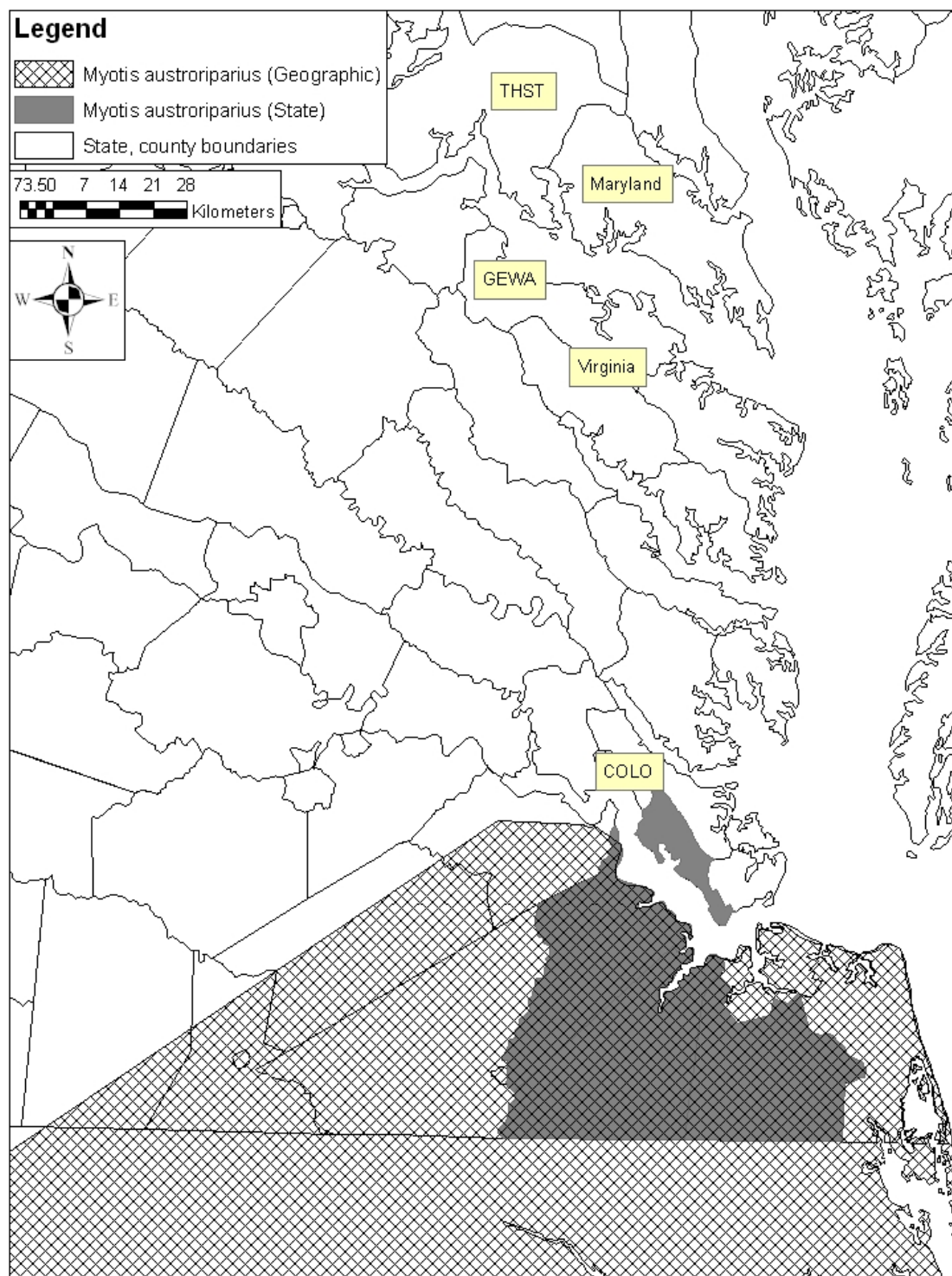


Figure 15. Geographic and state range of *Myotis lucifugus* in Maryland and Virginia.

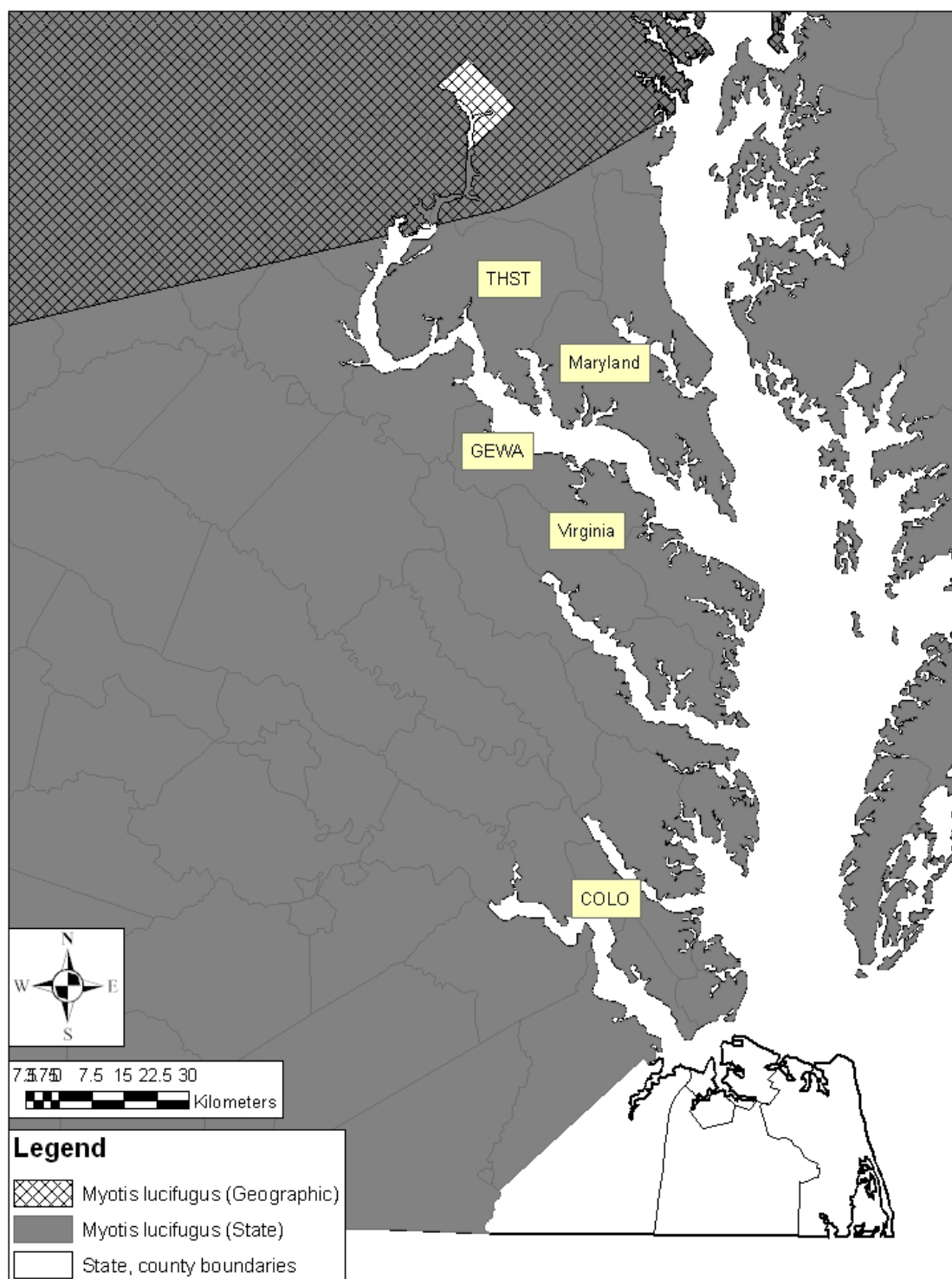


Figure 16. Geographic and state range of *Myotis septentrionalis* in Maryland and Virginia.

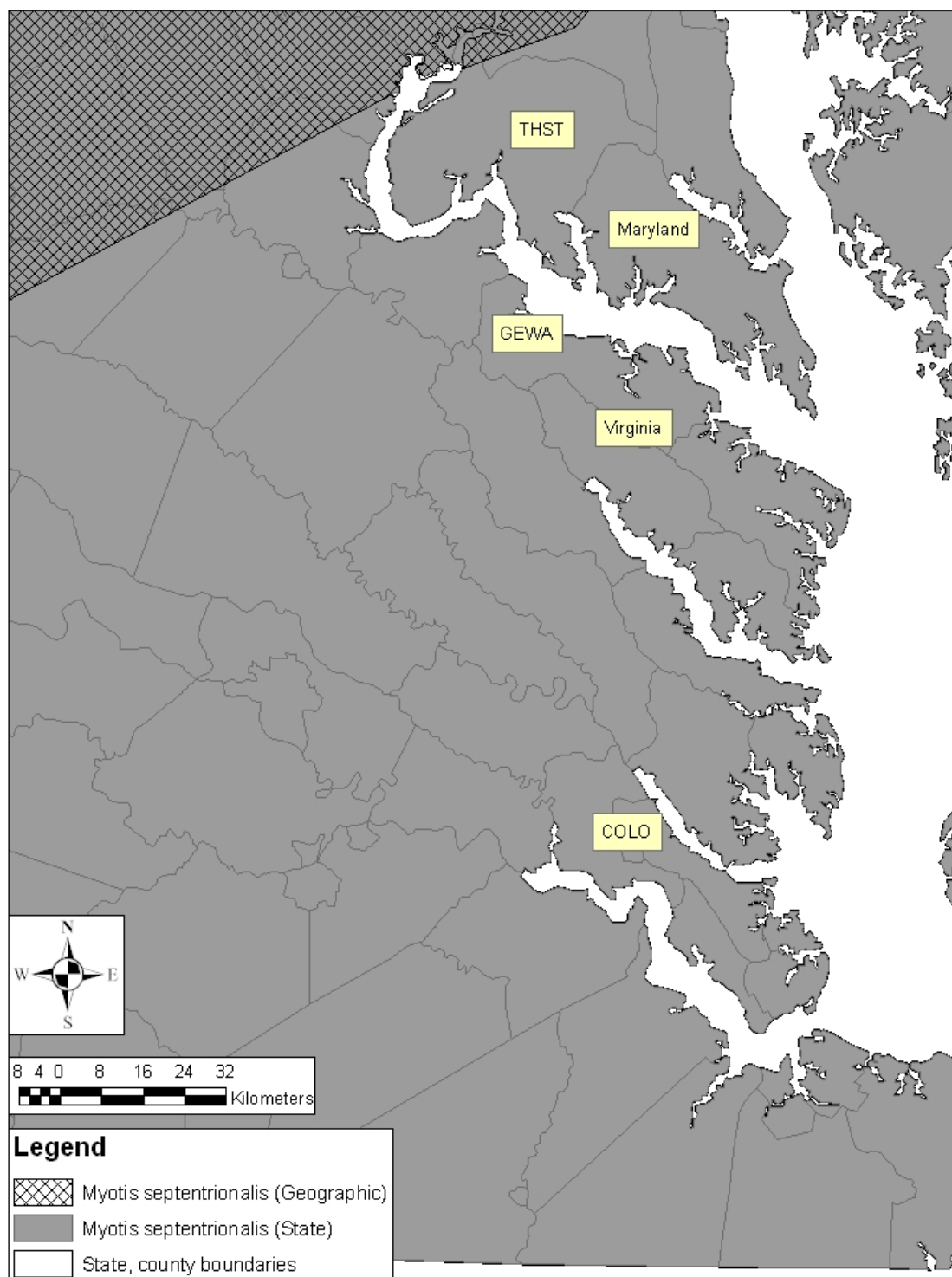


Figure 17. Geographic and state range of *Nycticeius humeralis* in Maryland and Virginia.

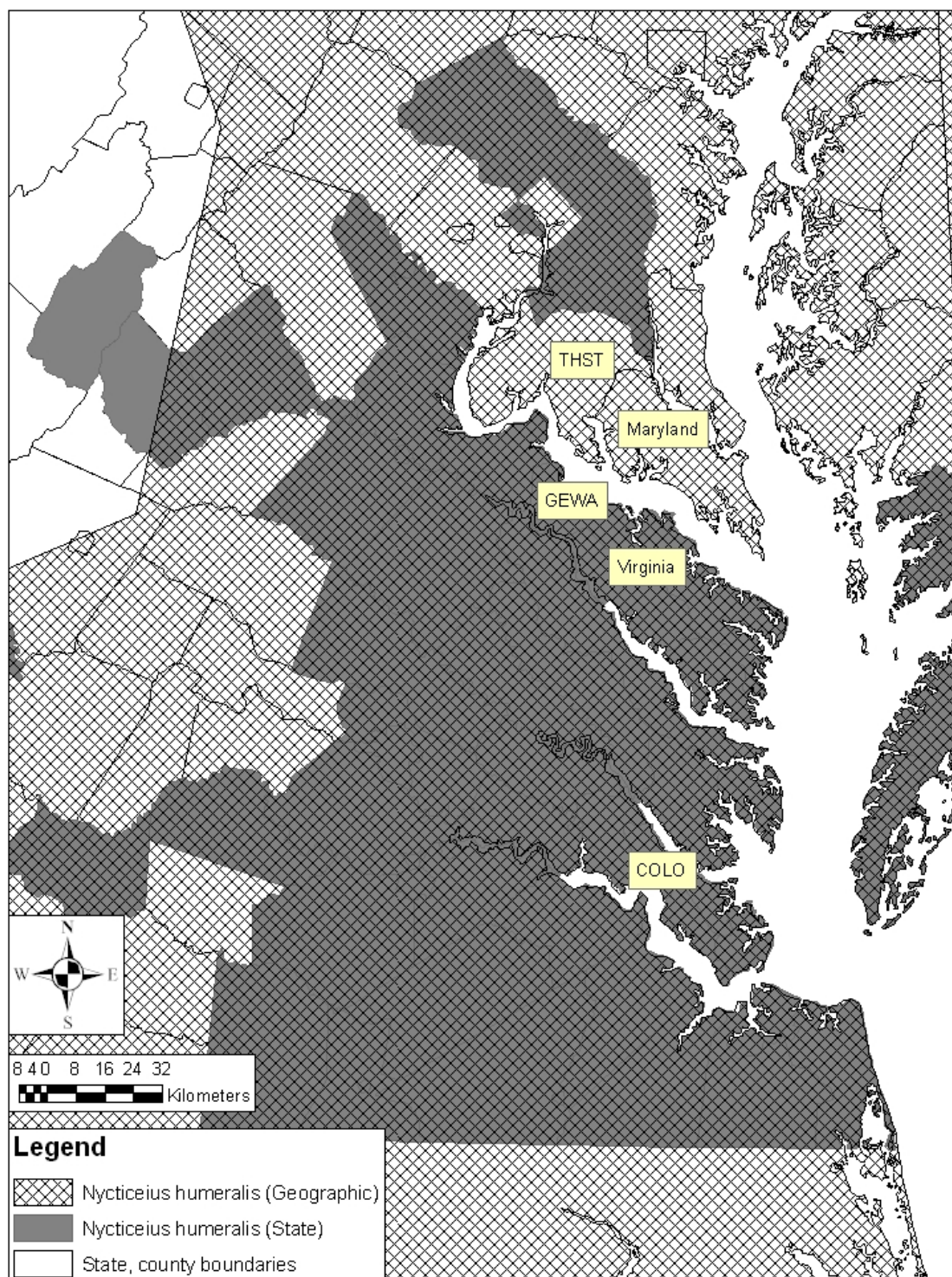


Figure 18. Geographic and state range of *Pipistrellus subflavus* in Maryland and Virginia.

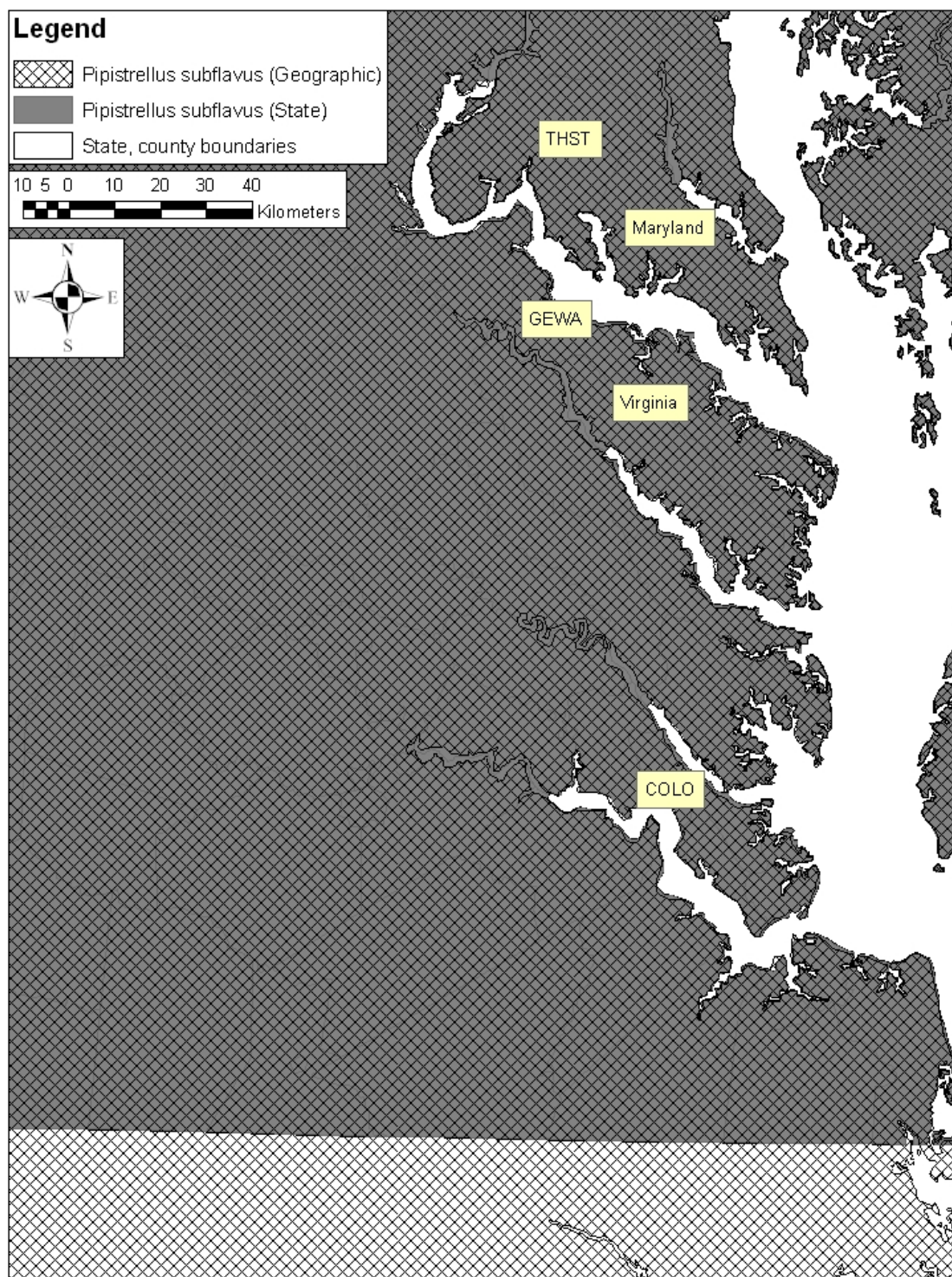
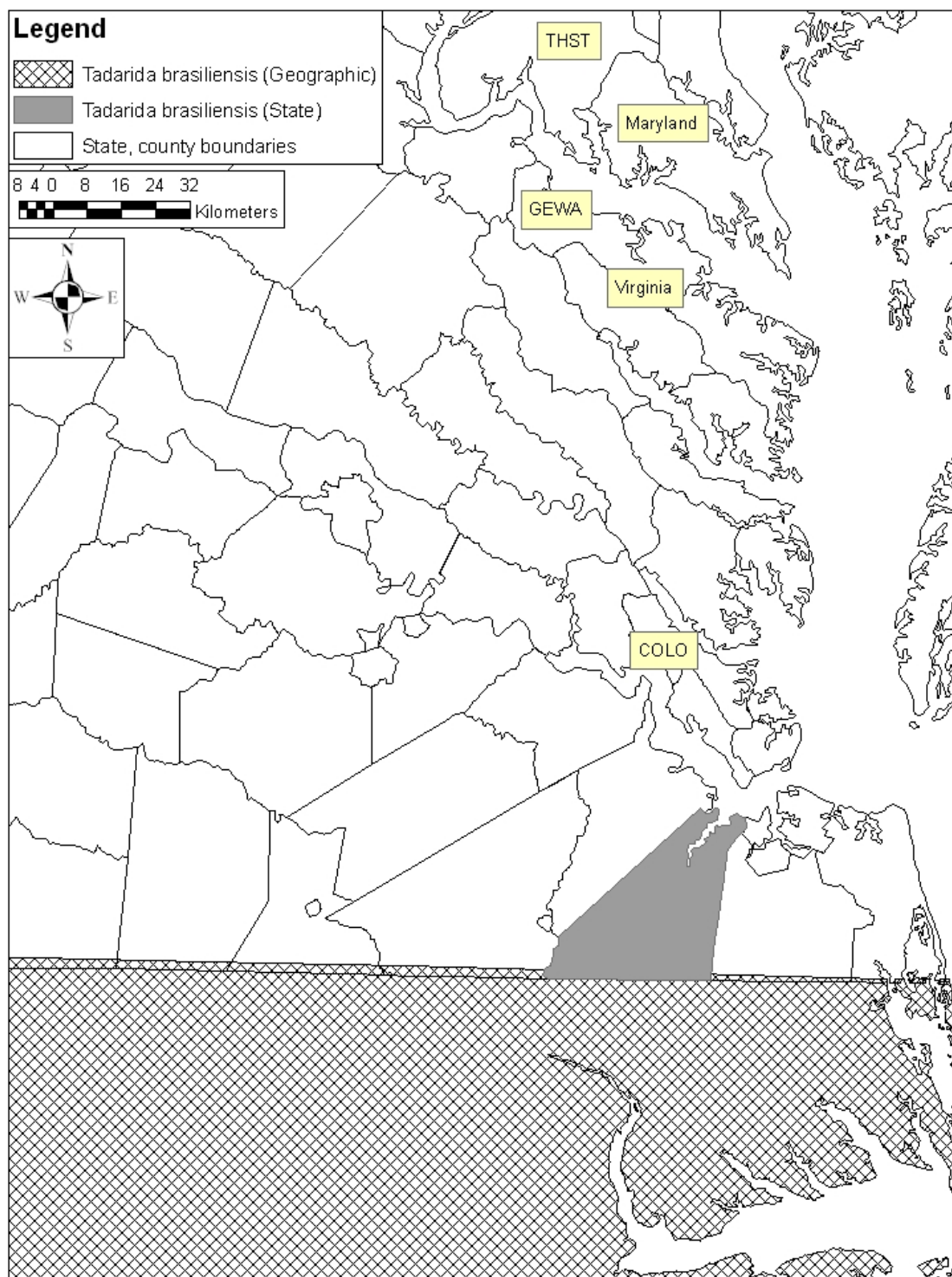


Figure 19. Geographic and state range of *Tadarida brasiliensis* in Virginia.



Appendix I. Accounts of bat species potentially occurring at Colonial National Historical Park (COLO) and George Washington Birthplace National Monument (GEWA), Virginia; and Thomas Stone National Historic Site (THST), Maryland.

### Family Vespertilionidae

All but 1 bat species inhabiting or potentially inhabiting COLO, GEWA, and THST belong to the Vespertilionidae family. This family contains 42 genera and 355 species on 6 continents (Nowak 1994). Within the United States, 10 genera and 45 species occur (Harvey et al. 1999). Potentially, up to 7 genera and 12 species occur within COLO, GEWA, and THST.

#### Rafinesque's big-eared bat (*Corynorhinus rafinesquii macrotis*)

*Morphology*—Of the 2 subspecies of Rafinesque's big-eared bat, 1 (*C. r. macrotis*) potentially occurs at COLO, GEWA, and THST. Weights typically range from 8–14 g and head to tail lengths range from 8–11 cm (Jones 1977). Longevity records of >10 years have been reported for Rafinesque's big-eared bat (Paradiso and Greenhall 1967).

*Range and migration*—Rafinesque's big-eared bat is a species of special concern throughout its range, which includes the southeastern United States from Florida, north to southeastern Virginia, west to southern Illinois, and south to eastern Texas (Jones 1977). Rafinesque's big-eared bats are not considered migratory (Barbour and Davis 1969).

*Roosting*—Rafinesque's big-eared bats roost under bridges and in buildings, tree cavities, caves, and mines (Barbour and Davis 1969, Hurst and Lacki 1999, Trousdale and Beckett 2004). In the northern part of their range, Rafinesque's big-eared bats hibernate in caves and mines (Barbour and Davis 1969). In summer, females form maternity colonies of up to dozens of individuals (Hurst and Lacki 1999). In Mississippi, Rafinesque's big-eared bats roosted in relatively large *Magnolia* spp. and *Nyssa* spp. snags located in bottomland hardwoods (Trousdale and Beckett 2005).

*Reproduction*—Rafinesque's big-eared bats give birth to 1 young each in June (Barbour and Davis 1969).

*Foraging*—In Kentucky, Rafinesque's big-eared bats foraged <2.5 km from their day roosts and had home ranges encompassing 61.6–225.3 ha. They foraged on oak-hickory forested ridges (Hurst and Lacki 1999). In South Carolina, mean home range size of male Rafinesque's big-eared bats was 93.1 ha. Most foraging occurred in young pine stands in an otherwise bottomland hardwood-dominated land cover (Menzel et al. 2001b).

Although Rafinesque's big-eared bats are considered Lepidopteran- (moth) specialists, they are known to consume a variety of insects including coleopterans (beetles), dipterans (flies), homopterans (leaf hoppers), hymenopterans (flying ants), tricopterans (caddisflies), and hemipterans (stinkbugs, squashbugs) (Hurst and Lacki 1997).

*Status in NPS parks*—Rafinesque's big-eared bats have been documented in counties adjacent to COLO. It is possible that this species occurs at COLO, but probably not at GEWA or THST.

### **Big brown bat (*Eptesicus fuscus*)**

*Morphology*—Of the 11 subspecies of big brown bat, 1 (*E. f. fuscus*) potentially occurs at COLO, GEWA, and THST. Big brown bats are 1 of the largest bat species that occur in the region. Weights typically range from 13–25 g and head to tail lengths range from 10–13 cm (Kurta and Baker 1990). Longevity records of up to 19 years have been reported (Paradiso and Greenhall 1967).

*Range and migration*—The big brown bat is common throughout its range, which includes southern Canada, the continental United States, Central America, and northern South America (Kurta and Baker 1990). Migratory distances typically are <80 km between hibernacula and summer roosts (Griffin 1940, Beer 1955, Mills et al. 1975).

*Roosting*—Big brown bats typically hibernate in mines (Pearson 1962), caves (Hall and Brenner 1968, Gates et al. 1984), storm sewers (Goehring 1954), tunnels (Gates et al. 1984), and sometimes buildings (Whelden 1941, Whitaker and Gummer 2000). In summer, big brown bats roost in snags, buildings, and caves (Hall and Brenner 1968, Barbour and Davis 1969, Betts 1996). Females form maternity colonies that commonly are located in snags and buildings (Davis et al. 1968, Barbour and Davis 1969), and occasionally in rock crevices (Lausen and Barclay 2002). Big brown bats commonly return to the same structure to form maternity colonies each year, typically in May (Davis et al. 1968, Mills et al. 1975).

*Reproduction*—Maternity colonies may consist of >100 individuals (Brigham 1991). After a 60-day gestation period, females give birth to 1–2 young each in June. Young become volant at 3–5 weeks of age (Barbour and Davis 1969, Kurta and Baker 1990). Some female young return to their natal roost the next year (Mills et al. 1975).

*Foraging*—Big brown bats are among the first bats observed at dusk (Kunz 1973). Big brown bats often are observed foraging around streetlights (Furlonger et al. 1987), but they also forage in open areas, forest stands, forested riparians areas, and over waterways (Kurta 1982, Owen et al. 2004).

Big brown bats consume a variety of insects including coleopterans (beetles, weevils), dipterans, hemipterans, homopterans, hymenopterans, lepidopterans, orthopterans (locusts, katydids, crickets, grasshoppers), and tricopterans. The majority of the big brown bat's diet consists of coleopterans, including many agricultural pests, e.g., spotted cucumber beetles (Griffith and Gates 1985, Whitaker 1995, Agosta and Morton 2003, Carter et al. 2003).

*Status in NPS parks*—It is likely that big brown bats commonly occur at COLO, GEWA, and THST.

**Silver-haired bat (*Lasionycteris noctivagans*)**

*Morphology*—The silver-haired bat is the only species in Genus *Lasionycteris*, and it is monotypic. It is a relatively average-sized bat compared to other bat species potentially occurring COLO, GEWA, and THST. Weights range from 8–11 g, and head to tail lengths range from 9–11 cm (Kunz 1982).

*Range and migration*—The silver-haired bat is considered common throughout the continental United States, southern Canada and Pacific coast to southern Alaska (Kunz 1982). The winter range of the silver-haired bat is the southern half of the continental United States. In spring, they migrate to the northern United States and Canada (Izor 1979). No studies have focused on migratory distances of silver-haired bats. During migration, silver-haired bats are known to collide with tall structures including lighthouses (Saunders 1930) and wind turbines (Johnson et al. 2003a).

*Roosting*—Silver-haired bats have been documented hibernating in caves (Beer 1956, Krutzsch 1966), house basements (Bartsch 1956, Gosling 1977), mines (Pearson 1962), and in hollow trees (Jackson 1961). Summer and winter roosting colonies are small at <20 individuals (Barbour and Davis 1969). Little is known about specific summer roost characteristics of the silver-haired bat in the mid-Atlantic. The majority of silver-haired bat summer roosts have been documented in coniferous forests of the Pacific Northwest and Canada. Silver-haired bats have been documented roosting in abandoned woodpecker holes in Ontario, Saskatchewan, and British Columbia (Vonhof and Barclay 1996, Parsons et al. 1986). Crampton and Barclay (1998) found silver-haired bats roosting in cavities of trees in early stages of decay. In Washington, silver-haired bats have been found roosting under loose bark and in tree cavities (Campbell et al. 1996). In Manitoba, migrating silver-haired bats roosted singly in heavily furrowed bark and

splits in tree trunks (Barclay et al. 1988). In West Virginia, Menzel et al. (2000b) found a silver-haired bat roosting beneath leaf litter, possibly during its fall migration.

*Reproduction*—During summer, females form maternity colonies of 3–16 individuals (Betts 1996). Females give birth to 1–2 young in late June after a 50–60 day gestation (Easterla and Watkins 1970, Kunz 1982). The young become volant by late July (Kunz 1971). Males typically occur singly throughout their range during summer (Kunz 1982).

*Foraging*—Silver-haired bats commonly forage in riparian areas near coniferous and mixed deciduous forests (Jones 1966, Edwards et al. 2001, Owen et al. 2004). The echolocation call structure and wing morphology of silver-haired bats are suited for foraging in the open and near trees (Barclay 1986, Patriquin and Barclay 2003). Silver-haired bats consume a wide variety of insects. In West Virginia, silver-haired bat diets consisted mainly of lepidopterans, but also dipterans, homopterans, and coleopterans (Carter et al. 2003). Black (1974) considered silver-haired bats a moth-specialist. Other insects that have been consumed by silver-haired bats include tricopterans, neuropterans (dobsonflies, lacewings), and hemipterans (Whitaker 1972, Brack 1983, Warner 1985).

*Status in NPS parks*—Silver-haired bats most likely occur at COLO, GEWA, and THST during spring and fall migration.

### **Eastern red bat (*Lasiurus borealis*)**

*Morphology*—Of the 5 subspecies of eastern red bat, only 1 (*L. b. borealis*) potentially occurs at COLO, GEWA, and THST. It is a medium-sized bat with weights ranging from 10–13 g, and head to tail lengths averaging 11 cm (Shump and Shump 1982a).

*Range and migration*—The eastern red bat is considered common throughout its range, which includes the continental United States (except for the Rocky Mountain region), south

through Central and South America into Argentina and Chile. Eastern red bats are migratory, traveling to northern latitudes in April–June for summer and to southern latitudes in August–October for winter (Shump and Shump 1982a). They migrate in groups during fall and sometimes collide with tall structures including buildings (Terres 1956), lighthouses (Saunders 1930), communications towers (Crawford and Baker 1981), and wind turbines (Johnson et al. 2003a). Eastern red bats have been documented <210 km from land over the Atlantic Ocean during migration (Norton 1930, Carter 1950, Mackiewicz and Backus 1956).

*Roosting*—During winter, eastern red bats roost under tree foliage, in woodpecker holes (Fassler 1975), or under leaf litter (Moorman et al. 1999). During summer, eastern red bats roost under foliage of deciduous (McClure 1942, Mager and Nelson 2001) and coniferous trees (Menzel et al. 1998), behind shingles, under leaf litter (Mager and Nelson 2001), and in rare instances have been found in caves (Quay and Miller 1955). When roosting under tree foliage, eastern red bats may be 1.5–16.5 m above ground (McClure 1942, Menzel et al. 1998, Hutchinson and Lacki 1999, Mager and Nelson 2001). Roost tree switching occurs every 1–3 days (Menzel et al. 1998, Hutchinson and Lacki 1999, Mager and Nelson 2001). Eastern red bats roost in riparian and upland forests (Menzel et al. 1998, Hutchinson and Lacki 1999).

*Reproduction*—Females roost singly under tree foliage during the maternity season. In June, they give birth to as many as 4 young (Gates and Wolcott 1946, Packard 1956, Stains 1965, LaVal and LaVal 1979). Young become volant in 3–6 weeks (Barbour and Davis 1969).

*Foraging*—Eastern red bats typically forage within the first 2 hours after sunset (Kunz 1973) over open areas and wooded streams (Hart et al. 1993, Owen et al. 2004). In Kentucky, eastern red bats foraged 1.2–7.4 km from roosting sites and had home ranges encompassing 334.0 ha ( $\pm 82.1$  SE) (Hutchinson and Lacki 1999).

Eastern red bats are considered a moth specialist (Dunning et al. 1992), but they have also been documented consuming coleopterans, dipterans, hemipterans, homopterans, hymenopterans, orthopterans, and tricopterans (Ross 1961, Carter et al. 2003, Carter et al. 2004). Whitaker et al. (1997) reported red bats consuming lepidopterans and dipterans in winter months in Great Dismal Swamp, North Carolina and Virginia.

*Status in NPS parks*—It is likely that eastern red bats commonly occur at COLO, GEWA, and THST.

### **Hoary bat (*Lasiurus cinereus*)**

*Morphology*—Of the 3 subspecies of hoary bat, 1 (*L. c. cinereus*) potentially occurs at COLO, GEWA, and THST. It is the largest bat occurring in the region with weights ranging from 18–30 g, and head to tail lengths averaging 13 cm (Shump and Shump 1982b).

*Range and migration*—The range of the hoary bat includes Canada north to the tree line, the continental United States and Hawaii, south to Argentina and Chile (Shump and Shump 1982b). The hoary bat is considered common in the Pacific Northwest and prairie states, and uncommon in the eastern United States (Shump and Shump 1982b). Hoary bats have been documented in Iceland and far from land over the Atlantic Ocean during migration (Hayman 1959). The hoary bat occurs in the southern United States during winter and throughout the United States during summer. Fall migration occurs in concentrations of individuals in August–October. Spring migration is less organized in April–June (Findley and Jones 1964). During migration, hoary bats are known to collide with tall structures including lighthouses (Saunders 1930), communications towers (Crawford and Baker 1981) and wind turbines (Johnson et al. 2003a).

*Roosting*—Few studies have investigated the roosting habits of hoary bats. Hoary bats have primarily been observed roosting singly in tree foliage 3–5 m from the ground (Constantine 1966, Tenaza 1966). In Saskatchewan, hoary bats were observed roosting on white spruce (*Picea glauca*) branches that were facing southeast and about 13 m above the ground (Willis and Brigham 2005). Occasionally, hoary bat remains are found in caves (Mumford 1953, Beer 1954). In Georgia, a hoary bat was observed roosting in a squirrel's nest (Neill 1952).

*Reproduction*—In June, females roost singly under tree foliage and give birth to 1–4 young, averaging 2 (Bogan 1972, Shump and Shump 1982b). Young become volant at 4–5 weeks of age (Bogan 1972).

*Foraging*—Hoary bats emerge for foraging subsequent to sympatric bat species (Kunz 1973). Barclay (1989) observed female hoary bats emerging from their roosts 30–45 minutes after sunset. Hoary bat foraging activity is highest after sunset and just before sunrise (Kunz 1973). Hoary bats forage in riparian areas, uncluttered areas (Owen et al. 2004), forest edges (Furlonger et al. 1987), and over waterways (Hart et al. 1993) and marshes (Barclay 1989). Hoary bats have been tracked foraging up to 20 km from their day roosts (Barclay 1989).

The diet of the hoary bat consists primarily of Lepidopterans (Black 1972). In West Virginia, Lepidopterans comprised 98% of hoary bat diets (Carter et al. 2003). Other insects that hoary bats consume include coleopterans, dipterans, neuropterans, hymenopterans, and homopterans (Zinn and Baker 1979, Warner 1985).

*Status in NPS parks*—Hoary bats likely migrate through COLO, GEWA, and THST during spring and fall. A few male hoary bats may use the parks during summer.

**Northern yellow bat (*Lasiurus intermedius*)**

*Morphology*—Of the 3 subspecies of northern yellow bat, only 1 (*L. i. floridanus*) potentially occurs at COLO, GEWA, and THST. It is a medium-sized bat with head to tail lengths ranging from 12–13 cm (Webster et al. 1980).

*Range and migration*—The northern yellow bat is considered common throughout its range, which includes the coastal region of the southeastern United States, south into Central America and Cuba. The geographic range of the northern yellow bat coincides with the range of Spanish moss (*Tillandsia usneoides*). Only 2 records of northern yellow bats have been documented north of South Carolina; 1 at Willoughby Beach, Virginia (Rageot 1955) and 1 at Westfield, New Jersey (Koopman 1965). Northern yellow bats are not considered migratory.

*Roosting*—Northern yellow bats commonly roost in Spanish moss hanging from live oak (*Quercus virginiana*) limbs (Barbour and Davis 1969, Menzel et al. 1999). Roosts typically are located near permanent water (Webster et al. 1980).

*Reproduction*—Females may form loose maternity aggregations in Spanish moss festoons during summer (Barbour and Davis 1969). In June, they give birth to as many as 4 young (Webster et al. 1980).

*Foraging*—Northern yellow bats typically forage in open areas and along forest edges. In Georgia, a northern yellow bat tracked with radio-telemetry foraged 109 m ( $\pm 43$  SE) from its roosting sites and had a home range encompassing 10.5 ha (Krishon et al. 1997). Northern yellow bats consume a variety of insects, including homopterans, dipterans, coleopterans, and hymenopterans (Webster et al. 1980).

*Status in NPS parks*—Northern yellow bats may occur at COLO. However, its occurrence is unlikely, as few records have been documented north of South Carolina.

**Seminole bat (*Lasiurus seminolus*)**

*Morphology*—*Lasiurus seminolus* is a monotypic species. It is a medium-sized bat with weights ranging from 9–14 g, and head to tail lengths averaging 10 cm (Wilkins 1987).

*Range and migration*—The Seminole bat is considered common throughout its range, which includes the southeastern United States, from southeastern Virginia to Florida and west to Arkansas and eastern Texas. Extralimital records of Seminole bats have been documented in New York (Layne 1955), Pennsylvania (Poole 1932), southern Texas and Mexico (Wilkins 1987). The geographic range of the Seminole bat is considered to loosely coincide with the range of Spanish moss (Harvey et al. 1999). Seminole bats are not considered migratory.

*Roosting*—During winter, Seminole bats roost in Spanish moss, under pine leaf litter, and in pine needle clusters suspended from live vegetation (Barbour and Davis 1969, Hein et al. 2005). During summer, Seminole bats roost under foliage of deciduous and coniferous trees (Menzel et al. 1998), and in Spanish moss (Wilkins 1987). Seminole bats may roost on tree branches 1.0–16.3 m above ground (Wilkins 1987, Menzel et al. 1998, 1999).

*Reproduction*—Females roost singly under tree foliage during the maternity season. In June, they give birth to as many as 4 young (Barbour and Davis 1969).

*Foraging*—Seminole bats typically forage over open areas, pine barrens, and watercourses at treetop level (Wilkins 1987). In Georgia, the average distance Seminole bats foraged from their day roosts was <1 km. Home ranges encompassing <300 ha have been documented (Krishon et al. 1997).

Seminole bats consume a variety of insects, including coleopterans, dipterans, homopterans, and hymenopterans (Sherman 1935, Zinn 1977).

*Status in NPS parks*—Similar to northern yellow bats, Seminole bats may occur at COLO. However, few records have been documented north of North Carolina.

### **Southeastern myotis (*Myotis austroriparius*)**

*Morphology*—The southeastern myotis is monotypic. Its weight averages 6 g, and head to tail length ranges from 8–10 cm (Jones and Manning 1989). A longevity record of 6 years has been reported (Paradiso and Greenhall 1967).

*Range and migration*—The southeastern myotis is considered a species of concern throughout its range, which includes the southeastern United States Coastal Plain, west to eastern Texas and the Mississippi Valley north to Indiana (Jones and Manning 1989). Although southeastern myotis use different summer and winter roosts, their summer and winter ranges are identical (Barbour and Davis 1969).

*Roosting*—In summer, females form maternity colonies of >1,000 individuals in caves. Smaller maternity colonies occupy houses and tree cavities (Jones and Manning 1989, Gooding and Langford 2004).

*Reproduction*—Southeastern myotis are unique in the genus *Myotis* in that they commonly give birth to 2 young each. Other myotines give birth to a single pup each year (Barbour and Davis 1969). Young become volant at 5–6 weeks of age (Harvey et al. 1999).

*Foraging*—Southeastern myotis typically forage over ponds or rivers, close to the surface of the water (Jones and Manning 1989).

Southeastern myotis consume a wide variety of insects. They have been documented consuming lepidopterans, coleopterans, trichopterans, dipterans, ephemeropterans (mayflies), and plecoptera (stoneflies) (Zinn 1977, Zinn and Humphrey 1981).

*Status in NPS parks*—The southeastern myotis may occur at COLO. It has been documented in the Great Dismal Swamp, but appears to be very uncommon in the mid-Atlantic region.

### **Little brown myotis (*Myotis lucifugus*)**

*Morphology*—Of the 6 subspecies of little brown myotis, 1 (*M. l. lucifugus*) potentially occurs at COLO, GEWA, and THST. Little brown myotis weights range from 4–8 g, and head to tail lengths average 9 cm (Fenton and Barclay 1980). Little brown myotis have been documented living  $\leq 30$  years (Griffin and Hitchcock 1965, Keen and Hitchcock 1980).

*Range and migration*—The little brown myotis is considered common throughout its range, which includes Alaska, east through Canada, all continental United States except for the plains states, and parts of Florida and coastal areas of the southeast United States (Fenton and Barclay 1980). Little brown myotis migrate  $< 272$  km (Griffin 1940) between winter and summer ranges. They may form large groups that travel with cold fronts (Zimmerman 1937). There are no distinct latitudes occupied during summer and winter. Little brown myotis occupy northern and southern latitudes in eastern United States year round (Barbour and Davis 1969).

*Roosting*—Little brown myotis hibernate in mines, road tunnels, and caves (Mohr 1942, Pearson 1962). They form loose aggregations within a hibernaculum, which may contain as many as 100,000 individuals (Barbour and Davis 1969)

In summer, males and females roost in separate locations. Males may occupy caves (Krutzsch 1961, Hall and Brenner 1968), buildings, trees, and woodpiles during summer (Fenton and Barclay 1980). Maternity colonies of hundreds to over a thousand individuals are established in barns, attics, and buildings (Cagle and Cockrum 1943, Smith and Goodpaster 1956, Davis et al. 1965). Few studies have documented non-commensal little brown myotis

maternity roosts. Barclay and Cash (1985) documented a maternity colony of <25 individuals in a hollow tree.

*Reproduction*—Gestation lasts 50–60 days before a single young is born in June (Wimsatt 1945, Kunz 1971). The young become volant at 3 weeks (Anthony and Kunz 1977).

*Foraging*—Little brown myotis emerge from their day roosts shortly after sunset to begin foraging along clearing edges (Patriquin and Barclay 2003), riparian areas (Owen et al. 2004), streams (Kurta 1982, Barclay 1991), and cluttered forest interiors (Adams 1996). In Canada, little brown myotis had a mean home range size of 30.1 ha ( $\pm 15.0$  SE) when pregnant and  $17.6 \pm 9.1$  when lactating (Henry et al. 2002). The diet of little brown myotis is diverse and includes coleopterans, dipterans, ephemeropterans, hemipterans, homopterans, hymenopterans, lepidopterans, neuropterans, and tricopterans (Buchler 1976, LaVal and LaVal 1980, Warner 1985, Carter et al. 2003).

*Status in NPS parks*—The eastern limit of the geographic range of the little brown myotis is just northwest of THST. They have been documented in and around counties in which these parks are located and likely occur at COLO, GEWA, and THST

### **Northern myotis (*Myotis septentrionalis*)**

*Morphology*—The northern myotis is monotypic. Its weight ranges from 4–8 g, and head to tail length averages 9 cm (Caceres and Barclay 2000). A longevity record of >18.5 years has been reported (Hall et al. 1957).

*Range and migration*—The northern myotis is considered common throughout its range, which is the eastern half of continental United States and southern Canada (Caceres and Barclay 2000). Migrations of 56 km (Caire et al. 1979, Nagorsen and Brigham 1993) and 88 km have been documented (Griffin 1940).

*Roosting*—Northern myotis hibernate in caves (Dalton 1987), mines (Pearson 1962), and storm sewers (Goehring 1954), where they are difficult to observe because they roost in tight crevices (Caire et al. 1979, Gates et al. 1984). During summer, males typically roost singly in caves (Hall and Brenner 1968), mines (Johnson et al. 2003b) and tree cavities (Barbour and Davis 1969). Females form maternity colonies in tree cavities, crevices, and under loose bark (Sasse and Pekins 1996, Foster and Kurta 1999). In West Virginia, Menzel et al. (2002c) found that northern myotis maternity colonies preferred roosting in understory black locust (*Robinia pseudoacacia*) snags. In Kentucky, northern myotis maternity colonies roosted in cavities of hardwood trees and under bark of shortleaf pines (*Pinus echinata*) located on mid and upper slopes (Lacki and Schwierjohann 2001).

*Reproduction*—Females form maternity colonies of 11–65 individuals and give birth to 1–2 young each in June (Barbour and Davis 1969, Menzel et al. 2002c). The young become volant at 4 weeks of age (Kunz 1971).

*Foraging*—Northern myotis are able to glean prey off foliage or other substrates and take prey on the wing (Ratcliffe and Dawson 2003). They forage in forested riparian areas (Owen et al. 2004), along forested trails (Broders et al. 2003), in the understory of non-riparian areas (Brack and Whitaker 2001), within diameter-limit harvests and forested road corridors (Owen et al. 2003), and in intact forest stands (Patriquin and Barclay 2003).

In West Virginia, the average home range size of pregnant or lactating females was 65 ha (Owen et al. 2003). Sasse and Pekins (1996) documented an average foraging distance of 602 m ( $\pm 66.6$  SE, range 60–1719) for northern myotis in New Hampshire.

Northern myotis consume a wide variety of insects. Northern myotis have been documented consuming lepidopterans, coleopterans, tricopterans, dipterans, hymenopterans,

homopterans, hemipterans, ephemeropterans, plecopterans, and neuropterans (Griffith and Gates 1985, LaVal and LaVal 1980, Brack and Whitaker 2001, Carter et al. 2003).

*Status in NPS parks*—The eastern limit of the geographic range of the northern myotis in Virginia is just northwest of THST. It has only been documented in the western and northern portions of Virginia, but is considered to occur statewide by the Virginia Department of Game and Inland Fisheries. It may occur in low numbers in COLO, GEWA, and THST.

### **Evening bat (*Nycticeius humeralis*)**

*Morphology*—Of the 3 subspecies of evening bat, only 1 (*N. h. humeralis*) potentially occurs at COLO, GEWA, and THST. It is a medium-sized bat with weights ranging from 8–14 g, and head to tail lengths averaging 9 cm (Watkins 1972).

*Range and migration*—Evening bats are considered common throughout their range, which includes the southeastern United States from southeastern Nebraska, east to New Jersey, south into Florida and west into northeastern Mexico (Watkins 1972). Evening bats migrate several hundred kilometers between summer and winter ranges (Humphrey and Cope 1968).

*Roosting*—During all seasons, evening bats roost under loose bark and tree cavities (Menzel et al. 1999, 2001a) and structures including barns (Humphrey and Cope 1968). Evening bats are not typically associated with cave-like environs (Barbour and Davis 1969). In May and June, females form maternity colonies of several hundred individuals in house attics and barns (Humphrey and Cope 1968, 1970, Wilkinson 1992). In South Carolina, tree cavities and loose bark provided roosts for smaller maternity colonies averaging  $10.9 \pm 5.8$  (2 SE) individuals (Menzel et al. 2001a).

*Reproduction*—Each female evening bat gives birth to 1–4 young, averaging 2 (Watkins 1972). Parturition takes place in mid-May in southern latitudes and in mid-June in the northern parts of its range. Young become volant at 3 weeks (Jones 1967).

*Foraging*—Evening bats fly in a slow, steady pattern while foraging (Watkins 1972). Menzel et al. (2002a) found that evening bat activity was higher along forest gaps and edges than within forest stands. Home ranges of evening bats on Sapelo Island, Georgia, averaged 15.11 ha with distances from day roosts averaging 157 m ( $\pm$  115 SE) (Krishon et al. 1997). Diets of evening bats consist primarily of coleopterans, but they also consume dipterans, hemipterans, homopterans, hymenopterans, lepidopterans, neuropterans, orthopterans, and tricopterans (Whitaker and Clem 1992, Carter et al. 2004).

*Status in NPS parks*—Evening bats commonly occur on the Coastal Plain and therefore may occur at COLO, GEWA, and THST. Evening bats have been documented in counties near the parks.

### **Eastern pipistrelle (*Pipistrellus subflavus*)**

*Morphology*—Of the 4 subspecies of eastern pipistrelle, only 1 (*P. s. subflavus*) potentially occurs at COLO, GEWA, and THST. It is 1 of the smallest bats in the region, with weights ranging from 4–8 g, and lengths averaging 8 cm (Fujita and Kunz 1984). Longevity records of >11 years have been recorded for eastern pipistrelles (Paradiso and Greenhall 1967).

*Range and migration*—The eastern pipistrelle is considered common throughout its range, which includes the eastern half of the continental United States, south to the Gulf of Mexico coastline (Fujita and Kunz 1984). Eastern pipistrelles may migrate up to 120 km, but typically migrate <50 km (Griffin 1940, 1945).

*Roosting*—During winter, eastern pipistrelles hibernate in storm sewers (Goehring 1954), mines (Pearson 1962, Menzel et al. 1997), and caves (Gates et al. 1984, Briggler and Prather 2003). They typically are the first bat species to enter and last to leave hibernacula (LaVal and LaVal 1980).

During summer, eastern pipistrelles segregate sexually. Males typically roost solitarily in leaf clusters (Findley 1954), caves (Hall and Brenner 1968), and mines (Johnson et al. 2003b). Females have been documented forming maternity colonies of 11 individuals in a barn (Winchell and Kunz 1993), <29 individuals in barns, pavilions, sheds (Whitaker 1998), and <3 individuals in live- and dead-leaf clusters on broken branches of live trees (Carter et al. 1999, Veilleux et al. 2003). Females have been observed roosting singly in Spanish moss and understory trees (Menzel et al. 1999).

*Reproduction*—After a 44 day gestation period, females give birth to 2 young in June or early July (Wimsatt 1945, LaVal and LaVal 1980). The young become volant after 3 weeks (Lane 1946, Hoying 1983).

*Foraging*—Eastern pipistrelles are among the first bats to emerge at dusk to forage. They forage in forested riparian areas (Owen et al. 2004), over open water, in small forest gaps (Krusic and Neefus 1996), and along forest edges (Davis and Mumford 1962). Few studies have investigated home range size of eastern pipistrelles. A radio-telemetered female in Georgia had a home range of 389.2 ha and foraged 1137 m on average from her roost (Krishon et al. 1997). A radio-telemetered female in South Carolina had a home range of 395.5 ha (Carter et al. 1999). Eastern pipistrelles have a diverse diet that includes coleopterans, dipterans, hemipterans, homopterans, hymenopterans, lepidopterans, and tricopterans (Sherman 1939, LaVal and LaVal 1980, Carter et al. 2003).

*Status in NPS parks*—Eastern pipistrelles likely occur at COLO, GEWA, and THST.

They have been documented in counties containing or adjacent to the parks.

### **Family Molossidae**

Family Molossidae, the free-tailed bats, are represented by 16 genera and 86 species in 5 continents including southern Europe, Asia, Africa, northern South America, and southern North America (Nowak 1994). In North America, 2 genera and 6 species have been documented. Only 1 species potentially occurs at COLO, GEWA, and THST.

#### **Brazilian free-tailed bat (*Tadarida brasiliensis*)**

*Morphology*—Of the 9 subspecies of Brazilian free-tailed bat, only 1 (*T. b. cynocephala*) potentially occurs at COLO, GEWA, and THST. Brazilian free-tailed bat weights range from 9–15 g, and lengths range from 9–10 cm (Wilkins 1989). As its common name implies, the distal portion of the Brazilian free-tailed bat's tail extends freely past the uropatagium. Longevity records of >4 years have been recorded for Brazilian free-tailed bats (Paradiso and Greenhall 1967).

*Range and migration*—The Brazilian free-tailed bat is considered common throughout its range, which includes the southern half of the continental United States, south to western South America and southern Brazil (Wilkins 1989). In the southeastern United States, Brazilian free-tailed bats are not considered migratory, although short-distance seasonal shifts among roosts may occur (Wilkins 1989).

*Roosting*—In the southeastern United States, Brazilian free-tailed bats typically roost in houses and sometimes in tree cavities and bridge expansion joints (Barbour and Davis 1969, Wilkins 1989). Although Brazilian free-tailed bats are known to form colonies containing >1 million individuals in the southwestern United States, in the southeast, the colonies are smaller,

usually containing less than a few hundred individuals (Harvey et al. 1999). During the summer maternity period, males and females may occupy the same structure, but typically form separate clusters (LaVal 1973).

*Reproduction*—Mating occurs in spring, which is different from all other bats in Maryland and Virginia that mate in fall. Typically, litters contain 1 young, although observations of 2 and 3 young/litter have been documented (DiSalvo et al. 1969).

*Foraging*—Little is known about the foraging behavior (i.e., home range size, habitat use) of Brazilian free-tailed bats in the southeastern United States. Brazilian free-tailed bats have a diverse diet that includes coleopterans, dipterans, hymenopterans, and lepidopterans (Sherman 1939).

*Status in NPS parks*—It is unlikely that Brazilian free-tailed bats occur at COLO, GEWA, and THST. Only 1 record exists in Virginia, from a house in Suffolk.

Appendix II. Presence likelihood within 3 National Park Service units, summer roosting behavior, and conservation ranking of bat species occurring in Virginia.

|                                            |                             | Park <sup>a</sup> |      |      | Summer roosts <sup>b</sup> |        |           |      | Rank <sup>c</sup> | Comments                                                                                          |
|--------------------------------------------|-----------------------------|-------------------|------|------|----------------------------|--------|-----------|------|-------------------|---------------------------------------------------------------------------------------------------|
| Species                                    |                             | COLO              | GEWA | THST | Foliage                    | Cavity | Structure | Cave |                   |                                                                                                   |
| <i>Corynorhinus rafinesquii</i>            | Rafinesque's big-eared bat  | X                 |      |      |                            | X      | X         | X    | G3, S2            | <i>C. r. macrotis</i> subspecies only; <i>C. r. rafinesquii</i> occurs in western Virginia        |
| <i>Corynorhinus townsendii virginianus</i> | Virginia big-eared bat      |                   |      |      |                            |        |           | X    | G4T2, S1          | Occurs in western Virginia                                                                        |
| <i>Eptesicus fuscus</i>                    | Big brown bat               | X                 | X    | X    |                            | X      | X         |      | G5, S5            | Likely the most common species at all parks                                                       |
| <i>Lasiurus borealis</i>                   | Eastern red bat             | X                 | X    | X    | X                          |        |           |      | G5, S4            | Probably very common in all parks                                                                 |
| <i>Lasiurus cinereus</i>                   | Hoary bat                   | X                 | X    | X    | X                          |        |           |      | G5, S3            | Few vagrant males occur in parks in summer; probably more common during spring and fall migration |
| <i>Lasiurus intermedius</i>                | Northern yellow bat         |                   |      |      | X                          |        |           |      | G4, S1            | May occur at COLO, if at any parks, but very unlikely                                             |
| <i>Lasionycteris noctivagans</i>           | Silver-haired bat           | X                 | X    | X    |                            | X      |           |      | G5, S4            | Most likely occurs at parks during spring and fall migration, but not summer                      |
| <i>Lasiurus seminolus</i>                  | Seminole bat                |                   |      |      | X                          |        |           |      | G5                | May occur at COLO, if at any parks, but very unlikely                                             |
| <i>Myotis austroriparius</i>               | Southeastern myotis         |                   |      |      |                            |        |           |      | G3, S1            | May occur at COLO, if at any parks, but very unlikely                                             |
| <i>Myotis grisescens</i>                   | Gray myotis                 |                   |      |      |                            |        |           | X    | G3, S1            | Occurs in western Virginia                                                                        |
| <i>Myotis leibii</i>                       | Eastern small-footed myotis |                   |      |      |                            |        |           | X    | G3, S1            | Occurs in western Virginia                                                                        |
| <i>Myotis lucifugus</i>                    | Little brown myotis         | X                 | X    | X    |                            | X      | X         | X    | G5, S5            | May occur at all parks, but probably not as common as big brown bats                              |

## Appendix II. Continued.

|                               |                           | Park <sup>a</sup> |      |      | Summer roosts <sup>b</sup> |        |           |      | Rank <sup>c</sup> | Comments                                                                                                                                                                     |
|-------------------------------|---------------------------|-------------------|------|------|----------------------------|--------|-----------|------|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Species                       |                           | COLO              | GEWA | THST | Foliage                    | Cavity | Structure | Cave |                   |                                                                                                                                                                              |
| <i>Myotis septentrionalis</i> | Northern myotis           |                   |      |      |                            | X      |           |      | G4, S3            | Only confirmed reports come from northern and western Virginia; may occur at parks, but in very low numbers<br>Known to occur in western Virginia; summer range undetermined |
| <i>Myotis sodalis</i>         | Indiana myotis            |                   |      |      |                            | X      |           |      | G2, S1            |                                                                                                                                                                              |
| <i>Nycticeius humeralis</i>   | Evening bat               | X                 | X    | X    |                            | X      | X         |      | G5, S4            |                                                                                                                                                                              |
| <i>Pipistrellus subflavus</i> | Eastern pipistrelle       | X                 | X    | X    | X                          |        | X         | X    | G5, S5            |                                                                                                                                                                              |
| <i>Tadarida brasiliensis</i>  | Brazilian free-tailed bat |                   |      |      |                            | X      | X         | X    | G5                | Only 1 record in southeastern Virginia                                                                                                                                       |

<sup>a</sup> COLO = Colonial National Historical Park; GEWA = George Washington Birthplace National Monument; THST = Thomas Stone National Historic Site.

<sup>b</sup> Foliage = bat species roosts among tree canopy foliage; Cavity = bat species roosts in hollow trees or under exfoliating bark; Structure = bat species roosts in buildings; Cave = bat species roosts in caves or mines.

<sup>c</sup> G = These ranks reflect an assessment of the condition of the species or ecological community across its entire range. T = The status of infraspecific taxa (subspecies or varieties). S = The status of a species at the "subnational" level, referring to state or province-level jurisdictions. Ranks are 1–5; 1 = Critically Imperiled—At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors; 2 = Imperiled—At high risk of extinction due to very restricted range, very few

populations (often 20 or fewer), steep declines, or other factors; 3 = Vulnerable—At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors; 4 = Apparently Secure—Uncommon but not rare; some cause for long-term concern due to declines or other factors; 5 = Secure—Common; widespread and abundant.

Appendix III. Itemized budget and estimated project cost for baseline bat inventory of Colonial National Historical Park, George Washington Birthplace National Monument, and Thomas Stone National Historic Site beginning in 2007.

| <b>ITEM</b>                                                                       | <b>2007</b>     |
|-----------------------------------------------------------------------------------|-----------------|
| <b>1. DIRECT LABOR</b>                                                            |                 |
| <b>Personnel</b>                                                                  |                 |
| PI: J. Edward Gates (8.33% of time, 1 mo)                                         | 7,732           |
| FRA: Joshua B. Johnson (100% of time, 8 mo)                                       | 20,610          |
| Internships (2 × \$400/week × 11 weeks)                                           | 8,800           |
| <b>Total Personnel Costs</b>                                                      | <b>\$37,142</b> |
| <b>Fringe Benefits</b>                                                            |                 |
| PI (27%)                                                                          | 2,088           |
| FRA (23%)                                                                         | 4,740           |
| Interns (8%)                                                                      | 704             |
| <b>Total Fringe Benefits</b>                                                      | <b>\$7,532</b>  |
| <b>TOTAL SALARIES, WAGES, AND FRINGE</b>                                          | <b>\$44,674</b> |
| <b>2. OTHER DIRECT COSTS</b>                                                      |                 |
| <b>Materials and Supplies</b>                                                     |                 |
| Mist nets (different widths)/net poles/harp trap                                  | 1,526           |
| Field notebook computer (1)                                                       | 2,800           |
| Software purchase, upgrades, licensing, and support                               | 250             |
| Computer and printer supplies/backup                                              | 300             |
| Miscellaneous field supplies                                                      | 700             |
| <b>Total Materials and Supplies</b>                                               | <b>\$5,576</b>  |
| <b>Travel</b>                                                                     |                 |
| Vehicle (\$28/day for first 70 miles, 0.09/mile thereafter)                       | 2,800           |
| Meal allowance (\$39/diem/person)                                                 | 546             |
| Regular lodging (\$80/night)                                                      | 560             |
| Lodging for 3 people for approx. 11 weeks (gratis @ COLO, 6 weeks; GEWA, 5 weeks) | 0               |
| Conferences, meetings                                                             | 1,000           |
| <b>Total Travel Costs</b>                                                         | <b>\$4,906</b>  |

| <b>ITEM</b>                                                              | <b>2007</b>     |
|--------------------------------------------------------------------------|-----------------|
| <b>Other</b>                                                             |                 |
| Pre-exposure rabies vaccinations (\$600/person × 2)                      | 1,200           |
| Communications (including cell phone), postage, copying, office supplies | 780             |
| Publication costs                                                        | 1,000           |
| <b>Total Other Costs</b>                                                 | <b>\$2,980</b>  |
| <b>TOTAL DIRECT COSTS</b>                                                | <b>\$58,136</b> |
| <b>INDIRECT COSTS (17.5% CESU)</b>                                       | <b>\$10,174</b> |
| <b>TOTAL PROJECT COSTS</b>                                               | <b>\$68,310</b> |

### **Budget justification**

#### 1) Direct Labor:

- a) The PI requests 1 month salary for himself and 8 month salary for his Faculty Research Assistant (FRA), Joshua B. Johnson, who will play a significant role in all aspects of the inventory, including any data analysis and preparation of the final report; as well as funds for hourly interns. The FRA will analyze the data, integrate GPS coordinates of sampling locations into LULC digital databases of the park, and help with preparation of maps, data files, and reports provided as **Deliverables**.

#### 2) Other Direct Costs:

- a) Materials and Supplies: Funds are requested for field supplies, e.g., mist nets, notebook, and software, for analyzing the data. Miscellaneous field supplies include flashlights, headlamps, spotlights, batteries, calipers and other measuring devices, balances and scales, materials for repair of nets and traps, weather measurement instruments, first aid kit, insect repellent, etc.

- b) Travel: The PI requests funds to cover mileage during weekly sampling periods.

Lodging for FRA and 2 interns will be provided at no charge by NPS for approximately 11 weeks from June–August. Funds for meals and lodging for the PI are requested for planned visits to the site. We also request funds to cover attending a conference or meeting to present the results of the inventory.

- c) Other: Funds are also requested for pre-exposure rabies vaccinations for field personnel; communications in the field (cell phone); postage, copying, and miscellaneous office supplies; and publication costs.

### **Deliverables and timeline**

All deliverables will be developed in accordance with the Northeast Region Inventory and Monitoring Program's Product Specifications.

#### *Species data*

Copies of raw capture and historical data as recorded on field data sheets and acquired from other sources will be provided to the Northeast Coastal and Barrier Network (NCBN) Staff. These data will also be submitted electronically and on CD-ROM in Microsoft Access using the NPS I&M database template or one specifically developed for this particular project as advised by the NCBN Data Manager. A data dictionary describing field names and values will accompany each database. All data will be entered and verified by the investigators. The investigators will be responsible for implementing and documenting quality assurance/quality control (QA/QC) measures used to assure the accuracy of the data. QA/QC documentation will be provided to the NPS with all databases in MS Word.

Metadata for all biological data sets will be provided following the Federal Geographic Data Committee (FGDC) Metadata Biological Data Profile. All metadata will be parsed using

the USGS metaparser (mp) and provided in the following 3 file formats: ASCII text, HTML, and SGML on CD-ROM.

#### *GPS data*

Differentially corrected GPS coordinates (UTM NAD83) meeting National Map Accuracy Standards for 1:24,000 scale mapping for all sampling locations will be provided as ArcInfo coverages (exported to .e00file, preferred deliverable) or ArcView 3.2 / ArcGIS 8x shapefiles (including .shp, .dbf, and .shx files). The investigators also will provide GPS coordinates of any other opportunistic captures or sampling sites. GIS coverages will include all sampling locations overlaid with stream/river coverages, landuse/landcover coverages, Park boundary coverages, and other relevant and mutually agreed upon coverages. **Each sampling location will have an associated data table containing a list of species captured and descriptors of the sampling site.** All spatial data are to be supplied as a coverage compatible with the current version of ArcGIS for the MS Windows operating system, both electronically and on CD-ROM.

#### *Spatial metadata*

Metadata will be provided in Federal Geographic Data Committee (FGDC) format for all spatial datasets including coverages generated from GPS coordinate collection.

#### *Voucher specimens*

Photo documentation will be the primary voucher source. All voucher photos will be submitted to the NCBN Staff in the original JPEG or TIFF format on CD-ROM with accompanying documentation in MS Word.

All data associated with voucher specimens will be provided to the NCBN Staff in the NPS NPSpecies database format. Only bats collected due to capture mortality/injury will be

preserved as voucher specimens. Although all specimens collected within the park will remain property of the NPS, they will be housed at Frostburg State University (FSU) Museum. All specimens will be catalogued in the FSU Museum databases as well as the NPSpecies database.

As some southeastern bat species may be at the limits of their northern range, we may seek to acquire tissue (wing punch) or hair samples of such species for genetic analysis in order to avoid any questions concerning their identification. For example, several bat biologists have raised questions over whether Seminole bats can be distinguished visually from dark-morphed red bats. Bat biologists have worked out protocols for these types of sampling procedures. In view of the fact that hair re-grows and the tiny hole made in the wing membrane heals over quickly, bats are only affected temporarily by these procedures.

All Anabat recordings will be submitted as raw data files. The files will serve as voucher records for NPS.

### **Reports**

A progress report will be submitted in MS-Word format electronically **on or before 1 October 2007**. A **draft final report** will be submitted electronically, on CD-ROM and in hard copy, in MS-Word format, to the NCBN Coordinator **on or before 15 December 2007**. A **final report** will be submitted electronically, on CD-ROM and in hard copy, in MS-Word format, to the NCBN Coordinator **on or before 1 March 2008**.

The **final report will include** summary of findings including species richness and relative abundance estimates based on capture data, sampling methods, analyses, results, project significance, sensitive species/data information and issues, and recommendations for long-term monitoring for use by NCBN staff and NERI park management. The final report will also include all capture data (legible field sheets and MS Access or Excel database format), database

data-dictionary, FGDC compliant metadata, voucher photographs and location of voucher specimens, Anabat recordings, and GPS/Spatial data for sampling locations as described above.

Following submission of the Final Report, Cooperators will develop a manuscript for publication in a refereed journal.

Appendix IV. Itemized budget and estimated project cost for baseline bat inventory of George Washington Birthplace National Monument and Thomas Stone National Historic Site beginning in 2007.

| <b>ITEM</b>                                                 | <b>2007</b>     |
|-------------------------------------------------------------|-----------------|
| <b>1. DIRECT LABOR</b>                                      |                 |
| <b>Personnel</b>                                            |                 |
| PI: J. Edward Gates (2 weeks)                               | 3,866           |
| FRA: Joshua B. Johnson (100% of time, 6 mo)                 | 15,458          |
| Internships (2 × \$400/week × 5 weeks)                      | 4,000           |
| <b>Total Personnel Costs</b>                                | <b>\$23,324</b> |
| <b>Fringe Benefits</b>                                      |                 |
| PI (27%)                                                    | 1,044           |
| FRA (23%)                                                   | 3,555           |
| Interns (8%)                                                | 320             |
| <b>Total Fringe Benefits</b>                                | <b>\$4,919</b>  |
| <b>TOTAL SALARIES, WAGES, AND FRINGE</b>                    | <b>\$28,243</b> |
| <b>2. OTHER DIRECT COSTS</b>                                |                 |
| <b>Materials and Supplies</b>                               |                 |
| Mist nets (different widths)/net poles/harp trap            | 1,526           |
| Miscellaneous field supplies                                | 700             |
| <b>Total Materials and Supplies</b>                         | <b>\$2,226</b>  |
| <b>Travel</b>                                               |                 |
| Vehicle (\$28/day for first 70 miles, 0.09/mile thereafter) | 1,273           |
| Meal allowance (\$39/diem/person)                           | 234             |
| Regular lodging (\$80/night)                                | 320             |
| Lodging for 3 people for approx. 5 weeks (gratis @ GEWA)    | 0               |
| <b>Total Travel Costs</b>                                   | <b>\$1,827</b>  |
| <b>Other</b>                                                |                 |
| Pre-exposure rabies vaccinations (\$600/person × 2)         | 1,200           |
| Communications (including cell phone)                       | 150             |
| <b>Total Other Costs</b>                                    | <b>\$1,350</b>  |

| <i>ITEM</i>                        | <i>2007</i>     |
|------------------------------------|-----------------|
| <b>TOTAL DIRECT COSTS</b>          | <b>\$33,646</b> |
| <b>INDIRECT COSTS (17.5% CESU)</b> | <b>\$5,888</b>  |
| <b>TOTAL PROJECT COSTS</b>         | <b>\$39,534</b> |

### **Budget justification**

#### 1) Direct Labor:

- a) The PI requests 2 weeks salary for himself and 6 month salary for his Faculty Research Assistant (FRA), Joshua B. Johnson, who will play a significant role in all aspects of the inventory, including any data analysis and preparation of the final report; as well as funds for hourly interns. The FRA will analyze the data, integrate GPS coordinates of sampling locations into LULC digital databases of the park, and help with preparation of maps, data files, and reports provided as **Deliverables**.

#### 2) Other Direct Costs:

- a) Materials and Supplies: Funds are requested for mist nets and miscellaneous field supplies, including flashlights, headlamps, spotlights, batteries, calipers and other measuring devices, scales, materials for repair of nets and traps, weather measurement instruments, first aid kit, insect repellent, etc.
- b) Travel: The PI requests funds to cover mileage during weekly sampling periods. Lodging for FRA and 2 interns will be provided at no charge by NPS for approximately 5 weeks. Funds for meals and lodging for the PI are requested for planned visits to the sites.

- c) Other: Funds are also requested for pre-exposure rabies vaccinations for field personnel and communications in the field, primarily cell phones.

### **Deliverables and timeline**

All deliverables will be developed in accordance with the Northeast Region Inventory and Monitoring Program's Product Specifications.

#### *Species data*

Copies of raw capture and historical data as recorded on field data sheets and acquired from other sources will be provided to the Northeast Coastal and Barrier Network (NCBN) Staff. These data will also be submitted electronically and on CD-ROM in Microsoft Access using the NPS I&M database template or one specifically developed for this particular project as advised by the NCBN Data Manager. A data dictionary describing field names and values will accompany each database. All data will be entered and verified by the investigators. The investigators will be responsible for implementing and documenting quality assurance/quality control (QA/QC) measures used to assure the accuracy of the data. QA/QC documentation will be provided to the NPS with all databases in MS Word.

Metadata for all biological data sets will be provided following the Federal Geographic Data Committee (FGDC) Metadata Biological Data Profile. All metadata will be parsed using the USGS metaparser (mp) and provided in the following 3 file formats: ASCII text, HTML, and SGML on CD-ROM.

#### *GPS data*

Differentially corrected GPS coordinates (UTM NAD83) meeting National Map Accuracy Standards for 1:24,000 scale mapping for all sampling locations will be provided as ArcInfo coverages (exported to .e00file, preferred deliverable) or ArcView 3.2 / ArcGIS 8x

shapefiles (including .shp, .dbf, and .shx files). The investigators also will provide GPS coordinates of any other opportunistic captures or sampling sites. GIS coverages will include all sampling locations overlaid with stream/river coverages, landuse/landcover coverages, Park boundary coverages, and other relevant and mutually agreed upon coverages. **Each sampling location will have an associated data table containing a list of species captured and descriptors of the sampling site.** All spatial data are to be supplied as a coverage compatible with the current version of ArcGIS for the MS Windows operating system, both electronically and on CD-ROM.

#### *Spatial metadata*

Metadata will be provided in Federal Geographic Data Committee (FGDC) format for all spatial datasets including coverages generated from GPS coordinate collection.

#### *Voucher specimens*

Photo documentation will be the primary voucher source. All voucher photos will be submitted to the NCBN Staff in the original JPEG or TIFF format on CD-ROM with accompanying documentation in MS Word.

All data associated with voucher specimens will be provided to the NCBN Staff in the NPS NPSpecies database format. Only bats collected due to capture mortality/injury will be preserved as voucher specimens. Although all specimens collected within the park will remain property of the NPS, they will be housed at Frostburg State University (FSU) Museum. All specimens will be catalogued in the FSU Museum databases as well as the NPSpecies database.

As some southeastern bat species may be at the limits of their northern range, we may seek to acquire tissue (wing punch) or hair samples of such species for genetic analysis in order to avoid any questions concerning their identification. For example, several bat biologists have

raised questions over whether Seminole bats can be distinguished visually from dark-morphed red bats. Bat biologists have worked out protocols for these types of sampling procedures. In view of the fact that hair re-grows and the tiny hole made in the wing membrane heals over quickly, bats are only affected temporarily by these procedures.

All Anabat recordings will be submitted as raw data files. The files will serve as voucher records for NPS.

### **Reports**

A progress report will be submitted in MS-Word format electronically **on or before 1 October 2007**. A **draft final report** will be submitted electronically, on CD-ROM and in hard copy, in MS-Word format, to the NCBN Coordinator **on or before 15 November 2007**. A **final report** will be submitted electronically, on CD-ROM and in hard copy, in MS-Word format, to the NCBN Coordinator **on or before 31 December 2007**.

The **final report will include** summary of findings including species richness and relative abundance estimates based on capture data, sampling methods, analyses, results, project significance, sensitive species/data information and issues, and recommendations for long-term monitoring for use by NCBN staff and NERI park management. The final report will also include all capture data (legible field sheets and MS Access or Excel database format), database data-dictionary, FGDC compliant metadata, voucher photographs and location of voucher specimens, Anabat recordings, and GPS/Spatial data for sampling locations as described above. Following submission of the Final Report, Cooperators will develop a manuscript for publication in a refereed journal.