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Distribution and Status of the Southern Bog Lemming, *Synaptomys cooperi,* in Southeastern Virginia

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ABSTRACT

The Dismal Swamp subspecies of the southern bog lemming, *Synaptomys cooperi helaletes,* was named based on specimens collected during the 1895-1898 biological surveys conducted in the Dismal Swamp by the US Department of Agriculture. Unknown in the 20th Century until re-discovered in 1980, this small boreal rodent was believed to be restricted to the Great Dismal Swamp of Virginia and North Carolina where the cool damp conditions had permitted it to survive during the Holocene. However, field studies conducted since 1980 have revealed southern bog lemmings to be widespread throughout southeastern Virginia, with populations encompassing an area of more than 3300 km^2, including the cities of Virginia Beach, Chesapeake, and Suffolk, and Isle of Wight County. Lemmings were present on 38 of 165 (23%) pitfall-trapping sites; their frequency was much greater in prime habitats dominated by grasses and sedges on damp organic soils. Thus, southern bog lemmings are distributed widely in southeastern Virginia and, where present, they often are among the most numerous species of small mammal.

INTRODUCTION

The southern bog lemming, *Synaptomys cooperi*, distributed from Kansas and Nebraska northward through Minnesota and Manitoba, eastward through Canada, and southward into the Appalachian Mountains of North Carolina and Tennessee (Hall 1981), is one of the most enigmatic small mammals in North America. In some Midwestern states, highly trappable and high-density populations coexist with prairie voles in mesic or xeric grassland habitats (Kansas: Gaines et al. 1977; Illinois: Beasley and Getz 1986; Indiana: Krebs et al. 1969). In other permanently wet sites where herbivorous potential competitors often are absent, however, southern bog lemmings are difficult to trap. For example, isolated relic populations associated with permanently flowing springs (now incorporated into state-run fish hatcheries) are known from Meade County in southwestern Kansas and Dundy County in southwestern Nebraska. Other relic populations are believed to be restricted to the Pine Barrens of southern New Jersey and to the Dismal Swamp of southeastern Virginia and adjacent North Carolina.

Thus, populations of this small stocky rodent with short tail and tiny ears are highly patchy in both space and time. For example, in Douglas County in eastern Kansas, where generations of mammalogists have been trained at the University of Kansas since the 1920s, grassland populations existed for about four years starting in the middle 1920s (Lindale 1927, Burt 1928), then disappeared, reappeared in the middle 1940s, disappeared, and then reappeared in the mid-1960s, since when they have persisted (Rose et al. 1977, Norman A. Slade, University of Kansas, pers. comm., October 2005). Understanding its spatial distribution is made difficult because

Synaptomys cooperi often is reluctant to enter live traps. For example, Connor (1959) caught only 38 bog lemmings during four years of study in the swampy habitats of the New Jersey Pine Barrens. By contrast, other populations are readily trappable. Hundreds of *S. cooperi* were routinely trapped in two different kinds of live traps (Rose et al. 1977) in damp and dry oldfields in eastern Kansas, where they reached densities of 42-65 per hectare (Gaines et al. 1977, Gaines et al. 1979).

Clearly the name "bog lemming" is misleading because *Synaptomys* is not restricted to bogs or even to damp places. *Synaptomys* has been reported from areas of woody vegetation (Hamilton 1941, Coventry 1942, Connor 1959), moist grassy areas (Howell 1927, Stewart 1943, Smyth 1946, Burt 1928, Getz 1961), and from dry, south-facing grassy fields, such as in eastern Kansas (Gaines et al. 1977, Rose et al. 1977, Gaines et al. 1979).

First described in 1858 from specimens taken near Jackson, New Hampshire (Hall 1981), the generic name was given because Baird believed it to be a link (= *synapse*) between the lemmings (*Lemmus*) and the true mice (= *mys*). In 1895, investigators from the US Biological Surveys, led by A. K. Fisher, collected southern bog lemmings from cane brakes near Lake Drummond in Virginia's Dismal Swamp which Merriam (1896) described as a new species, *Synaptomys helaletes.* However, in his revision of the genus, Howell (1927) demoted the taxon to a subspecies, *S. cooperi helaletes,* a decision accepted by Wetzel (1955) in his taxonomic study of *S. cooperi.* More recently, Wilson and Ruff (1999) recognize seven subspecies, including the isolated forms in Kansas, Nebraska, and the Dismal Swamp region of Virginia and North Carolina.

Fisher collected other southern bog lemmings from the Dismal Swamp as late as 1898, but none was taken thereafter, despite the efforts of several investigators, including Charles O. Handley, Jr., Smithsonian Curator of Mammals, who trapped some of Fisher's sites in 1953, and in other years and places, all without success. Handley (1979) and others (Meanley 1973, Taylor 1974) speculated that since no specimens had been collected since 1898, the Dismal Swamp subspecies might be extinct. However, Rose (1981), using pitfall traps placed under powerlines in the northwest corner of the Great Dismal Swamp National Wildlife Refuge (GDSNWR), caught 13 specimens from three locations in 1980, laying to rest doubts about its existence.

During the 1980s and early 1990s, my students and I conducted survey trapping at over 100 sites throughout southeastern Virginia for the Dismal Swamp southeastern shrew, *Sorex longirostris fisheri,* then a federally listed mammal; the southern bog lemmings reported here were taken in those same collections. These studies have revealed the Dismal Swamp subspecies, *Synaptomys cooperi helaletes,* to be widespread in appropriate habitats throughout southeastern Virginia, with populations extending west of the Dismal Swamp at least through Isle of Wight County.

METHODS

Both live and pitfall traps were used in our studies, with the latter being used more extensively. Systematic live trapping was conducted in the open habitats under a 40-m wide powerline in the northwestern corner of the GDSNWR (Stankavich 1984). Fitch live traps (Rose 1973), set at 7.6-m intervals in two rectangular grids (0.38 and 0.40 ha), were tended for two days every two weeks from October 1980 to February 1982.

Other live trapping in the following two decades, conducted throughout the region in a range of habitats, has yielded only one other *Synaptomys* with live traps, except for an (unpublished) study conducted by L. J. Ford in Suffolk during 1987-1988.

Most information on distribution and relative abundance comes from pitfall traps set on 0.25-ha grids in a range of habitats in southeastern Virginia (Rose et al. 1990). Placed at 12.5-m intervals on a 5 X 5 grid, each pitfall trap was a #10 tin can placed in the ground flush with the surface and partly filled with water. Earlier studies (e.g., French 1980) had shown that southeastern shrews (and to a lesser extent, southern bog lemmings) are rarely taken in live or snap traps, necessitating the use of pitfall traps to collect distribution and status information on these species. In the initial study, funded by the Office of Endangered Species (Rose 1983, Everton 1985), 37 pitfall grids were set in a range of habitats centering on the GDSNWR. A later study (Padgett 1991), funded by the Virginia Department of Game and Inland Fisheries, added 29 grids, mostly placed at greater distances from the GDSNWR in an effort to learn the geographic extent of distribution of the Dismal Swamp southeastern shrew. Another 85 pitfall grids were set at a variety of sites in the region in surveys conducted between 1986 and 1995. Finally, current information on the western limit of distribution comes from a study conducted in 1992 on 14 grids set in the open habitats under powerlines in Isle of Wight County (Rose 2005).

Specimens collected in pitfall traps were returned to the lab, measured, weighed and evaluated for reproductive condition, and then saved (mostly as skull and skeleton). Most of these specimens now are in the collections of the Smithsonian Institution, with a few remaining in the teaching collection at Old Dominion University. Collectively, these surveys provide information on the habitats and extent of distribution of southern bog lemmings in southeastern Virginia.

RESULTS

Live trapping

Biweekly trapping for 17 months on the two live trap grids in the GDSNWR yielded 13 bog lemmings, two on Grid 1 and 11 on Grid 2 (Stankavich 1984). On Grid 2, none was caught until the 10th month, and then all were captured within a period of a few weeks. However, bog lemmings were known to be present from the start because they produce distinctive bright green bullet-shaped fecal pellets, plus they strip and eat the green outer covering from the softrush, *Juncus effusus,* leaving behind the spaghetti-like bits of pith.

Ford's year-long mark-and-release study was conducted on a large study grid in a regenerating clearcut near the intersection of Desert and Clay Hill Roads in Suffolk, on a site close to the GDSNWR. She caught several dozen each of bog lemmings and woodland voles (*Microtus pinetorum*) using modified Fitch live traps (Rose, 1994). For unknown reasons, the southern bog lemmings on this site were much more prone to entering live traps than the same species had been in Stankavich's (1984) study. The only other *Synaptomys* taken in live traps was an adult female collected early in 1999 in early successional habitat in a wetland bank now reverting to Dismal Swamp vegetation in southern Chesapeake.

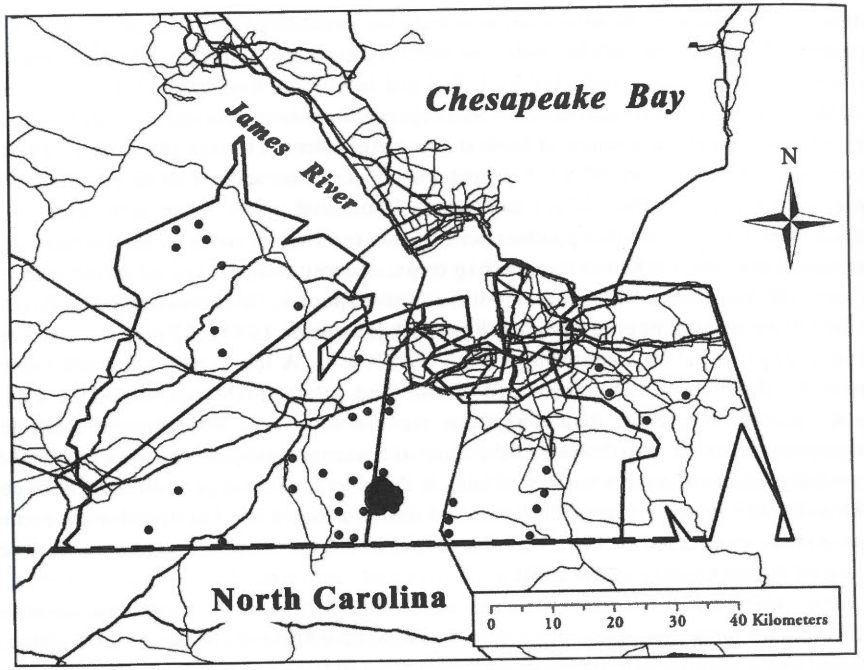

FIGURE 1. Map of southeastern Virginia showing the 38 locations in which southern bog lemmings were found in field studies conducted in the region. Starting from the left, there were 8 sites in Isle of Wight County, 16 in the City of Suffolk, 10 in the City of Chesapeake, and 4 in the City of Virginia Beach. Nine of the sites in Suffolk and 6 from Chesapeake were Great Dismal Swamp, mostly in the Great Dismal Swamp National Wildlife Refuge.

Pitfall trapping

Southern bog lemmings have been collected from 38 sites throughout the southeastern Virginia region (Figure 1). Many are from the GDSNWR and its margins, the area of most intensive study, but populations of the species were scattered over the entire region, from West Neck Creek, Farrell Parkway, and Gum Swamp in Virginia Beach, to the Naval Security Group-Northwest site, near Route 17, and the Hickory region in Chesapeake, to several locations in eastern and southwestern Suffolk, and eight localities in Isle of Wight County.

The best information on the composition of the small mammal communities of which *Synaptomys* is a part comes from Rose (1983), who found bog lemmings on 17 of 37 sites in and near the GDSNWR. When present, southern bog lemmings constituted 11.8 to 51.4 percent of animals on these 17 grids (Table 1). On sites with bog lemmings, they comprised an average of 25.3 percent of total captures. Similar results were seen in Isle of Wight County (Table 2), with bog lemmings being present on 8 of 14 grids, and comprising 17.1 percent of captures on grids with *Synaptomys*. Thus, when present, southern bog lemmings comprise a substantial proportion of the small mammal community.

Information on the small mammals associated with *Synaptomys* is presented in the bottom rows of Tables 1 and 2. *Sorex longirostris* was the most frequent associate (n

TABLE 1. Results of pitfall trapping on seventeen 0.25 ha grids with southern bog lemmings, set in and near the Great Dismal Swamp National Wildlife Refuge in Suffolk, Virginia (Rose, 1983). The mnemonics refer to the species names: Sc, southern bog lemming, *Synaptomys cooperi;* Sl, southeastern shrew, *Sorex longirostris;* Bl, short-tailed shrew, *Blarina brevicauda and B. carolinensis;* Cp, least shrew, *Cryptotis parva;* Mpe, meadow vole, *Microtus pennsylvanicus;* Pl, white-footed mouse, *Peromyscus leucopus;* Mm, house mouse, *Mus musculus;* Mpi, pine or woodland vole, *Microtus pinetorum;* On, golden mouse, *Ochrotomys nuttalli;* Op, marsh rice rat, *Oryzomys palustris.* "Associates" refers to the number of grids (out of 17 with Sc) that the species in that column was associated with. Thus, Sl was present on 15 of 17 grids with Sc.

Grid	Sc	Sl	Bl	Rh	Cp	Mpe	Pl	Mm	Mpi	On	Op	Totals
2	2	8	5									15
3	4	3	9	1			1					18
6	2	3	2									7
8	2		2	8	4		1					17
9	6	12	2	6	2		1	2	2			33
10	14	7	7	1								29
11	11	21	4							1		37
12	5	1		11	6		4			1		28
13	6	2	1	2			1	1	1		1	15
14	18	10		1	4		1		1			35
19	3			4	6	1	2	1				17
25	5	9	10	2						2		28
28	3	3	1	1	9		1					18
30	6	14	1	4			2		2			29
31	4	2		3	5		1					15
34	5	8	18	1	1				3			36
37	6	11	8			1						26
Totals	102	114	70	45	37	2	15	4	9	4	1	403
Associates	(17)	15	13	13	8	2	10	3	5	3	1	

= 15 of 17 grids) in Table 1 (Dismal Swamp and vicinity) but for the mostly drier sites in Isle of Wight County (Table 2), it was among the least common (n = 3 of 8 grids). *Reithrodontomys* was a common associate at both locations (15, 7); by contrast, *Cryptotis* was always present with *Synaptomys* in Isle of Wight County but these two species were found together on slightly less than half (8/17) of grids in the Dismal Swamp vicinity. Perhaps the most relevant associate because of its alleged competition with *Synaptomys* (Linzey 1984), *Microtus pennsylvanicus* (meadow vole) was found with *Synaptomys* on only 2 of 17 grids in the Dismal Swamp and on 3 of 8 grids in Isle of Wight County. In all instances, only one or two meadow voles were taken on grids also yielding *Synaptomys*. The mean number of associated small mammals in the varied habitats of the Dismal Swamp region was 11.8, compared to 12.1 small mammals in the open habitats under powerlines in Isle of Wight County.

Reproduction and body size

Sexual maturity is attained early in southern bog lemmings, in females sometimes before they are weaned. Except for one female, the nine pregnant *Synaptomys* in this study weighed 30 g or more (exclusive of their pregnant uteri), indicating that they

TABLE 2. Results of pitfall trapping on eight 0.25 ha grids with southern bog lemmings, set in locations throughout Isle of Wight County, Virginia (Rose, 2005). The mnemonics for the species names are defined in the legend to Table 1. "Associates" refers to the number of grids (out of 8 grids with *Synaptomys*) that the species in that column was associated with *Synaptomys*.

Grid	Sc	Sl	Bl	Rh	Cp	Mpe	Mpi	Totals
1	4		3	4	2		13	
2	2	2	2	2	10			18
3	4	3		16	6			29
4	1		2	3	3			9
5	1			4	5	2		12
6	1			3	5			9
7	1		2		4	1		8
8	6	1		3	6	2	1	19
Totals	20	6	9	35	41	5	1	117
Associates	(8)	3	4	7	8	3	1	

likely were mated after reaching 20 g. The exception was a 21-g female collected on February 25 with one embryo in each uterine horn. Litter sizes (embryo counts at necropsy) were either two or three, for a mean litter size of 2.56. However, counts of placental scars (indicating earlier litters) of four (from a 29-g female in late December), five (n = 3, all weighing 31-35 g), and six (from a 29-g female in late November) were also recorded. These placental scars were similar in color and size, more likely indicating one rather than two previous litters. Together these results indicate that females in this population can breed at low body weights and have litters of moderate size; both attributes are typical of the reproductive biology of microtine rodents.

Pregnant females were recorded for the months of November, December, and January to June. The appearance of juvenile animals (< 20 g) in the population during these months confirms this pattern of breeding throughout the winter months and into the early summer.

Male reproductive competency was assessed by the presence in convolutions in the cauda epididymis of the testis. Although the pattern of a November-to-June breeding season is less clear for males than for females, the absence of epididymal convolutions from July-September indicated that breeding was suspended during the hottest months of summer for males. Thus, in eastern Virginia, the breeding season of *Synaptomys* begins in late autumn (November) and extends into early summer (June).

The analysis of body size of a population or subspecies requires identification of adult animals in order to reduce the variation when juveniles and sub-adults are included. Adulthood can be identified empirically by the presence of embryos, sperm in testicular tubules, or by certain cranial features, the latter not considered here. In many mammals, adults can be defined by creating age classes based on tooth wear, but this method is not applicable to *Synaptomys* because all microtine rodents have ever-growing (open-rooted) teeth. Because I found only nine pregnant females and many more fertile males (many animals collected in warm months could not be accurately assessed for reproductive features), I cannot make a meaningful statistical analysis of

TABLE 3. Body dimensions for *Synaptomys* from the cities of Virginia Beach, Chesapeake, and Suffolk (combined) and from Isle of Wight County, Virginia. The asterisk (*) indicates significant differences in that body dimension compared to the other sex from that sample.

	Cities		Isle of Wight County	
	Males	Females	Males	Females
Sample size	65	51	13	7
Total length (mm)	118.71	117.63	118.54	128.86*
SE mean	1.47	1.58	2.44	4.72
Min-max values	83-143	80-151	102-129	117-151
Tail length (mm)	18.95	18.02	20.69	23.00
SE mean	0.34	0.61	0.86	2.90
Min-max values	12-25	7-23	15-26	18-23
Weight (g)	29.71*	27.34	27.96	32.17
SEmean	0.98	1.06	2.09	3.79
Min-max values	10-45	11-47.4	14.63-41.63	24.05-47.36

only adults. However, I can assume that males and females of all ages have equal probability of being caught in unbaited pitfall traps, and thus I believe these 78 males and 58 females (Table 3) are random samples of their sexes. When specimens from all four geographic areas were combined, the means of all males from Table 3 were 118.68 mm total length and 29.42 g, and those of females were 118.98 mm and 27.92 g. No dimorphism was detected for either body length ($t = 0.15$, $P > 0.05$) or body mass ($t = 1.09$, $P > 0.2$).

Habitat associations

The study grids with *Synaptomys* were dominated by grasses and sedges, often liberally sprinkled with seedlings of sweet gum (*Liquidambar styraciflua*) and red maple (*Acer rubrum*) and such shrubs as sweet pepperbush (*Clethra alnifolia*) and groundsel (*Baccharis halimifolia*). This vegetation is typical of regenerating sites in the region, such as those found after the clearcutting of plantations of loblolly pines (*Pinus taeda*) or sites under powerline rights-of-way which get mowed every 3-5 years. Monocots are essential for *Synaptomys* but the other vegetation does not seem to be so important. *Synaptomys* was present in some young pine plantations, but only in those with grasses. Several sites with *Synaptomys* were naturally regenerating recent clearcuts of pine trees, now with diverse vegetation including seedling volunteer trees, vines, shrubs, and the requisite grasses and sedges. Grass-dominated marshes, such as the 'remnant marsh' in the southern section of the GDSNWR (which had been burned and grazed by generations of farmers before this land became part of the refuge) and a similar grassy site near Driver (in rural Suffolk) that also appeared to have been maintained by burning or grazing, were most predictable in yielding southern bog lemmings. The presence of American cane (*Arundinaria gigantea*) also is a good predictor of the presence of southern bog lemmings, especially if the 3-4 cm cuttings of cane made by feeding *Synaptomys* are detected before setting the pitfall traps.

DISCUSSION

Live trapping

As with some other populations, southern bog lemmings from eastern Virginia are reluctant to enter live traps, as shown by their absence until the 10th month of biweekly trapping on Stankavich's Grid 2 and the capture of only one other *Synaptomys* in many years of survey trapping in the region. However, Ford (unpublished) caught several dozen *Synaptomys* on a young regenerating forest site where it was a co-dominant with *Microtus pinetorum*, a most unlikely pairing of herbivorous mammals. By contrast, Fitch live traps, also used in Rose et al. (1977), caught >200 *Synaptomys* in eastern Kansas. Gaines et al. (1977) used Longworth traps to catch hundreds of *Synaptomys*, also over a three-year period. Although the trapping effort was not comparable in these two studies, Longworth traps probably are superior in catching southern bog lemmings from oldfields in eastern Kansas. Handley (1979) used snap traps, and perhaps Sherman live traps, in his futile attempts to locate *Synaptomys* in the Dismal Swamp region. J. F. Merritt (Illinois Natural History Survey, pers. comm., October 2005) also failed to catch *Synaptomys* with Sherman traps in his field work in eastern Virginia from 1976-1979.

Pitfall trapping

Pitfall traps provided much more information than live traps on the presence and relative abundance of southern bog lemmings in the region. Nearly half of 0.25 ha study grids in and near the GDSNWR yielded *Synaptomys* (Table 1), and slightly more than half of 14 study grids in Isle of Wight also had southern bog lemmings (Table 2). Overall, 23 percent (38) of the 165 study grids yielded *Synaptomys* (Figure 1), and when they were present, southern bog lemmings constituted about 20 percent of captures. Thus, although patchy in distribution, southern bog lemmings can be numerous when present. If the term 'rare' is to be applied to this mammal, patchy distribution rather than number of individuals in the population must be the primary criterion.

Reproduction and body size

Embryo counts (= litter size) were either two or three for this study but some females had 4, 5, or 6 placental scars of similar age, indicating that some larger litters were achieved in this population. The range of litter sizes for the species is one to six (Linzey, 1983).

The breeding season began in late autumn (November) and continued into early summer (June); uterine embryos were recorded during every month during this period. Breeding was suspended in the hottest months of summer, and did not resume until the cooling effects of late autumn were present. This pattern of suspended breeding during the hottest months also was seen in Kansas populations of prairie voles, *Microtus ochrogaster* (Rose and Gaines, 1978). The very adaptations (short ears and tails, chunky bodies, and thick fur) that make microtine rodents suited for conserving heat in the winter make it difficult for them to dump heat in the summer months. Thus, microtine rodents must become highly nocturnal during the summer months in order to avoid the heat, and this change in feeding schedule may impinge on their ability to reproduce during the hottest months.

Furthermore, finding the resources to sustain breeding in the winter months is not a problem in the southern limits of distribution, because winter temperatures in eastern Virginia are like those of autumn in the northern states or provinces. The mean high temperature for the coldest month, January, is 9° C, and green grasses and sedges are present and growing year-round. Furthermore, microtine rodents are able to extract energy even from standing dead vegetation, relying on microbial fermentation and, in the case of *Synaptomys*, a massive spiral-shaped caecum which slows passage of food through the gut and further facilitates fermentation. Microtine rodents also consume their own soft moist fecal pellets (a behavior called coprophagy), extracting additional energy and nutrients as a result.

The greatest body weight of the 136 animals examined for body dimensions (Table 3) was 45 g for males and 47 g for females. However, the mean body lengths and masses of each sex were similar and less than 120 mm and 30 g, respectively. Because the samples of the sexes included juveniles and sub-adults as well as adults, sexual size dimorphism cannot be categorically demonstrated but is suggested by an analysis of all males and females. Neither Wetzel (all subspecies: 1955) nor Linzey (1983), for *Synaptomys cooperi stonei*, found sexual dimorphism. However, the body dimensions of *Synaptomys cooperi helaletes* from southeastern Virginia are considerably smaller than those of *S. c. gossii* from eastern Kansas, where Danielson and Gaines (1987a) reported males to average 39.1 g and females 37.1 g.

Habitat associations

Southern bog lemmings were present in 23 percent of sites that were trapped using pitfalls in this study. Originally the focus of study was the GDSNWR and its perimeter; later studies searched more widely for populations, and eventually populations were found in 8 of 14 sites in Isle of Wight County, well west of Dismal Swamp habitat type. Dense covering vegetation of grasses and sedges provided the most reliable clues that *Synaptomys* might be present. American cane was another useful predictor of its presence, especially if damp and peaty soil conditions prevailed. Everton (1985), using principal components analysis to examine the relationship between the presence of small mammals and 13 habitat variables, found *Synaptomys* to be associated with both short-tailed and southeastern shrews in habitats with structural diversity provided by shrubs, but also having substantial grassy and litter layers.

Although moist conditions and peaty soils often seemed to be predictors of the presence of *Synaptomys* in the Dismal Swamp, these habitat features seemed less important in Isle of Wight County, where most sections of almost all sites were considered uplands with dry mineral soils. There southern bog lemmings were often found in cane patches and also in small swales dominated by sedges and softrushes.

Although Rose and Spevak (1978) report behavioral dominance of prairie voles over bog lemmings in a laboratory study, Danielson and Gaines (1987b) found little evidence for mutual avoidance in the field.

By contrast, Linzey (1984) presents evidence, based on patterns of co-occurrence in marginal habitat and on removal experiments, that *Synaptomys cooperi stonei* competes for space, usually unsuccessfully, with *Microtus pennsylvanicus* near Blacksburg, in montane western Virginia. My results tend to support her contention (Tables 1 and 2). In the Dismal Swamp, both species were found together on only 2

of 37 grids, *Synaptomys* was found alone on 15 grids (mean of 5.8 lemmings/grid), *M. pennsylvanicus* was alone on 10 grids (mean of 5.4 voles/grid), and neither species was present on the other 10 grids (Rose 1983). On the two grids with both species, there was a single meadow vole on each, compared to 3 and 6 southern bog lemmings. Thus, the avoidance was not complete, but on the two grids with both species, only a single meadow vole was present. In Isle of Wight County, the pattern is less clear because both species were found together on 3 of 14 grids, *Synaptomys* was found alone on 5 grids (mean of 2.4 lemmings/grid), *M. pennsylvanicus* was alone on 4 grids (mean of 3.0 voles/grid), and neither species was present on the other 2 grids. Two of the 3 grids with both species had one or two of each species; the other grid had 6 southern bog lemmings and 2 meadow voles. I interpret these results to mean that the powerline rights of way in Isle of Wight County were marginal habitat for both species. Linzey and Cranford (1984) also found habitat differences between the two species near Blacksburg.

Geographic distribution in the region

In all, *Synaptomys cooperi* was found in 38 (23.0%) of 165 pitfall-trapping sites spread over an area (Figure 1) encompassing the cities of Virginia Beach (formerly Princess Anne County), Chesapeake (formerly Norfolk County), Suffolk (formerly Nansemond County), and Isle of Wight County. The total area of these three municipalities and one county is 3,380 km^2, or 1305 mi^2. These 165 sites included many small patches (often surrounded by farm fields or development) as well as forested sites, where bog lemmings are not likely to be present. Thus, for prime habitats, with dense covering vegetation of grasses and sedges and damp organic soils, the likelihood of the presence of *Synaptomys* probably approaches 50 percent in this region.

Conservation and management of Synaptomys in eastern Virginia

At present, *Synaptomys cooperi helaletes* is a taxon of Tier IV Greatest Conservation Need status in Virginia (VDGIF: Comprehensive Wildlife Conservation Strategy, 2005), primarily because its distribution is believed to be limited to a small area of the state, its populations are patchily distributed, and its prime habitats are rapidly being lost to development in eastern Virginia. Furthermore, the species remains difficult to assess for population status because it is predictably resistant to being taken with live or snap traps, the usual methods for surveying small mammals. However, the results of my study, conducted primarily with pitfall traps, revealed *S. c. helaletes* to be more widely distributed in Virginia than previously believed and, where present, its numbers often are substantial, comprising about one-fifth of small mammal captures. Rather than being restricted to the Dismal Swamp (for which the GDSNWR is now the core area) as previously believed, southern bog lemmings were found in 38 locations across three cities and one county, with a total area of 3,380 km^2.

This pattern of distribution well beyond the forested swamps such as the Dismal Swamp also has been observed in North Carolina, based on 4 specimens collected over a large area (Clark et al. 1993, Webster et al. 1992). Thus, populations of *Synaptomys cooperi helaletes* in eastern Virginia, and perhaps in eastern North Carolina, are doing moderately well, existing far beyond the cool moist swamps that still may be their refugia in times of extreme drought. As boreal mammals and microtine rodents,

southern bog lemmings are poorly adapted to the hot and sometimes dry conditions that dominate the weather in eastern Virginia for the May-September period. Their physical adaptations make dumping heat difficult, forcing them to become primarily nocturnal during the hottest months. Worse still, southern bog lemmings might require more water than other small mammals in the region during the hottest months, in part because of greater water losses for thermoregulation. At present, nothing is known about the renal efficiencies of southern bog lemmings or their tolerances to heat loads compared to meadow voles, for example.

On the positive side, however, southern bog lemmings often readily colonize the early successional habitats that are created when even-aged plantations of loblolly pines are harvested in the region, especially when scattered adult trees remain as the seed sources for revegetating newly logged sites. *Synaptomys* is vagile and readily invades appropriate habitat when its requirements are present. Vagility and modestly broad habitat requirements are useful attributes for a species formerly believed to have been restricted to cool damp swamps. However, when woody logging debris is bulldozed into windrows, seedling pines are planted by machine, and volunteer vegetation is controlled with herbicides, southern bog lemmings are absent from such pine plantations. Dolan (1998) used both live and pitfall trapping methods on fifty-six 0.25 ha sites in pine stands of four age classes in Isle of Wight County, and collected no *Synaptomys* in 39,600 trap nights with live traps and 28,500 trap nights with pitfall traps. This is the same county in which southern bog lemmings were found in 8 of 14 sites in the varied but open habitats under powerlines (Table 2). Thus, forestry methods may be important in determining whether southern bog lemmings can colonize pine plantations during the early years of forest regrowth in eastern Virginia. This speculation is testable.

Overall, then, *Synaptomys cooperi helaletes* is more widespread and abundant in eastern Virginia than previously believed, but it probably deserves to retain its present conservation status because of the rapid land development in the region. Future surveys must use pitfall trapping methods in order to locate populations.

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