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Natural History of the Southern Bog Lemming in Southeastern Virginia

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ABSTRACT

The isolated subspecies of Southern Bog Lemming of southeastern Virginia, *Synaptomys cooperi helaletes*, has been studied extensively since its "rediscovery" in the Great Dismal Swamp in 1980. Multiple studies using pitfall traps, starting in the Great Dismal Swamp National Wildlife Refuge and then extending elsewhere in southeastern Virginia and adjacent northeastern North Carolina, have revealed lemmings to be much more widespread and often more common than previously believed, with their presence now confirmed as far west as Surry and Sussex counties, about 30 km east of Petersburg, Virginia. When present, lemmings often are among the most numerous members of the small mammal community. Even in appropriate habitat, its presence seemingly is determined by its proximity to another arvicoline rodent, the Meadow Vole, *Microtus pennsylvanicus*, which usually is larger and perhaps competitively and behaviorally dominant.

Keywords: competition, meadow vole, *Microtus pennsylvanicus*, *Synaptomys cooperi.*

INTRODUCTION

The Southern Bog Lemming, *Synaptomys cooperi*, is a short-tailed rodent in the family Muridae, subfamily Arvicolinae (formerly Microtinae), a subfamily with a worldwide distribution in the northern latitudes, and includes the only rodents active year-round in high Arctic environments. *Synaptomys cooperi* is distributed in eastern North America from the Canadian maritime provinces westward to southern Manitoba and western Minnesota, southward through the eastern part of the Great Plains, and eastward in the cooler montane habitats of the southern Appalachians. Isolated populations are known from Meade County in southcentral Kansas, Dundy County in southwestern Nebraska, the Great Dismal Swamp region of southeastern Virginia and adjacent North Carolina, and the Pine Barrens region of New Jersey. C. H. Merriam (1896) believed the Southern Bog Lemmings discovered in the Great Dismal Swamp to be distinctive from others and thus named it a new species, *Synaptomys helaletes*, but later this taxon was relegated to subspecies status (Wetzel, 1955), so it is now called *Synaptomys cooperi helaletes*.

Baird (1858) proposed the name *Synaptomys* because he believed its features represented a link between true lemmings (*Lemmus*) and mice. The one other species in the genus, *Synaptomys borealis*, overlaps with *S. cooperi* only in the southern parts of its distribution, which extends beyond the Arctic Circle. Much more is known about the biology of *Synaptomys cooperi* because population studies have been conducted in eastern Kansas (Gaines et al., 1977), eastern Illinois (Beasley & Getz, 1986), western Virginia (Linzey, 1984), and southeastern Virginia (Rose & Ford, 2012). Across its distribution there are hints that the Southern Bog Lemming is more able to coexist with Prairie Voles (*Microtus ochrogaster*) than with Meadow Voles (*M. pennsylvanicus*).

GENERAL CHARACTERISTICS

The Southern Bog Lemming is a thick-bodied, short-tailed rodent with grizzled brownish fur above and gray fur below (Fig. 1). Each sex of *S. c. helaletes* averages about 28 g, with some individuals weighing up to 47 g (Rose, 2006; Rose & Ford, 2012). Rose (2006) found the sex ratio of *S. c. helaletes* is 1:1, and both sexes have similar total lengths, about 120 mm, of which the tail is about 20 mm. Its tail is about as long as the hind foot, and only half as long as that of its closest relative in southeastern Virginia, the Meadow Vole. Its blunt snout hides a pair of grooved upper incisors, a feature

Fig. 1. Photograph of Southern Bog Lemming, *Synaptomys cooperi* (credit Wayne Van Devender).

distinguishing this rodent from others of similar size in southeastern Virginia. Its small ears are nearly obscured by the long fur and the eyes also are small.

DISTRIBUTION

Like the other isolated subspecies, *Synaptomys cooperi helaletes* was believed to have a restricted distribution, probably limited to the historic Great Dismal Swamp of Virginia and North Carolina, which when Europeans colonized Virginia may have had an area of 1,800 km^2 (Lewis & Cocke, 1929). The Great Dismal Swamp, a distinctive geological feature of the mid-Atlantic coast, developed during the Holocene and is characterized by peaty soils, high water table, especially in winter, and cooler and wetter habitats than in nearby uplands, qualities that likely enabled *S. c. helaletes* to survive in place after the last Pleistocene glacier retreated northward starting about 10,000 years ago, taking with it most other boreal species.

Synaptomys cooperi helaletes was discovered when the U.S. Bureau of Biological Survey sent a team, headed by A. K. Fisher, to conduct a survey of plants and animals in the Great Dismal Swamp. From 1895 to 1898, Fisher's team spent a total of 23 weeks collecting many kinds of organisms there, including 23 Southern Bog Lemmings in kill traps. Later efforts to find lemmings in the Swamp were futile, including multiple efforts by Smithsonian Curator Charles O. Handley (1979), until Rose (1981) collected 13 Southern Bog Lemmings in pitfall traps at three locations in the northwest section of the Great Dismal Swamp National Wildlife Refuge (hereafter "Refuge") in late winter of 1980. Later studies extending outward from the Refuge revealed Southern Bog Lemmings at numerous locations in Virginia Beach, Chesapeake, and Suffolk (all former counties) and as far west as Isle of Wight County, where they were caught in pitfall traps at eight of 14 sites (Rose, 2005). Later, evidence of populations was detected at 10 sites farther west, in Southampton, Surry, and Sussex counties, and confirmed when Southern Bog Lemmings were caught in live traps at three of five locations in these counties (Rose, 2011).

Their presence in western Surry and Sussex counties, within 30 km of Petersburg, Virginia, suggests that Southern Bog Lemming populations might be found even farther west. With the addition of these three counties, the known distribution of *S. cooperi helaletes* has been extended to 7,000 km^2 (2,700 mi^2), much broader in Virginia than previously believed.

FORM AND FUNCTION

As in other arvicoline rodents, the dense fur, short tails, and short ears are adaptations for conserving heat in the north temperate environments in which most populations of Southern Bog Lemmings live. The same features that conserve heat create heat-dumping problems in summer for boreal species living in temperate locations, probably resulting in them becoming more nocturnal during the warmest months in order to avoid life-threatening heat stress. For Southern Bog Lemmings, information on such behavioral changes is unknown but adjustments in the timing of their breeding season are suggestive (see Reproduction).

The distinctive feature of the alimentary canal is the large spiral-shaped caecum, useful in the foregut fermentation that is crucial to extracting energy from their low-caloric foods, such as grasses, sedges, and mosses. Other arvicoline rodents have large caeca, but only the caecum of the Southern Bog Lemming has the spiral shape, a feature that increases the surface area without increasing the capacity of the caecum. The caecum slows the flow of digesta through the gut, allowing microbial action and fermentation sufficient time to break down and release simple sugars and amino acids for absorption in the small intestine. It is unclear why the spiral-shaped caecum is present in *Synaptomys* but not in other arvicoline rodents.

The efficiency of digestion is increased by Southern Bog Lemmings practicing coprophagy (i.e., the eating of feces). Soft pellets, plucked before they drop to the ground, are swallowed after chewing, and their second passage through the alimentary canal extracts nitrogen and water, and retains more minerals than initial digestion (Kenagy & Hoyt, 1980). Coarse pellets with undigestible fibers, the product of the second passage, are allowed to drop to the ground at latrines.

Like other arvicoline rodents, *S. c. helaletes* is active year-round and thus must find the calories to sustain itself day to day. Fat stores probably play a minor role in winter survival because Southern Bog Lemmings (also Prairie and Meadow Voles) have little body fat at any time of year (pers. obs.). Arvicolines, and presumably *S. c. helaletes*, have high metabolic rates, higher than rodents of similar size that live in more temperate locations. The reasons for their high metabolic rates are not entirely understood but may be related to their high biotic potential, such as their ability to double population size in as little as a month via their short gestation and nursing periods. Many arvicoline rodents, including Southern Bog Lemmings, undergo multi-annual population cycles; in eastern Kansas, populations of *S. c. gossii* underwent multi-year cycles on two sample grids but had annual cycles on a third grid (Gaines et al., 1977). No pattern was evident in the population study of *S. c. helaletes* in Suffolk, Virginia (Rose & Ford, 2012). After nearly a century of study, the reasons for multi-year population cycles in arvicoline rodents remain unclear (Krebs, 2013).

REPRODUCTION

Litter size of necropsied *S. c. helaletes* females (n = 9) collected in pitfall traps was 2.56, but some other females had same-sized placental scars numbering 4, 5, and 6; these values conform with litter sizes in other subspecies (Rose, 2006). Pregnant females were recorded for all months from November through June, but none from July-October. This suggests that Southern Bog Lemmings in southeastern Virginia may suspend breeding during the warmest months, perhaps because of problems with dealing with summer heat. Although the November-June pattern of reproduction seen in females is not as clear for male *S. c. helaletes*, the absence of epididymal convolutions from July-September indicates that males were infertile during this period. The winter breeding of Southern Bog Lemmings in southeastern Virginia is different from northern populations, where breeding usually is suspended in mid-winter (Linzey, 1983). Part of the reason for continued winter breeding of *S. c. helaletes* may relate to the continual growth of grasses, sedges, and softrushes during the mild winters in southeastern Virginia, where the mean January high temperature is 9º C. Using external features only, *S. c. helaletes* near the Refuge in Suffolk (Rose & Ford, 2012) showed high levels of reproductive readiness throughout the 18-month study: 84% of adult females showed two of three reproductive features and 52% of males had descended testes; monthly values did not depart greatly from these values, suggesting year-round reproduction.

There is little information on reproduction from other populations or subspecies of *S. cooperi.* Connor (1959) attempted to breed Southern Bog Lemmings in the laboratory but only one female produced litters (n = 6) and a total of 22 young during a 26-week period. The average interval between litters was 23-26 days, indicating a post-partum estrus and breeding soon after the birth of a litter, a common feature in arvicoline rodents. Much remains to be learned about the patterns of reproduction in the geographic populations of Southern Bog Lemmings.

ECOLOGY

Although *Synaptomys cooperi* sometimes is found in forests (Krupa & Haskins, 1990; Linzey, 1983), its diet is composed almost exclusively of herbaceous vegetation (Linzey, 1984; Rose & Ford, 2012), including mosses and fungi, but mostly grasses and sedges, plants rarely found in forests with closed canopies. Fruits of huckleberries and blueberries were important foods in New Jersey and bark and roots were eaten sometimes too (Connor, 1959). In southwestern Virginia, broomsedge (*Schizachyrium scoparium*) was the most important food during summer and mosses in winter (Linzey, 1984). In the only study of diet of *S. c. helaletes* from southeastern Virginia, feces obtained from 3-7 lemmings each season showed that seeds and sedges dominated the winter diet; in spring, sedges remained important but significant amounts of grasses and mosses were also eaten (Rose & Ford, 2012). The summer diet was nearly 80% cane (*Arundinaria* sp.), with seeds and sedges comprising most of the rest. In autumn the diet was more varied, with cane and grasses combining for about 80%, followed by sedges, lichens, and seeds. In this study, soft rushes (*Juncus* spp.) were sometimes consumed, but were never more than 5% of seasonal diets. By contrast, in habitat under powerlines in the Dismal Swamp, Rose & Stankavich (2008) sometimes found piles of the spaghetti-like pith of *Juncus* left after Southern Bog Lemmings had peeled and eaten the green cover from this soft rush; this behavior seemed to be more common in winter. The discarded 3-4 cm sections of cane near latrines of green feces indicate its frequent consumption by Southern Bog Lemmings in southeastern Virginia. Most plants in the diet are found in damp or wet environments and some, such as the sedges (*Carex*), soft rushes (*Juncus*), and spikerushes (*Eleocharis*), are obligate wetland plants.

The presence of Southern Bog Lemmings in these habitats often is indicated by 3-4 cm cut and discarded sections of grasses, sedges, or cane and by latrines with their distinctive green feces. These fecal pellets are 5-6

mm long and 2-3 mm wide and rounded at both ends, in effect sausage-shaped (Rose, 2016). The reasons for the feces being green are unknown, but may relate to the unique spiral-shaped caecum.

In southeastern Virginia, Southern Bog Lemmings are part of some small mammal communities but not others, even in appropriate habitats. One reason may be due to its competitive abilities with other species. Evidence that *S. c. helaletes* does not compete well with Meadow Voles was seen in the study in which they and Woodland Voles (*Pitymys pinetorum*) were co-dominants in a regenerating pine plantation in the absence of Meadow Voles (Rose & Ford, 2012). After mature pines were logged on the site, located 2 km west of the Refuge in Suffolk, the stumps and logging debris were bulldozed into parallel windrows about 40 m apart. Loblolly pine seedlings were mechanically planted in the peaty soils, with furrows between rows that filled with water after heavy rains and for much of the winter. These conditions were tolerated by Southern Bog Lemmings and Woodland Voles, which reached modest densities, but none of the larger herbivorous rodents in the region (Meadow Voles, Hispid Cotton Rats [*Sigmodon hispidus*], and Marsh Rice Rats [*Oryzomys palustris*]) was ever trapped during this 18-month field study in which Fitch live traps (Rose, 1994) were used. We did catch seven Eastern Harvest Mice (*Reithrodontomys humulis*), but none during the last 15 months. In all, we caught and tagged 47 Southern Bog Lemmings, 110 Woodland Voles, and 15 Short-tailed Shrews (*Blarina brevicauda*), resulting in densities of up to 14 Southern Bog Lemmings per hectare on one 0.55 ha grid and 32 Woodland Voles per hectare on the other grid.

In field studies near Blacksburg, Virginia, Linzey (1984) presented evidence, based on removal experiments and patterns of co-occurrence, that *Synaptomys cooperi stonei* is not successful in competition for space with Meadow Voles. In another field study, *S. c. stonei* was a regular occupant of clearings in the 4,450-ha Robinson Forest in southeastern Kentucky until Meadow Voles migrated southward into this region, after which it has largely replaced Southern Bog Lemmings in these forest clearings except when densities of Meadow Voles are low (Krupa & Haskins, 1990). In the New Jersey Pinelands, Shenko et al. (2012) also found populations of Southern Bog Lemmings, primarily in wet grassy areas, in the almost complete absence of Meadow Voles. By contrast, Danielson & Gaines (1987) report that *S. c. gossii* in eastern Kansas shows no evidence of microhabitat selection, and thus is a habitat generalist, being able to survive on the sidelines when the more productive habitat is occupied by more competitive species, such as *Microtus*.

Other studies besides Rose & Ford (2012) also indicate that *S. c. helaletes* does not compete well with Meadow Voles in southeastern Virginia. Of the 38 study grids located in and near the Refuge, the 17 grids with Southern Bog Lemmings (n = 102) yielded only two Meadow Voles (Everton, 1985; Rose, 2006). In Isle of Wight County, either Meadow Voles or Southern Bog Lemmings were present on 12 of 14 grids but both species were found on only three grids (Rose, 2005), and when the latter species was present, only 1-2 Meadow Voles were trapped. In general, when Southern Bog Lemmings are present, Meadow Voles usually are not. For example, Everton (1985) caught lemmings on 11 grids, but only one Meadow Vole in these wet sites. Thus, mounting circumstantial evidence is accumulating that Southern Bog Lemmings in Virginia do not compete well with Meadow Voles, to the point that they are absent in habitats with many Meadow Voles and thrive only in their absence.

Additional information on their habitats in southeastern Virginia is provided by field studies in pine plantations in Isle of Wight County (Dolan & Rose, 2007), where *S. c. helaletes* was absent in stands of ages 1, 8, 18, and 24 years: none was caught on 56 0.25-ha grids despite 39,600 traps 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 eight of 14 grids set in the more varied habitats under powerlines (Rose, 2005).

Even in appropriate habitat and in the absence of Meadow Voles, Southern Bog Lemmings have patchy distributions. But when they are present, they often are among the most numerous small mammal in that community (Rose, 2006). In a pitfall study conducted in and near the Refuge, Southern Bog Lemmings were present in 17 of 21 0.25-ha grids, and lemmings (n = 102) were second in abundance to Southeastern Shrews, *Sorex longirostris* (n = 114) on those 17 sites (Everton, 1985; Rose, 2006).

Synaptomys cooperi helaletes often does not readily enter live traps. For example, Rose & Stankavich (2008) observed that latrines with green feces were common but Southern Bog Lemmings were not trapped until the 10th month of biweekly live trapping in the Dismal Swamp; then 13 different lemmings were tagged over the next few weeks. Linzey (1984) had such low recapture success after a year of trapping Southern Bog Lemmings with small Sherman traps that she used unbaited dropping boards to determine relative abundance and spacing patterns thereafter. I believe that *S. c. helaletes* is more prone to entering live traps during winter, perhaps finding the mixed seed baits worth the risk of

entering Fitch live traps then but not at times when their energy requirements are more easily met. The patchy distributions and reluctance of Southern Bog Lemmings to enter live traps inhibit efforts to understand their role in rodent communities in southeastern Virginia.

In January and February of 2011, I tested the idea that green feces could be used to accurately predict the presence of *S. cooperi* (Rose, 2011). I carefully searched 27 sites across Southampton, Sussex, and Surry counties in southeastern Virginia, places with grassy and sedge habitats suitable for Southern Bog Lemmings but beyond their known distribution. I spent 1-3 hours at each site, and detected latrines with green feces at 10 sites, indicating their possible presence. Then I placed baited Fitch live traps at five of these 10 sites, and in two nights of trapping caught four Southern Bog Lemmings at three of these sites, confirming that green feces are a good predictor of their presence. In late June 2014, I applied the same methods to determine whether the two isolated subspecies in the Midwest were still present. After spending a day searching for green feces at each of the localities in Kansas and Nebraska where the isolated subspecies of *Synaptomys cooperi* had been discovered, I found no evidence for *S. c. paludis* at the fish hatchery near Meade, Kansas, but multiple evidences of *S. c. relictus* at and especially downstream from the fish hatchery near Parks, Nebraska.

From 2002 to 2012, my students and I conducted monthly live trapping on 1-ha grids to evaluate the small mammal communities at two sites in southern Chesapeake. These old fields were dominated by grasses that had vegetated abandoned farm fields, mostly bluestem (*Andropogon virginicus*) and panic grasses (*Panicum* spp.), plants that Everton (1985) reported having the highest total contacts in association with the presence of Southern Bog Lemmings. Some places on the grids were wet and harbored clumps of soft rushes, spikerushes, and wool grass (*Scirpus cyperinus*). Meadow Voles were common on both grids, reaching high densities of ca. 50/ha on one grid and over 150/ha on the other, and hispid cotton rats were common too, but in all of these years of trapping we never caught any *S. c. helaletes.* I believe this is the strongest evidence, together with Rose & Ford (2012), that the lemming populations cannot persist with populations of Meadow Voles. Despite one or two individuals of each species sometimes being taken on the same pitfall grid, in general, if *S. c. helaletes* is present, Meadow Voles usually will be absent. It is entirely circumstantial evidence for *S. c. helaletes*, but studies over the years have increasingly supported that contention.

BEHAVIOR

I have found the Southern Bog Lemming to be more docile than most rodents, and easily handled after removal from live traps. When placed in the bottom of a bucket, it is more likely to sit on its haunches, "rest," or nibble on seeds rather than to "run laps" around the perimeter, as most rodents do at first capture. By contrast, a Meadow Vole of similar size often will sit on its haunches, raise its snout skyward while baring its teeth and squeak, in an aggressive posture.

It is unclear whether Southern Bog Lemmings make and maintain runways, as many arvicoline rodents do, but they do leave the characteristic piles of clippings and use latrines, usually along runways. The discarded clippings have diagonal cuts on the ends, and average 3-4 cm for Southern Bog Lemmings, similar lengths to those cut by Meadow Voles but shorter by half compared to Cotton Rat cuttings. The cuttings of the lower sections of grasses and sedges are discarded, probably because they are more fibrous and less nutritious, and seemingly only the upper sections and their seeds are consumed. We can imagine a Southern Bog Lemming sitting on its haunches, cutting, discarding, repeating both many times, and finally consuming the younger, fleshier and (probably) more nutritious upper sections and seeds of grasses and sedges, all the while sitting at the base of a clump of grass or sedge, mostly protected from view by birds of prey.

The blunt appearance of the snout is accentuated when the facial hairs are directed forward. The placement and function of these vibrissae is not entirely understood in mammals but undoubtedly relates to collecting information on their closest environment, where their senses of touch and smell likely become more important than vision.

REMARKS

The reasons for the isolation of *Synaptomys cooperi* populations being sufficiently long for them to have diverged to become subspecies remain enigmatic, although the speculation that persistence and divergence are related to consistent or reliable water sources, whether springs (in Kansas and Nebraska) or swamps (in Virginia and New Jersey), is plausible. Equally in need of explanation is how *S. c. gossii*, the Midwest subspecies, became adapted to life in the mesic-to-xeric grasslands of Kansas and Illinois, where thriving populations have been studied extensively. Further, the Midwest subspecies seems to be readily trappable, in

contrast to the isolated population in New Jersey, where Connor (1959) caught only 48 Southern Bog Lemmings in his four-year field study using Sherman traps. Linzey (1984) ceased trapping in western Virginia after one year in favor using dropping boards, and Rose & Stankavich (2008) observed the characteristic green feces in southeastern Virginia for nearly a year before the first lemming was trapped.

In conclusion, except for its smaller size, *Synaptomys cooperi helaletes,* the Southern Bog Lemming of southeastern Virginia, is typical in many ways to the other subspecies that have been studied in other regions. In the absence of its apparently competitive superior, the Meadow Vole, it can reach densities as high as 14 per hectare. Found mostly in damp habitats dominated by grasses and sedges, its distribution is patchy but when present, it often is one of the 2-3 most numerous species taken in pitfall traps at a site. Often difficult to catch in live traps, its presence can be detected because of its habit of depositing distinctive green feces in latrines along runways. Formerly believed to be restricted to the Great Dismal Swamp of southeastern Virginia, the distribution of *S. c. helaletes* now extends westward to include locations in western Sussex and Surry counties.

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