

**Sorex cinereus.** By John O. Whitaker, Jr.

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***Sorex cinereus* Kerr, 1792**

Masked Shrew

- Sorex arcticus cinereus* Kerr, 1792:206. Type locality “Fort Severn, Ontario.”
- Sorex personatus* I. Geoffroy St.-Hilaire, 1827:122. Type locality “eastern United States.”
- Sorex forsteri* Richardson, 1828:516. Type locality “Hudsons Bay Countries.”
- Sorex cooperi* Bachman, 1837:388. Type locality “North Western Territory.”
- Sorex fimbripes* Bachman, 1837:391. Type locality “Drury Run, Pennsylvania.”
- Otiosorex platyrhinus* De Kay, 1842:22. Type locality “Tappan, Rockland Co. New York.”
- Amphisorex lesueurii* Duvernoy, 1842:33. Type locality “Wabash River Valley, Indiana.”
- Sorex acadicus* Gilpin, 1867:2. Type locality “Nova Scotia, assumed to be near Halifax, Halifax Co.”
- Sorex idahoensis* Merriam, 1891:32. Type locality “Timber Creek 8,200 feet, Salmon River Mts. [Lemhi Mountains], Lemhi Co., Idaho.”
- Sorex personatus streator* Merriam, 1895:62. Type locality “Yakutat, Alaska.”
- Sorex miscix* Bangs, 1899:15. Type locality “Black Bay, Labrador.”
- Sorex frankstounensis* Peterson, 1926:292. Type locality “Frankstown Cave, near Holidaysburg, Blair Co., Pennsylvania.”

**CONTEXT AND CONTENT.** Order Insectivora, family Soricidae, subfamily Soricinae. Seventy species were recognized in the genus *Sorex* by Wilson and Reeder (1993). Some taxa that were considered in *Sorex cinereus* but are recognized as separate species (Wilson and Reeder 1993) are *camtschatiaca* Yudin, 1972; *haydeni* Baird, 1857; *jacksoni* Hall and Gilmore, 1932; *leucogaster* Kuroda, 1933; *portenkei* Stroganov, 1956; and *ugyunak* Anderson and Rand, 1945. *Sorex fontinalis* Hollister, 1911, was considered as a subspecies of *S. cinereus* by Wilson and Reeder (1993), although Kirkland (1977a) found that these taxa overlapped in southeastern Pennsylvania, apparently without interbreeding, and resurrected *fontinalis* as a separate species. George (1988) also supported separation of *cinereus* and *fontinalis*, on the basis of allozyme data, and I tentatively recognize them as separate here. *Sorex milleri* Jackson (1947) from Coahuila and Nuevo Leon, Mexico, was considered as a separate species by Findley (1955). *S. milleri* may be a relict population of *S. cinereus* that has not attained specific status (van Zyll de Jong and Kirkland 1989), but quantitative evidence shows *S. milleri* differ morphologically from *S. cinereus* (van Zyll de Jong 1991). The 8 subspecies of *S. cinereus* recognized are as follows:

- S. c. acadicus* Gilpin, 1867:2, see above.
- S. c. cinereus* Kerr, 1792:206, see above (*cooperi* Bachman, *fimbripes* Bachman, *forsteri* Richardson, *frankstounensis* Peterson, *idahoensis* Merriam, *personatus* I. Geoffroy St.-Hilaire, and *platyrhinus* De Kay are synonyms.)
- S. c. hollisteri* Jackson, 1925:17. Type locality “St. Michael, Alaska.”
- S. c. lesueurii* (Duvernoy, 1842:33), see above.
- S. c. miscix* Bangs, 1899:15, see above.
- S. c. nigriculus* Green, 1932:387. Type locality “alluvial tidewater marsh on Tuck River, E. Tuckahoe, Cape May Co., New Jersey.”
- S. c. ohionensis* Bole and Moulthrop, 1942:89. Type locality “Hunting Valley, Cuyahoga Co. Ohio.”
- S. c. streator* Merriam, 1895:62, see above.

*Sorex c. ohioensis* is transitional between *S. c. cinereus* and *S. c. lesueurii*, so may not represent a valid subspecies (van Zyll de Jong and Kirkland 1989). No primary isolating mechanisms separate the other 8 subspecies; thus, Whitaker (1970) and Whitaker and Hamilton (1998) question the rest of the subspecies.

**DIAGNOSIS.** *Sorex cinereus* (Fig. 1) is most similar to *S. fontinalis*, *S. haydeni*, and *S. longirostris*. *S. cinereus* is distinguished from *S. longirostris* by having a longer thicker tail, a longer thinner rostrum (ratio of greatest rostral width, the width measured across the rostrum from outside 1st large molariform teeth with the length measured as the distance from posterior end of palate to anterior end of I1 is <2.0), and pigmentation of inner ridges of upper unicuspid. Unicuspid 3 and 4 are usually subequal in size in *S. cinereus* (Fig. 2), whereas the 3rd unicuspid is usually smaller than the 4th in *S. longirostris*, and the 4th unicuspid is often, but not always, larger than the 3rd in *S. fontinalis*. *S. cinereus* is distinguished from *S. haydeni* by its darker brownish color and longer tail with more tuft.

**GENERAL CHARACTERS.** *Sorex cinereus* is a small, brown, long-tailed shrew usually silvery beneath. Snout is long and pointed. Tips of teeth are chestnut, including inner ridges of upper unicuspid. Males and females are larger in northeastern part of range, along coast in Pacific Northwest in the United States and in central Canada, than animals in more southern latitudes (Huggins and Kennedy 1989). Mean measurements (in mm) with ranges in parentheses for 151–161 adults from Vigo County, Indiana (French 1980) are total length, 89.7 (83–100); length of tail, 35.6 (29–41); length of hind foot, 11.47 (10.5–12.5); condylobasal length, 15.22 (14.3–16.1); cranial breadth, 7.48 (7.10–7.90); maxillary breadth, 4.26 (3.80–4.55); interorbital breadth, 2.99 (2.70–3.20); palatal length, 6.2 (5.7–6.6); cranial height, 4.94 (4.3–5.5); length of maxillary toothrow, 5.6 (5.2–5.9); length of I1, 1.44 (1.2–1.7); length of i1, 2.89 (2.48–7.10). Body mass of 82 adults is 3.63 g (2.5–6.0). Similar or slightly larger measurements were given for *S. cinereus* from Alaska (Hoffmann and Peterson 1967); Athabasca region of northern Canada (Preble 1908); Yukon (Youngman 1975); Sherburne County, Minnesota (Bailey 1929); Brown’s Peak, Wyoming (Long 1965); Rexville, Ripley County, Indiana (Lindsay 1960); Ohio (Opper et al. 1988); southwestern Pennsylvania (Grimm and Roberts 1950); and Missouri (Easterla and Damman 1977). Still larger measurements were given for *S. cinereus* from Newfound Gap, Clingman’s Dome, Tennessee (Linzey 1995); Adirondack Mountains (Harper 1929); Otsego and Schoharie counties (Connor 1960); Tug Hill Plateau (Connor 1966); and Long Island, all in New York (Connor 1971). The mean  $\pm$  SE mass of 22 male and 24 female *S. cinereus* from several localities was  $4.2 \pm 0.1$  g and  $4.4 \pm 0.2$  g, respectively (Innes 1994). Mean measurements (in mm) with ranges in parentheses for 23 males and 22 females from



FIG. 1. Adult female *Sorex cinereus* from Ithaca, New York. Photograph by Douglass Payne.

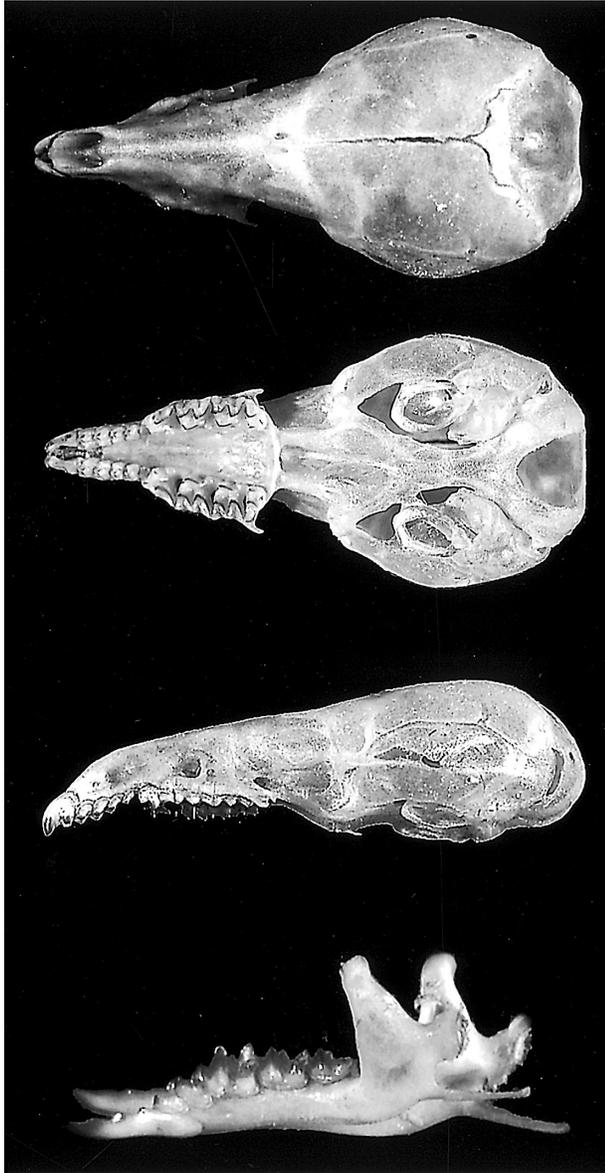


FIG. 2. Dorsal, lateral, and ventral views of cranium and lateral view of mandible of adult female *Sorex cinereus* (Indiana State University ISU catalog no. 5154). Greatest length of skull is 15.1 mm.

spruce-fir forest between Newfound Gap and Clingmans Dome, Tennessee (Linzey 1995), were, respectively, total length, 102.2 mm (89–114), 99.6 (89–113); length of tail, 44.5 (40–48), 44.4 (40–50); length of hind foot, 11.9 (7–13), 12.2 (8–13); and body mass 4.1 g (3.0–5.9), 3.97 g (3.1–5.6). Body masses (in g) for *S. cinereus* from Maine (Palmer 1947) are 4.7 (4.4–4.8,  $n = 7$  adult males), 5.1 (3.1–6.6,  $n = 7$  adult females), 3.4 (2.9–3.9,  $n = 10$  subadult males), and 3.3 (3.2–3.4,  $n = 5$  subadult females). Body mass averaged 4.15 g in 93 individuals (Merritt 1995).

**DISTRIBUTION.** *Sorex cinereus* occurs throughout Alaska and most of mainland Canada from British Columbia to Labrador (but not Prince Edward Island) and south through most of Washington, Idaho, central Utah, and Colorado into northcentral New Mexico, east through Wyoming and most of Nebraska, Iowa, northern Illinois, and most of Indiana and Ohio and south through the Appalachian Mountains to northeast Georgia and on the East Coast south to northern Maryland and New Jersey (Fig. 3). *S. cinereus* is present in eastern Siberia according to Hoffmann (1971) but not Wilson and Reeder (1993). In addition, it was introduced into Newfoundland specifically to control the larch sawfly, *Pristiphora er-*

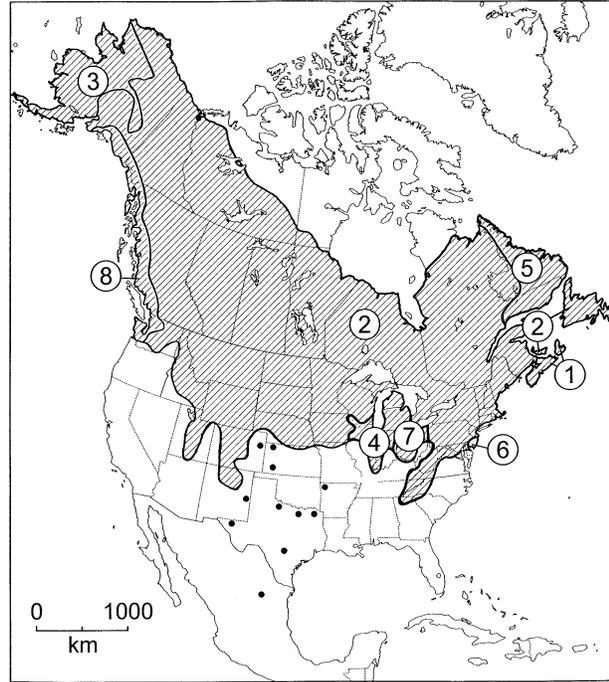


FIG. 3. Distribution of *Sorex cinereus* in North America. Subspecies are 1, *S. c. acadicus*; 2, *S. c. cinereus*; 3, *S. c. hollisteri*; 4, *S. c. lesueurii*; 5, *S. c. miscix*; 6, *S. c. nigriculus*; 7, *S. c. ohionensis*; and 8, *S. c. streatori* (modified from Hall 1981). Dots indicate some fossil records outside the present range (Kurtén and Anderson 1980; FAUNMAP Working Group 1996).

*ichsonii* (Buckner 1955; MacLeod 1960). It occurs throughout much of Pennsylvania (Merritt 1987; Roberts and Early 1952).

**FOSSIL RECORD.** The earliest definite record of *S. cinereus* is late Blancan (Pliocene), from the White Rock fauna, Republican County, Kansas (Eshelman 1975; Kurtén and Anderson 1980). *S. cinereus* has been found in several Rancholabrean faunas, including some in and some outside its present range. This species is common in many fossil sites in or near its present range, as summarized by Kurtén and Anderson (1980) and Faunmap Working Group (1994). The Pleistocene range of *S. cinereus* was greater than its present range. During the early Rancholabrean, it was found (often associated with *Microtus pennsylvanicus* and sometimes *Synaptomys cooperi*) in areas far to the south of its present range (Fig. 2; Faunmap 1994; Kurtén and Anderson 1980), with 1 locality in Mexico (Findley 1953). *S. cinereus* and other northern forms mostly disappeared from Texas ca. 40,000–45,000 years ago during the Sangamon interglacial period.

**FORM AND FUNCTION.** *Sorex cinereus* is among the world's smallest homeothermic mammals. Extreme physiological values include metabolic rate of 30.0 ml O<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>, heart rate of 1,320 beats/min, and respiration rate of 1,080 breaths/min (Morrison et al. 1959). Heart rate averaged 780 beats/min (and generally ranged from 630–1,000), and respiration rate averaged about 800 breaths/min (Morrison et al. 1959). Metabolism, as indicated by oxygen consumption, varied but averaged 9.0 ml O<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup> (Morrison et al. 1959). The role of seasonal changes in resting metabolic rate, nonshivering thermogenesis, thermal conductance, and body mass as they relate to winter survival of *S. cinereus* was examined by Merritt (1995) in the Appalachian Mountains in Pennsylvania, where temperatures at ground level ranged from  $-7^{\circ}\text{C}$  in February to  $22^{\circ}\text{C}$  in April and snow cover was intermittent from November to March. Mean resting metabolic rate was highest in autumn (8.30 ml O<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>) and lowest in spring (5.75 ml O<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>). Mean nonshivering thermogenesis was lowest in summer (8.02 ml O<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>) and peaked in winter (14.60 ml O<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>). Metabolic rates, measured as oxygen consumption over a 24-h period (Pearson 1947) were 16.8 and 14.4 ml O<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup> in 3.41-g and 3.65-g animals, respectively; minimum rates ranged from 10.6 to 13.7 ml

$O_2$   $g^{-1} h^{-1}$ , and maximum rates ranged from 18.9 to 21.5 ml  $O_2$   $g^{-1} h^{-1}$  ( $n = 4$ ). Metabolism tended to rise and fall in a cycle of ca. 1.5 h.

Mean body temperature is 38.8°C (range, 36.1–40.9°C). When handled or excited, body temperature rises to above 41°C and plateaus (Morrison et al. 1957) without ill effects.

The ability of *S. cinereus* to survive cold winters is due to its ability to increase thermogenic capacity by nonshivering thermogenesis coupled with energy conservation by reducing mass in winter (Merritt 1995). Shrews lack white adipose tissue and use brown adipose for insulation from cold and as a site for rapid production of energy in the form of nonshivering thermogenesis.

Two adult males and 2 adult females of *S. cinereus* from central Colorado (mean body masses of 4.6 and 5.2, respectively) had mean hemoglobin concentrations of 14.2 and 14.3 g/100 ml and mean hematocrits of 39.5 and 39.9%; mean corpuscular hemoglobin concentration was 35.9 g/100 ml in both sexes (Sealander 1964).

**ONTOGENY AND REPRODUCTION.** *Sorex cinereus* attains near adult size before leaving the nest, well before the onset of reproduction, but body mass initially declines after leaving the nest (Forsyth 1976); thus, body mass cannot be used as a reliable aging criterion. Based on degree of tooth wear and condition of P4, 4 age classes are (French 1980; Pruitt 1954a) juveniles and subadults with unworn or slightly worn teeth; young adults showing some tooth wear; adult or reproductive age animals with moderate tooth wear in their 2nd year; and old adults, in their 2nd year or older, with excessive tooth wear. Young are sexually mature after 2 months, but few individuals breed in their year of birth; most do not breed until the spring after their birth (Cawthorn 1994; Hamilton 1940; Rudd 1955; Teferi et al. 1992). In a longitudinal study of *S. cinereus* in Manitoba (Buckner 1966), 28 of 61 females bred once, 8 twice, 17 three times, 2 four times, and 6 five times. Of the 33 that bred  $\geq 2$  times, 13 did so in their 1st and 2nd years of life.

During a masked shrew irruption, 10 pregnant females were caught, none of which normally would be considered adults (Buckner 1966). Seven "subadults" averaged 3.0 young (1–5), and 3 "juveniles" had 1–2 embryos.

New juveniles seldom appear before June and are usually not found later than September. In late spring and in summer, 2 age classes may be present, young individuals (subadults) and adults; but because of rapid growth of young, measurements may overlap so much as to negate differences. Populations in July and August are dominated by juveniles, and autumn and winter populations consist primarily of young of the year that overwinter as subadults. Most overwintered adults breed and then die before autumn. In late winter and early spring, all individuals are essentially 1-year-old adults. Few individuals live beyond ca. 16 months, but a lactating shrew found 15 October 1959 in Michigan was estimated by Rudd's (1955) aging criteria to be ca. 24–30 months old.

Nests of *S. cinereus* under unused wooden rabbit traps in Champaign County, Ohio (Forsyth 1976), consisted of balls of woven dry grass ca. 4–6 cm outside diameter, with an inside opening 2–3 cm in diameter ( $n = 9$ ). Leaves, often of *Crataegus*, or plastic film lined the nests. Nests were in concavities with 2 exit tunnels.

Average litter size for pregnant *S. cinereus* ranges from 4.2 ( $n = 6$ —Gifford and Whitebread 1951) to 9.5 ( $n = 15$ , taken in June—Innes et al. 1990) but usually is 6–7 embryos. In a pooled sample of 31 litters, average litter size was  $6.5 \pm 0.3$  SE (Innes 1994).

Newborn body mass is  $0.28$  g  $\pm$  0.02 SE ( $n = 15$ ), and length of crown to rump is 12–14 mm. Neonatal skin is transparent, hairless, and dark pink dorsally. Liver, intestines, and stomach are visible through abdominal wall. Skull sutures, superficial blood vessels, and black eye rings are visible through the skin. Claws are absent. Toes are fused throughout their length. Umbilicus is  $\leq 1$  mm. Eyes and ears are sealed. Ear pinnae are fused to head, and sides of mouth are sealed about halfway from corners. Neonates exhibit feeble kicking movements but are not able to crawl. Vibrissae, which 1st appear ca. day 2, are 3 mm long by day 7, more than half grown by day 16, and 80% of adult length of 12.5 mm at day 20. Gray pigmentation appears in dorsum and lower limbs at 5–6 days and increases progressively. Guard hairs, which appear as fine pubescence at ca. day 8, are black on dorsum and white on abdomen; tail is bicolored. Underfur erupts on day 11, and pelage

appears adult-like by day 20. Hair pencil on tail is barely visible at day 11 but is 2 mm at 15 days and is adult length (3–5 mm) at 20 days. Claws 1st appear about day 2 and are adult length by 16–17 days. Digits appear webbed rather than fused by day 9 but are completely free by days 15–16. Upper and lower incisors erupt on days 13–14. Ears open at 14–17 days, and eyes open at 17–18 days. In response to disturbance, young emit a few chirps at 5–8 days, are quite vocal and produce squeaks by day 12, but are less vocal by day 18, when their vocal behavior is similar to that of adults. Body mass peaks at 20 days, declines to subadult mass before young leave the nest at ca. 27 days of age, then increases to adult mass (Forsyth 1976). Young shrews observed by Pruitt (1954b) rarely tried to leave the nest even when they reached adult size (2.9–3.4 g).

Mean (range and sample size in parentheses) measurements for lengths of hind foot and tail (in mm) and body mass (in g), respectively, of nestlings at various ages (Forsyth 1976) are birth: 2.7 (2.5–3.0,  $n = 5$ ), 3.2 (3.0–3.5,  $n = 5$ ), 0.28 (0.23–0.36,  $n = 15$ ); 8 days: 7.1 (7.0–7.5,  $n = 7$ ), 12.9 (12–13,  $n = 11$ ), 2.1 (2.1–2.2,  $n = 7$ ); and 20 days: 11 (no variation,  $n = 5$ ), 32.6 (31–35,  $n = 5$ ), 3.5 (3.5–3.6,  $n = 6$ ).

Pregnant and lactating females usually occur from late April to August (Innes 1994). Males with enlarged testes are sometimes found as late as early October (Buckner 1966; Connor 1966, 1971).

**ECOLOGY AND BEHAVIOR.** The masked shrew inhabits a great range of habitats, including arid grasslands, moist areas, various kinds of woodlands, and tundra. The specific localities within these habitats with masked shrews are usually moist and often include mosses. *S. cinereus* did not breed in an upland hardwood community in dry years and may entirely abandon that habitat in excessively dry years (Anderson 1981). Masked shrews may be expected in nearly any terrestrial environment in Michigan (Baker 1983; Getz 1961). It was the most prevalent shrew in Manitoba (Wrigley et al. 1979), where it was captured in 29 of 30 habitats over 9 years; the greatest numbers were generally in the more moist habitats as follows (with parenthetical sample size): hydric: grass sedge marsh (216), willow–alder fen (147), heath moss bog (50), black spruce–tamarack swamp (37), tamarack swamp (29), and sedge–moss bog or tundra (28); mesic: alder–willow shrub (93), white cedar forest (88), mixed-grass prairie (74), white spruce (poplar) forest (65), black spruce forest (57), aspen (balsam poplar) forest (56), spruce–fir–birch forest (53), white spruce tamarack tree-line savanna (45), aspen–oak–spruce forest (33), elm–maple–ash forest (33), disturbed meadow (23), tallgrass prairie (18), maple–ash–cottonwood–willow beach-ridge forest (16), and marine beach grass (5); and xeric: dry shrub (26), mixed-grass prairie (sand) (12), jack pine–aspen forest (10), opportunists and pioneers (sand) (9), oak–aspen (spruce) savanna (4), red pine–jack pine–birch forest (3), black spruce forest (2), white spruce forest (2), black spruce–lichen woodland (1), and jack pine–lichen woodland (0).

Numerous masked shrews were found in the Ungava Bay Region of far northern Quebec at the same time as a meadow vole (*Microtus pennsylvanicus*) outbreak (Hildebrand 1949). *S. cinereus* was found in southern Quebec in mature deciduous and coniferous woods with thick leaf mold (Wrigley 1969) and in the Yukon in almost every habitat from 235 to 1,250 m elevation, from stabilized talus to wet mossy areas (Youngman 1975). *S. cinereus* was common on the taiga but not on the tundra in Northwest Territories (Martell and Pearson 1978). In the southern Appalachian Mountains, masked shrews were in mesic or even nearly hydric 2nd-growth oak–chestnut forest (Moore 1949). *S. cinereus* is restricted to higher elevations near the southern limits of its range (Moore 1949). It was in a variety of habitats in Otsego and Schoharie Counties, New York (Connor 1960), and up to 1,540 m in the Adirondack Mountains of New York (Harper 1929).

Masked shrews were found in almost every habitat in the Rocky Mountains in Wyoming (Brown 1967); on Tug Hill Plateau in New York (Connor 1966); Long Island, New York (Connor 1971); and Pennsylvania (Grimm and Roberts 1950; Merritt 1987; Richmond and Rosland 1949; Rosland 1951). They are probably most abundant in cool moist woodlands especially at high elevations (Grimm and Whitebread 1952) in northeastern Pennsylvania (Grimm and Roberts 1950; Grimm and Whitebread 1952) and at high elevations also in Virginia (Pagels et al. 1994). In much of western Pennsylvania, optimum habitat for masked shrews was cool moist rocky forests along with *S. fumeus*, but it was also in hot dry

abandoned fields of broomsedge (*Andropogon virginicus*) as well as in wetter grasslands in western Pennsylvania (Gifford and Whitebread 1951). Eleven masked shrews were captured in southeastern Montana, all in riparian situations (MacCracken et al. 1985). Masked shrews were captured in the Pisgah National Forest of western North Carolina (Brannon 2000) in association with high litter moisture, coarse woody debris, and small invertebrates.

*Sorex cinereus* was abundant in jack pine (*Pinus banksiana*) plantations in northern Ontario in the same year that numerous budworms (*Charistoneura pinus*) occurred (Innes et al. 1990), and they were more abundant and produced slightly larger litters and heavier young in 40-year-old stands than in younger stands.

No *S. cinereus* was captured in an Adirondack mine site in New York (Kirkland 1976) that was relatively barren, containing little soil and much bare rock, whereas 33 masked shrews were taken in adjacent woods. In uncut stands of deciduous and coniferous forest, *S. cinereus* was trapped at rates of 0.21 and 0.86/100 trap-nights (Kirkland 1977b). In clear-cut areas, it was trapped at rates of 0.94, 0.33, and 0.33 in deciduous forest cut <5 years, 6–15 years, and 16–25 years, respectively, and at rates of 2.12 and 1.21 in coniferous forest cut <5 and 6–15 years, respectively.

At 10 study sites at high elevations (1,082–1,524 m) in Virginia, *S. cinereus* ( $n = 388$ ) was the most abundant (89.4%) of 6 species of shrews (Pagels et al. 1994). All sites had red spruce (*Picea rubens*), an indicator of boreal habitat. Masked shrews were positively associated with soil moisture-holding capacity, soil organic matter, and total understory vegetation, all contributing to a moist habitat. Moisture and the shade that helps maintain moisture were the most important environmental factors favoring occurrence of short-tailed and masked shrews (Getz 1961; Pruitt 1953, 1959). Shrews with *S. cinereus* in Manitoba were *Blarina brevicauda* (197 individuals), *Sorex arcticus* (167), *S. palustris* (130), *S. hoyi* (20), and *S. monticolus* (12) along with red-backed voles (*Clethrionomys gapperi*), meadow voles, and deer mice (*P. maniculatus*—Wrigley et al. 1979). The masked shrew was the 3rd most abundant small mammal after *M. pennsylvanicus* and *B. brevicauda* in damp marshy areas of Goose Lake Prairie, Grundy County, Illinois (Birkenholz 1973).

In Otsego and Schoharie counties, New York, red-backed voles, other microtines, and jumping mice (*Zapus*, *Napaeozapus*) were associates of masked shrews (Connor 1960). Associated species at high elevations in Virginia were *B. brevicauda*, *Cryptotis parva*, *S. dispar*, *S. fumeus*, and *S. hoyi* (Pagels et al. 1994).

Because of their diminutive size, shrews use a strategy of feeding at frequent intervals throughout day and night. They can survive only a few h without feeding. Active periods alternate with rest periods during which they may exhibit depressed metabolic rates. *S. cinereus* was active ca. 217 min during ca. 19 foraging bouts throughout the 24-h period (Buckner 1964a). Average amount of food consumed by a 3.6-g masked shrew was 11.7 g/day over a 7-day period, or ca. 3.3 times its own mass per day (Blossom 1932), whereas values of 1.27–3.84 g/day (on liver in captivity) were given by Morrison et al. (1957). Feeding bouts on liver occurred at rates up to 17 per h but averaged 4 per h.

The most important foods eaten by masked shrews from several areas were insects 65.3% (Coleoptera and insect larvae most important), vertebrates 7.1% (including salamanders), centipedes 6.8%, worms 4.3%, mollusks 1.4%, sowbugs 1.2% in eastern United States and Nova Scotia ( $n = 62$ —Hamilton 1930); lepidopterous larvae 17.2%, coleopterous larvae 11.9%, slugs and snails 10.9%, spiders 9.0%, and Gryllidae 8.1% in Indiana ( $n = 50$ —Whitaker and Mumford 1972); spiders 28.8%, lepidopterous larvae 24.4%, adult Coleoptera 12.9%, larval Coleoptera 5.8%, harvestman 5.1%, centipedes 4.1% in Vigo County, Indiana ( $n = 167$ —French 1984); insects 85.1% (especially insect larvae and Coleoptera), spiders 5.8%, centipedes 2.7%, undetermined invertebrates 4.6%, and vegetation 1.9% in Tug Hill Plateau of New York ( $n = 50$ —Connor 1966); insect larvae 21.9%, spiders 12.6%, slugs and snails 5.8%, adult beetles 4.7%, adult flies 4.6%, adult moths 2.4%, and chinch bugs 2.4% in New Brunswick ( $n = 107$ —Whitaker and French 1984); Gryllidae 30.0%, lepidopterous larvae 28.8%, spiders 10%, Phalangida 10%, earthworms 7.2%, Cicadellidae 5.6%, Rhagionidae 4.4% in Minnesota ( $n = 9$ —Whitaker and Schmeltz 1973); and Chilopoda 48.3%, larval lepidopterans 24.2%, adult lepidopterans 24.2%, and adult dipterans 3.3% in North Carolina ( $n = 6$ —Whitaker et al. 1975). Other food items include the subterranean fungus *Endogone*.

Diet of masked shrews ( $n = 266$ ) in a high-density population on Bon Portage Island, Nova Scotia, was dominated by Diptera, Amphipoda, Araneae, and Coleoptera (Stewart et al. 1989). Numerous littoral amphipods and kelp flies (Coelopidae) indicate that shrews as far as 60 m inland were opportunistically preying on abundant food. The food of 71 masked shrews was compared with the abundance of lepidopterous larvae in a jack pine plantation in northern Ontario over 3 years (Bellocq et al. 1994). Lepidopterous larvae were the most abundant item, ranging from 51.5% to 81.8% of volume. The next most abundant items eaten were spiders and beetles. Juveniles ate a higher proportion of lepidopterous larvae than did adults. Of 10 items offered to masked shrews, relative preference was flies, lepidopterous larvae, spiders, hemipterans, and beetles; ants were avoided (Bellocq and Smith 1994).

In captivity, masked shrews preferred crickets to grasshoppers and either to beetles (Schmidt 1931). When they encountered a dead small mammal, they chewed a small hole in its side or back through which they ate the viscera.

*Sorex cinereus* preys on the larch sawfly, *Pristiphora erichsonii*, in eastern Manitoba (Buckner 1955, 1964a). Masked shrews were introduced to control the larch sawfly in forests in Newfoundland. *S. cinereus* is not native to Newfoundland but occurs in forests on the adjacent mainland. Initial attempts were unsuccessful, but in September 1958, 22 masked shrews (10 males, 12 females) from the Green River Watershed of northwestern New Brunswick (Warren 1970) were released near St. Georges, Newfoundland. In 1959, 130 masked shrews were caught in pitfalls set near the release site, including 11 of the original stock. Six females were pregnant (mean number of embryos = 7.8 compared to 7.2 over the range of the species—Jackson 1928). By 1973, *S. cinereus* was distributed throughout the island (Clark 1973), and the 1974 annual report of the Forest Insect and Disease Survey stated that the larval population of the larch sawfly was low in most parts of Newfoundland.

A masked shrew in Wisconsin (Komarek 1932) quickly killed and ate most of a grasshopper that was nearly as large as the shrew. Masked shrews were implicated as predators of eggs in a solitary vireo's nest in a vine maple tree (*Acer circinatum*—Horvath 1965).

After spraying with *Bacillus thuringiensis*, fewer adult male and more juvenile masked shrews were found in treated than control jack pine plantations (Bellocq et al. 1992). Caterpillars and spiders were the 2 most important foods eaten. After treatment, caterpillar consumption more than doubled in the control area, whereas it declined by 30% in the treated area.

Masked shrews are most active in moist weather and on nights with increased cloud cover and rain (Doucet and Bider 1974; Vickery and Bider 1978). Activity increases with increased temperature, but this effect is overridden by rain. Masked shrew activity increased or decreased as a result of the corresponding increase or decrease in the mean nocturnal temperature from the previous night.

Although *S. cinereus* is considered nocturnal, diurnal activity has been reported (Komarek 1932; Moore 1949; Quimby 1943; Sheldon 1936). Masked shrews were seen "scudding about" under the leaves at almost any time of day, with movements so rapid that they were difficult to follow (Blossom 1932; Cawthorn 1994; Harper 1929). Masked shrews often disappear under cover, then again emerge. Two captive masked shrews investigated any tiny hole or burrow (Blossom 1932). They pulled on worms until they either pulled them from the ground or pulled them apart. When they met, each stood on its hind legs in a defensive attitude and began to scold with rapid, excited squeaking notes (Blossom 1932). They also produced a rapid series of rather staccato squeaks when agitated, a succession of rapid twittering notes when foraging or feeding, and gritting of the teeth often when resting. When sleeping, masked shrews bent their heads under the body as far as possible. The weight of the body was on the hind feet, and the front feet were slightly elevated.

Masked shrews emit high-frequency pulses (30–60 kHz) of short duration from the mouth (Gould et al. 1964). *S. cinereus* has lateral scent glands that may be used in marking territories or burrows (Pearson 1950).

Masked shrews form a minor component (<1.5%) of the diets of long-eared owls *Asio otus* (Armstrong 1958; Latham 1950; Voight and Glen-Lewin 1978) and barn owls *Tyto alba* (Dexter 1970; Stupka 1931; Wallace 1948, 1950). Masked shrews are more prevalent in the diet of barn owls when voles are scarce (Wallace 1948). Other predators of *S. cinereus* include long-tailed weasel *Mustela frenata*

(Nichols and Nichols 1935), *Blarina brevicauda* (Eadie 1949), leopard frog *Rana pipiens* (Marshall 1951), eastern bluebird *Sialia sialis* (Pinkowski 1974), and brown trout *Salmo trutta* (Baker 1983). House cats (*Felis catus*) capture but do not eat masked shrews (Toner 1956).

Cestodes, *Hymenolepis falculata*, *H. parva*, and *H. schilleri*, occur in *S. cinereus* from Madison, Wisconsin, and *H. parva* in *S. cinereus* from Alaska (Rausch and Kuns 1950). Other internal parasites from *S. cinereus* are hymenolepid cestodes in 91 of 190 masked shrews from Madison, Wisconsin, and *H. falculata*, *H. intricatus*, *H. parva*, and *H. sphenomorphus* from Alaska (Voge and Rausch 1955); cestodes from Iowa (numbers in parentheses refer to number with parasites of 31 examined) are *Hymenolepis falculata* (1), *H. longi* (6), *H. macyi* (2), and *Lineolepis parva* (18); nematodes are *Capillaria maseri* (7) and *Capillaria* (1) from the urinary bladder, *C. rauschi* (1) in the small intestine, *Pseudophysalptera forosana soricina* (3) in the stomach, *Longistriata depressa* (5) in the small intestine, *Capillaria* (1) in the small intestines, and filaroidid metastrongyles (4) in the lungs (Whittrock and Hendrickson 1979). From Indiana, 5 of 113 masked shrews contained mature tapeworms in the intestines, 47 contained immature tapeworms, and 11 contained nematodes; 20 of 170 contained nematodes in the stomach (French 1980). Two shrews had nematodes encysted in the outer wall of the stomach or other membranes of the visceral cavity, *Porrocaecum* encysted subcutaneously (French 1980; Palmer 1947) on the shoulders, and whipworms (*Capillaria*) in the urinary bladder of some individuals (French 1980). *Capillaria plica* was in the urinary bladder of masked shrews from Montreal, Quebec (Bourque 1981), and *C. hepatica* occurred in liver of shrews from Mountain Lake, Virginia (Solomon and Handley 1971).

Twenty-five species of ectoparasites occurred on *S. cinereus* in Vigo County, Indiana (French 1982). The most abundant species was the hypopial glycyphagid mite *Orycteroxenus soricis*. This tiny form, an immature nonfeeding stage, was found on 93% of shrews and averaged >160 per individual. Second most abundant species was *Protomyobia claparedei* (Myobiidae) found on 27.6% of the shrews with an average of 1.2 per host, and another myobiid, *Amorphacarus hengererorum*, was found on 8 of 54 shrews. *Corrodopsylla curvata* is often the most abundant flea on *S. cinereus*.

Other ectoparasitic mites, chiggers, and ticks of *S. cinereus* are (free-living species excluded) Glycyphagidae: *Glycyphagus hypudaei*, *Orycteroxenus soricis*, *Xenoryctes latiporus*, *X. nudus*; Laelapidae: *Androlaelaps fahrenheitsi*, *Echinonyssus talpae*, *Eulaelaps stabularis*, *Haemogamasus ambulans*, *H. liponyssoides*, *Hypoaspis miles*, *Laelaps alaskensis*, *L. kochi*; Myobiidae: *Amorphacarus elongatus*, *A. hengererorum*, *Blarinobia cryptotis*, *B. simplex*, *Protomyobia americana*, *P. claparedei*; Pygmephoridae: *Bakerdania plurisetosa*, *Pygmephorus designatus*, *P. erlangensis*, *P. horridus*, *P. ideii*, *P. islandicus*, *P. moreohorridus*, *P. plurispinosus*, *P. scalopi*, *P. stammeri*, *P. whitakeri*; Psorergatidae: *Psorergates cinereus*; Trombiculidae (chiggers): *Cheladontia ouachitensis*, *Euschoengastia blarinae*, *E. jamesoni*, *E. jonesi*, *E. ohioensis*, *E. peromysci*, *Leptotrombidium peromysci*, *L. nr. peromysci*, *Miyatrombicula esoensis*, *Neotrombicula cavicola*, *N. harperi*; Ixodidae (hard ticks): *Dermacentor variabilis*, *Ixodes angustus*, *I. muris* (Dastyeh et al. 1991, 1992; Drummond 1957; Ewing 1938; French 1978, 1982; Jameson 1948; Keegan 1951; Kok et al. 1971; Lawrence et al. 1965; Mahunka 1975; Moore 1949; Mumford and Whitaker 1982; Rack 1975; Smiley and Whitaker 1979; Timm 1975; Whitaker and French 1982, 1988; Whitaker and Loomis 1978; Whitaker and Lukoschus 1982; Whitaker and Mumford 1972; Whitaker and Pascal 1971; Whitaker et al. 1975, 1982).

Siphonaptera (fleas) reported from *S. cinereus* are *Corrodopsylla curvata*, *C. hamiltoni*, *Ctenophthalmus pseudagyrtis*, *Doratomyia blarinae*, *Epidemia wemmanni*, *Megabothris asio*, *M. quini*, *Monopsyllus wagneri systaltis*, *Nearctopsylla genalis*, *Opirocrostis bruneri*, *Orchopeas leucopus*, *Peromyscopsylla catatina*, *P. hesperomys hesperomys*, and *Rhadinopsylla fraterna* (Amin 1976; Buckner 1964b, 1966; Buckner and Blasko 1969; French 1982; Haas and Wilson 1973; Holland and Benton 1968; Lawrence et al. 1965; Moore 1949; Timm 1975; Whitaker and French 1982, 1988; Whitaker and Lukoschus 1982; Whitaker et al. 1975). A beetle (Coleoptera) reported from *S. cinereus* is Leptiniidae: *Leptinus americana* (Whitaker and French 1988).

Chiggers on *S. cinereus* in Virginia lived in cup-shaped pock-

ets (Moore 1949) that form around the chiggers as they fasten into the skin.

A population of masked shrews had an estimated density of about 10.3/ha in mid-August near Shingleton, Michigan (Verme 1958). At another locality ca. 5 km away, no shrews were taken. In Ohio, 2.5–27 masked shrews were taken per ha (Bole 1939) and 7.6 to 10/ha in white cedar (*Thuja occidentalis*) and black spruce (*Picea mariana*) stands, respectively (Manville 1949). In southwestern Pennsylvania, population density ranged from 3 to 13 masked shrews per ha (Cawthorn 1994). Capture rate of *S. cinereus* in pitfalls was exceedingly high on Bon Portage Island, Nova Scotia (Teferi et al. 1992), with 30–188 animals taken per 3-day trapping session (22–125.3 animals per 100 trap-nights). *S. cinereus* is 1 of the most common and widespread mammals in Manitoba (Wrigley et al. 1979). Of 225 small mammals of 10 species taken in 9 nights at Churchill, 135 were masked shrews; masked shrews accounted for 120 of 749 small mammals of 14 species in 7 nights at Riding Mountain and 97 of 414 small mammals of 14 species in 5 nights along the Souris River south of Brandon. A widespread peak population in northern Ontario occurred during the late summer of 1955 (De Vos 1957), and *S. cinereus* was ca. 5 times more abundant in 1 year in Algonquin Park than in 5 other years (Fowle and Edwards 1955).

Population density fluctuated from 1 to 23 masked shrews per ha during a 7-year study (1952–1958) using live trapping and marking of *S. cinereus* in tamarack bogs at Whiteshell Provincial Park in southeastern Manitoba (Buckner 1957, 1966). In spring, populations were low and almost entirely adults. Juveniles and subadults entered the population in June and July, but peak numbers occurred in August–September and then declined. Population turnover was ca. 2 generations per year for *S. cinereus*. During an irruption in 1957, masked shrews were more excitable and harder to keep alive in captivity, and breeding started earlier and lasted into October. Many animals were observed in daylight, and individuals were found in suboptimum habitat.

Greatest mortality occurred in the first 2 months of life, then declined gradually (Buckner 1966). About 80% of masked shrews died before sexual maturity; the survivors were reduced by ca. 50% over the next 5 months, and most of the generation was gone by 15 months, although 3 individuals lived 17, 19, and 23 months. Mortality was similar in winter and summer. Immigration and emigration may be the chief causes of spring population fluctuations, but neither parasites nor predators appeared to be very important in population dynamics of *S. cinereus* (Buckner 1966).

Four weanlings, captured when ca. 4 weeks old, slept together and, when disturbed, ran from the nest in caravan fashion; each shrew maintained contact with the 1 immediately in front by burying its nose in the hair of that individual, but they did not hold on with the teeth as has been reported for some shrews. By the 3rd day, caravanning could be brought about by passing a shadow across the nest. Caravanning was observed several times a day for 3 days, but then on the 5th day caravanning and the shared nest were abandoned (Goodwin 1979).

Five individuals were caught in 1 afternoon (Tuttle 1964). They were near a round tunnel ca. 2 cm in diameter. The tunnel was excavated and reached a depth of ca. 23 cm. Most of the tunnel was under flat rocks, with only 1 or 2 tunnels leading to each rock. Several side tunnels contained enlargements where fresh orthopteran were stored. Four adult masked shrews were captured near Oxford, Butler County (Opper et al. 1988), in a common burrow system consistent with reports indicating that masked shrews can be gregarious even in the breeding season (Tuttle 1964; Wrigley et al. 1979).

Large and unusual concentrations of masked shrews sometimes occur. At ca. 210 m on the treeless summit at Carver's Gap, Roan Mountain, Carter County, Tennessee, on 2–3 September 1960, ca. 1400 h, shrews, mostly *S. cinereus*, in a relatively small area, were calling back and forth to one another (Tuttle 1964). At times they came together, reared up on their hind limbs, and struck each other in the face until 1 or both fell over, at which time they would usually run from each other and stop calling for several min. The observations were made in 1 small area, but shrews were calling over a much larger area (ca. 900 m<sup>2</sup>). This behavior was observed only once. Rustling on the ground attracted other authors to similar concentrations of shrews that were exceedingly active over a small area (Hieshetter 1972; Vispo 1988; Woolfenden 1959). At all locations, masked shrews were scurrying everywhere, but later ob-

servations turned up no further similar behavior. The shrews in 1 case seemed to be concentrated in a small area with adequate food in an otherwise very dry year and locality (Vispo 1988). Multiple captures indicating that masked shrews were sexually active adults suggested that small aggregations of *S. cinereus* are associated with mating behavior (Maier and Doyle, in press).

Mean home range for *S. cinereus* from Manitoba was 0.55 ha with no relationship to age, habitat, season, or sex (Buckner 1966). Home range size decreased as density increased but without an increase in home range overlap. Masked shrews had little tolerance for other individuals in their home ranges.

**GENETICS.** Karyotype of *S. cinereus* was 1st described for an individual from Ontario (Meylan 1967, 1968). *S. cinereus* has a diploid number of 66 and a fundamental number of 70. A young albino masked shrew was captured in October in Ingham County, Michigan (Husband 1963).

Based on morphometric analysis and protein electrophoresis (Stewart et al. 1993), *S. cinereus* and *S. haydeni* are morphologically distinct but less genetically differentiated within Alberta than populations of *S. cinereus* across Canada. No fixed allele differences occurred among the populations.

*Sorex* is Latin for shrew; *cinereus* is Latin for ash-colored. I thank Thomas W. French and Joseph F. Merritt for their thorough and very helpful reviews of this account.

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