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Identification and Distribution of Masked and Hayden's Shrews (genus *Sorex*) in Iowa

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Masked shrews (*Sorex cinereus*) and Hayden's shrews (*Sorex haydeni*) are both reported from Iowa, but the two species are difficult to tell apart and their relative distributions in Iowa have been unclear. We took 13 skull measurements and examined 2 qualitative features on more than 300 specimens of *Sorex* from Iowa. The vast majority of our specimens could be identified easily by cranial measurements, and more than half could be identified by the relative position of the maxillary plate. We found no evidence for intergradation between the two species. Masked shrews are present throughout most of Iowa, whereas Hayden's shrews are restricted largely to the western half of the state. Although Hayden's shrew is found mainly in areas of Iowa where grasslands predominate, we could not identify any clear habitat associations for the two species. Hayden's shrew may reach the eastern limits of its range in the grassland areas of northeastern Iowa.


Two species of long-tailed shrews presently occur in Iowa, the masked shrew (*Sorex cinereus*) and Hayden's shrew (*Sorex haydeni*). A third species, the pygmy shrew (*Sorex hoyi*), is known from Clay County in north central Iowa (Scott 1939) but is now considered extirpated (Bowles 1975, 1981, Bowles et al. 1998).

Until recently, most mammalogists considered Hayden's shrew to be a prairie subspecies of the widely distributed masked shrew, with Iowa in the zone of subspecies transition. For example, Jackson (1928) referred specimens from northwestern Iowa to *S. cinereus haydeni* and specimens from northeastern Iowa to *S. cinereus cinereus*. Scott (1937) followed Jackson in this interpretation and thought that the two forms met in Hamilton County in central Iowa. Hall and Kelson (1959) also considered *Sorex* from northwestern Iowa to be *S. c. haydeni*, but they followed Bole and Moulthrop (1942) in applying the name *S. c. leucurus* to specimens from northeastern Iowa.

In contrast, Bowles (1975) found no consistent morphological differences between long-tailed shrews from eastern and western Iowa and concluded that only one taxon was present, which he tentatively identified as *S. c. haydeni*. However, he noted that specimens from Adams and Union counties in southwestern Iowa had shorter and broader skulls than specimens from other areas of the state, and he suggested that these individuals might represent something different. Hall (1981) followed Bowles in assigning Iowa specimens of *Sorex* to *S. c. haydeni*.

These traditional interpretations were challenged by van Zyll de Jong (1976, 1980), who found consistent morphological and ecological differences between the two forms. In van Zyll de Jong's specimens, the rostrum was consistently longer and narrower in *cinereus* than in *haydeni*, and many cranial measurements had bimodal distributions. He also noted two qualitative differences: 1) the anterior edge of the maxillary plate generally was posterior to the mesial

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of the first upper molar in *cinereus* but anterior in *haydeni*, and 2) the first lower incisor usually was less intensely pigmented in *cinereus* than in *haydeni*. In addition, he found consistent habitat differences, with *haydeni* occurring in grasslands and *cinereus* occurring in more forested areas. These morphological and ecological differences were interpreted as indicating reproductive isolation, and van Zyll de Jong (1980) suggested that *haydeni* be recognized as a distinct species. Likewise, van Zyll de Jong and Kirkland (1989: 118) concluded that "the considerable morphological divergence between *haydeni* and the forms of *cinereus*, and evidence for absence of intergradation in contact zones, provide ample confirmation for specific status of *haydeni* and *cinereus*." Subsequent studies have supported this conclusion (van Zyll de Jong 1991, Foresman and Jensen 1992, and Volobouev and van Zyll de Jong 1994) identified a difference in chromosome number between the two species.

Despite the differences noted above, individual specimens often are difficult to identify, and the distributional patterns of the two forms have not been thoroughly studied in Iowa and adjacent states. We conducted a morphometric study of *Sorex cinereus* and *S. haydeni* in Iowa to identify individual specimens to species and to confirm that the two forms are distinct in Iowa. We also plotted the relative distributions of the two species in the state and looked for differences in habitat associations.

METHODS

Our methods followed those of van Zyll de Jong (1980) and van Zyll de Jong and Kirkland (1989). We took 5 cranial and 8 mandibular measurements (Table 1) on 315 *Sorex* specimens from Iowa plus 35 specimens from Illinois, Nebraska, and South Dakota (see Appendix for list of specimens). Sexual dimorphism is minimal in these shrews (van Zyll de Jong 1980, Foresman and Jensen 1992), so we did not separate the specimens by sex. We took cranial measurements under a dissecting microscope (0.7X-35X) using Mitutoyo sharp-point calipers, which the manufacturer reports as having an accuracy of 0.02 mm. Microsoft Excel 97 was used to generate basic descriptive statistics, and SPSS for Windows (version 10.0) was
Criminant analyses were performed for cranial and mandibular measurements. The principal components analysis used a correlation matrix that included all 13 skull measurements, but separate discriminant analyses were performed for cranial and mandibular measurements.

Lower incisor pigmentation was scored as whether the pigment formed one, two, or three discrete areas on the labial surface of the first lower incisor. The anterior edge of the maxillary plate (where the infraorbital foramen penetrates the side of the rostrum) was considered to lie posterior to, even with, or anterior to a line perpendicular to the alveolar border through the mesostyle of the first upper molar (Fig. 1). Most of the specimens we examined consisted of just unicuspid rows; many did not have external measurements. Therefore, we did not consider pelage characters or measurements of body size. We assessed habitat preferences using habitat data taken from specimen tags and collectors' field notes.

**RESULTS**

**Skull Measurements**

Skull measurements revealed the presence of two forms consistent with identification as *Sorex cinereus* and *S. haydeni*. Division into two groups was most obvious for specimens from the western half of Iowa. A histogram of unicuspid row lengths for 95 specimens from the Western and Loess Hills natural regions (as defined by Bowles et al. 1998) was strongly bimodal (Fig. 2), and there were no specimens with unicuspid row lengths of 2.18–2.20 mm. When these 95 specimens were identified by unicuspid row length (≤ 2.17 mm = *haydeni*, ≥ 2.21 mm = *cinereus*), a plot of greatest skull length and length of unicuspid toothrow produced two distinct and non-overlapping clusters of points (Fig. 3).

Separation into two species also could be seen when all the Iowa specimens were included, although the division was less obvious because the vast majority of specimens from the eastern half of Iowa were *cinereus*, and there was some overlap in unicuspid row lengths between 2.17 and 2.21 mm. However, only 15 specimens were in this range of overlap, and these 15 individuals seemed to fall into two groups based on rostral width, with M2–M2 breadth < 3.8 mm for *cinereus* and > 3.8 mm for *haydeni*. When specimens were identified by these criteria, plots of greatest skull length vs. length of unicuspid toothrow produced two distinct and non-overlapping clusters of points (Fig. 3).

The multivariate analyses provided additional support for the presence of two species. A plot of principal component 1 vs. principal component 2 separated the two groups, with the greatest degree of separation between the two species occurring between 2.17 and 2.21 mm (Fig. 2).

**Table 1. Descriptive statistics and t-test results for skull measurements of Iowa *Sorex cinereus* and *S. haydeni.*

<table>
<thead>
<tr>
<th>Measurement</th>
<th><em>Sorex cinereus</em></th>
<th><em>Sorex haydeni</em></th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Greatest length of skull</td>
<td>255</td>
<td>15.68</td>
<td>0.30</td>
</tr>
<tr>
<td>Width of cranium</td>
<td>227</td>
<td>7.59</td>
<td>0.22</td>
</tr>
<tr>
<td>Width of M2–M2</td>
<td>272</td>
<td>3.71</td>
<td>0.08</td>
</tr>
<tr>
<td>Length of unicuspid toothrow</td>
<td>274</td>
<td>2.34</td>
<td>0.07</td>
</tr>
<tr>
<td>Width across M1–M1</td>
<td>262</td>
<td>1.39</td>
<td>0.04</td>
</tr>
<tr>
<td>Length of lower incisor</td>
<td>268</td>
<td>2.98</td>
<td>0.18</td>
</tr>
<tr>
<td>Length of mandible</td>
<td>269</td>
<td>7.52</td>
<td>0.17</td>
</tr>
<tr>
<td>Height of coronoid process</td>
<td>269</td>
<td>3.32</td>
<td>0.08</td>
</tr>
<tr>
<td>Tip of coronoid to tip of condyle</td>
<td>270</td>
<td>2.46</td>
<td>0.09</td>
</tr>
<tr>
<td>Greatest depth of condyle</td>
<td>271</td>
<td>1.68</td>
<td>0.07</td>
</tr>
<tr>
<td>Width of lower condylar facet</td>
<td>271</td>
<td>1.01</td>
<td>0.04</td>
</tr>
<tr>
<td>Width of upper condylar facet</td>
<td>271</td>
<td>0.67</td>
<td>0.05</td>
</tr>
<tr>
<td>Length of mandibular toothrow</td>
<td>268</td>
<td>4.30</td>
<td>0.09</td>
</tr>
</tbody>
</table>

*aAn F-test found a significant difference in variance between species for this measurement, and therefore the test used was an option that did not assume equal variance.

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**Fig. 1.** Position of maxillary plate relative to the mesostyle of first upper molar (after van Zyll de Jong 1980). A, maxillary plate posterior to mesostyle. B, maxillary plate even with mesostyle. C, maxillary plate anterior to mesostyle.

**Fig. 2.** Histogram of lengths of the unicuspid toothrow for 95 Iowa *Sorex* specimens from the Western and Loess Hills natural regions (as defined by Bowles et al. 1998).
component 2 for the 220 specimens with complete skulls revealed two clusters of points with almost no overlap (Fig. 5). Also, the cranial and mandibular discriminant analyses correctly classified 100% and 97%, respectively, of the specimens that had been identified to species by unicuspid row length and $M^2$—$M^3$ breadth.

**Qualitative Features**

The lower incisors of *haydeni* generally were more intensely pigmented than those of *cinereus*, but both species contained individuals that were scored as having one, two, and three areas of pigmentation. Most *haydeni* were judged to have a maxillary plate that was anterior to the mesostyle of $M^3$, and none were scored as posterior; most *cinereus* were judged to have a maxillary plate that was posterior to the $M^1$ mesostyle, and none were scored as anterior (Table 2).

**Habitat Correlations and Distribution**

We could not identify any obvious patterns in habitat preference, although this may be because the habitat descriptions available from specimen tags and collectors' field notes were not made using uniform habitat categories. Specimens of *cinereus* were recorded from a wide variety of terrestrial habitats, including mesic forests, wet meadows, and remnant prairies; specimens of *haydeni* were recorded from agricultural areas, roadsides, and woodlots. Plotting the collection localities by species indicated that *S. cinereus* is distributed throughout Iowa except the northwestern corner, whereas *haydeni* appeared largely restricted to the western half of the state (Fig. 6).

**DISCUSSION**

Our results support the separation of *Sorex haydeni* from *S. cinereus* at the species level and confirm the presence of both forms in Iowa. Although a few specimens were difficult to identify (these are denoted with an asterisk in the Appendix), most skulls could be easily classified to species by cranial measurements. The measurement with the least overlap between species was length of the unicuspid toothrow (Table 1), and this measurement alone was enough to identify most specimens ($< 2.17 = haydeni, > 2.21 = cinereus$). We found no definitive qualitative way to identify specimens of *Iowa Sorex*, although the position of the maxillary plate relative to the mesostyle of $M^1$ will identify more than half of our specimens (Fig. 1; Table

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**Fig. 3.** Bivariate plot of greatest skull length vs. length of unicuspid toothrow for 95 *Iowa Sorex* specimens from the Western and Loess Hills natural regions (as defined by Bowles et al. 1998). Specimens are identified to species by length of unicuspid toothrow ($< 2.17 = haydeni, > 2.21 = cinereus$).

**Fig. 4.** Bivariate plots for *Iowa Sorex*. A, greatest skull length vs. length of unicuspid toothrow. B, width across $M^2$—$M^3$ vs. length of unicuspid toothrow.

**Fig. 5.** Bivariate plot of principal component 1 vs. principal component 2 for the correlation matrix of 13 skull measurements. Includes the 220 specimens with complete sets of measurements.
Table 2. Position of maxillary plate relative to the mesostyle of M1 in Iowa specimens of Sorex cinereus and S. haydeni.

<table>
<thead>
<tr>
<th>Species</th>
<th>Posterior</th>
<th>Even</th>
<th>Anterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorex cinereus</td>
<td>177</td>
<td>97</td>
<td>—</td>
</tr>
<tr>
<td>Sorex haydeni</td>
<td>—</td>
<td>15</td>
<td>21</td>
</tr>
</tbody>
</table>

2). Also, there does not seem to be a reliable way to distinguish these two species in the field, although individuals with unworn first lower incisors that have three well-separated areas of pigmentation are likely to be cinereus and those in which these incisors are more uniformly and intensely pigmented are likely to be haydeni.

We also found no evidence of intergradation between cinereus and haydeni. The two species were found together at five localities: Stonson Prairie in Kossuth County, Fort Defiance State Park in Emmet County, Iowa Lakeside Laboratory in Dickinson County, Whiting in Monona County, and Cedar Falls in Black Hawk County. However, specimens from these localities and adjacent areas were not more likely to be intermediate in form than specimens from other parts of Iowa. Instead, specimens that appeared morphologically intermediate came from all over the state, including areas where haydeni apparently is absent. This suggests that these intermediate specimens represent extremes in individual variation, rather than hybrids or intergrades. Some sample variability also may be due to age and tooth wear differences, which we did not assess: some specimens that appear intermediate are probably older individuals of cinereus with worn teeth and consequently shorter unicuspid toothrows.

Although there are some major gaps in our geographic sampling, cinereus appears to occur throughout Iowa with the possible exception of the extreme northwestern corner of the state, and haydeni appears largely restricted to the western half of Iowa, with some extension into the northeastern corner of the state (Fig. 6). Samples from eastern South Dakota (Brookings and Moody counties) contained just haydeni, whereas samples from eastern Nebraska (Cass and Cherry counties) and western Illinois (Carroll and Fulton counties) were all cinereus. These distributions are consistent with the hypothesis that haydeni entered Iowa from the northwest and followed grassland habitats as far east as Butler, Black Hawk, and Winneshiek counties. The apparent absence of cinereus from the northwestern corner of Iowa gives it a distribution similar to several eastern woodland mammals that reach their limits in northwestern Iowa, including the eastern chipmunk (Tamias striatus), southern flying squirrel (Glaucomys volans), and gray squirrel (Sciurus carolinensis) (Bowles 1975, Jones and Birney 1988). Although Sorex cinereus generally is considered to have boreal affinities (e.g., Hoffmann and Jones 1970), the distributional pattern that it shares with these eastern woodland species suggests

![Map of Iowa](image)

Fig. 6. Distribution of Sorex cinereus and S. haydeni in Iowa.
that it too may have entered Iowa from the east, rather than the north. Examination of fossil specimens may help to resolve the relative distributional patterns of these two shrews throughout the Holocene (see Bowles 1975, Semken 1983).

Further work is also needed to clarify the habitat preferences of these two species in Iowa. Although we could not identify any clear habitat associations, several previous studies have identified distinct habitat preferences. For example, van Zyll de Jong (1980) reported marked differences in habitat preference, with the two species occurring sympatrically only within the forest-grassland transition. Also, Foresman and Jensen (1992) reported that, in Montana, $S$. cinereus without exception was associated with forested and woodland habitats, whereas $S$. haydeni was collected only in drier grassland habitats. It seems likely that these species have similar habitat preferences in Iowa, and our information on habitat and collection localities may have been too inconsistent or coarse-grained to identify them.

ACKNOWLEDGMENTS

We are grateful to Central College students too numerous to mention individually for their assistance with field collecting and specimen preparation. We also thank the Central College Biology Department for facilities and equipment and the Central College Biology Club for help with necropseys. Field studies conducted by the Iowa Department of Natural Resources yielded many of the specimens used herein; we thank Daryl Howe in particular for discussions on Iowa mammals and for aiding us in many ways. For access to specimens, we thank R. Lampe (Buena Vista University), P. Weihe (Central College), J. Mahaffy (Dordt College), J. Christiansen (Drake University), E. Klaas (Iowa State University), T. Sordahl (Luther College), N. Bernstein (Mount Mercy College), J. Hall (Putnam Museum of Natural History), W. Gilbert (Siempel College), S. Pedersen (South Dakota State University), J. Choate (Sternberg Museum of Natural History), J. Hofmann (University of Illinois Museum of Natural History), H. Semken and R. Slaughter (University of Iowa Department of Geology), J. Golden and G. Schrimper (University of Iowa Museum of Natural History), R. Timm and T. Holmes (University of Kansas Museum of Natural History), P. Freeman (University of Nebraska Museum of Natural History), and N. Wilson (University of Northern Iowa). E. Vlaas, K. Kraft, Anderson, and Robin McNeely (Iowa Gap Analysis Program) provided GAP locality and habitat data and helped to prepare the specimen locality map. Finally, we thank Jerry Choate and Brent Danielson for comments that improved the manuscript.

LITERATURE CITED


APPENDIX—SPECIMENS EXAMINED

Abbreviations: BVC = Buena Vista University; CUI = Central College; DC = Dordt College; GMW = Greg M. Wilson personal collection; HMNH = Haslett Museum of Natural History at Luther College; HPW = Howard P. Whidden personal collection; ISU = Iowa State University; JBB = John B. Bowles personal collection; KE = Kansas State Museum of Natural History; MHP = Sternberg Museum of Natural History at Fort Hays State University; MMC = Mount Mercy College; PMNH = Putnam Museum of Natural History; SUI = University of Iowa Museum of Natural History; UIMNH = University of Illinois Museum of Natural History; UNSM = University of Nebraska State Museum.

* = identification to species uncertain.

$S$. cinereus

IOWA—Appanoose Co.: CUI1640, CUI1655, CUI1657, CUI1658, CUI1659, CUI1660, CUI1661, JBB3915, JBB3916, JBB3917, JBB3918, JBB3919, Benton Co.: UI134946, UI134947; Black Hawk Co.: CUI11656, CUI11742, CUI11743, CUI11762, CUI11763, CUI11764, CUI11765, CUI11766, CUI11767, CUU2090, KU122512, KU122513, KU122514, KU122516, UI134945, UI134949, UI134950; Boone Co.: BVC208; Clay Co.: CUI11667, CUI11668, CUI11669, CUI11670, CUI11671, CUI11672, CUI11673, CUI11674, CUI11675, CUI11676, CUI11676b, ISU156a, ISU157a, JBB4035, JBB4036; Clayton Co.: CUI1739, HPW464, HPW465, HPW466, HPW467, HPW468, HPW469, HPW470, HPW471; Dickinson Co.: BVC211, BVC212, BVC213, CUI11664, MMC87015, PMHN3, PMHN4, PMHN8, PMHN9, UI134800; Dubuque Co.: CUI11739, CUI11660, CUI11761, CUI11794; Emmet Co.: HPW631, HPW632, HPW633, HPW634, HPW635, HPW640,
HPW641, HPW642, HPW643, HPW652, ISU1117, ISU203a, ISU205a, ISU206a, JBB4038, KU115948, KU115949, KU115950; Fremont Co.: JBB4066, MHP28432*; Grundy Co.: KU109638, KU109639, Gutrie Co.: HMNH789, HMNH1867, ISU1483, ISU1485, ISU1742, ISU1743, Hardin Co.: CUI11800, SUI34386*; Harrison Co.: HPW493; Howard Co.: CUI1645, CUI1646, CUI1647, CUI1648, CUI1649, CUI1650, CUI1651, CUI1652, CUI1653, CUI1654, CUI1740, KU109638, KU109639, KU125135, KU125136, KU125137, SUI34052; Humboldt Co.: UIMNH32738; Jasper Co.: GMW191, GMW192, GMW193, HPW472, HPW473, HPW474, HPW475, HPW476, HPW477, HPW478, HPW479, HPW480, HPW481, HPW482, HPW483, HPW484, HPW485, HPW486, HPW487; Johnson Co.: KU119974, KU119975; Kossuth Co.: JBB4032, JBB4034; Linn Co.: MCC83002, MCC83029, Louisa Co.: SUI34801, SUI34802; Lucas Co.: CUI1662, CUI1686, JBB3522, JBB3908, JBB3925, JBB3926, JBB3974, JBB3975, JBB3977, JBB3978, JBB3980, JBB3982, JBB3985, JBB3986, JBB3992, JBB3997, JBB3998, JBB3999, JBB4005, JBB4007, JBB4008, JBB4015, JBB4016, JBB4018, JBB4019, JBB4020, JBB4021, JBB4024, JBB4025, JBB4026, JBB4027, JBB4028; Madison Co.: SUI34387; Mahaska Co.: HPW457, HPW458, HPW459, HPW460, HPW461, HPW462, HPW463, KU107892, KU107893, KU109644; Marion Co.: CUI1703, CUI1707, CUI1712, CUI1718, CUI1744, CUI1745, CUI1748, CUI1749, CUI1750, CUI1751, CUI1752, CUI1757, CUI1774, CUI1775, CUI1776, CUI1777, CUI1778, CUI1779, CUI1780, CUI1781, CUI1783, CUI1786, CUI1787, CUI1805, CUI2033, HPW491, KU109643, KU125135, KU125136, KU125137, SUI34061; Marshall Co.: KU109640; Mills Co.: SUI34068; Monona Co.: JBB3644, MMC85053, SUI34070; Muscatine Co.: KU109696, KU109697, KU109698; Palo Alto Co.: JBB4037, JBB4039; Pocahontas Co.: ISU1726; Pottawattamie Co.: SUI34811; Poweshiek Co.: GMW252, KU109642; Ringgold Co.: SUI34072, SUI34073, SUI34074; Scott Co.: KU119976, PMNH5, PMNH6, PMNH7; Story Co.: HMNH788, HMNH790, HMNH915; Union Co.: HPW489; Van Buren Co.: CUI1741; Wapello Co.: HPW488, HPW508; Warren Co.: HPW490; Wayne Co.: CUI1735, CUI1736, CUI1737, JBB3897, JBB3907, JBB3996, JBB4010, JBB4011, JBB4012; Webster Co.: JBB3969, JBB4057, JBB4058, SUI34075, SUI34076, SUI34077; Winnebago Co.: CUI1758, HMNH1073, HMNH1139, HMNH1310, HMNH1311, HMNH181, HMNH581, HMNH611, HMNH612, HMNH615; ILLINOIS—Fulton Co.: UIMNH57389, UIMNH57390, UIMNH57391, UIMNH57392, UIMNH57393, UIMNH57394, UIMNH57395, UIMNH57396, UIMNH57397, UIMNH57398, UIMNH57400, UIMNH57401, UIMNH57402, UIMNH57403, UIMNH57405, UIMNH57406, UIMNH57407, UIMNH57409; NEBRASKA—Cass Co.: UNSM19796, UNSM19798, UNSM19812, UNSM19855, UNSM19865, UNSM19867, UNSM19868; Cherry Co.: UNSM13212, UNSM13221, UNSM13363, UNSM16657; SOREX haydeni

IOWA—Adams Co.: KU114156; Black Hawk Co.: CUI1738, KU122511; Buena Vista Co.: BMC209, KU115952, KU115953, KU115954, KU121537; Butler Co.: KU103923; Cerro Gordo Co.: ISU21a; Cherokee Co.: JBB3863; Dickinson Co.: CUI1663, CUI1665, CUI1666, UIMNH104; Emmet Co.: ISU204a*, ISU1126, ISU209a; Guthrie Co.: JBB3862, KU122510; Harrison Co.: SUI34052; Kossuth Co.: JBB4033; Lyon Co.: ISU517a, ISU525a, KU115946, KU115947, SDSU1168, SUI34078; Marshall Co.: KU109641; Monona: SUI34069*; Plymouth Co.: KU115951; Sioux Co.: BMC217, DC5000, SUI34079; Union Co.: KU114157; Winnebago Co.: ISU29a; Winnebago Co.: HMNH74; SOUTH DAKOTA—Brookings Co.: SDSU679, SDSU1108, SDSU1201, SDSU1203, SDSU1212; Moody Co.: SDSU245, SDSU256.