Conservation Assessment for the Pygmy Shrew (Sorex hoyi hoyi) in Washington

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June 2015

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Interagency Special Status and Sensitive Species Program
USDA Forest Service Region 6, Oregon and Washington
USDI Bureau of Land Management, Oregon and Washington

Disclaimer

This Conservation Assessment was prepared to compile the published and unpublished information on the pygmy shrew (Sorex hoyi hoyi). If you have information that will assist in conserving this species or questions concerning this Conservation Assessment, please contact the interagency Conservation Planning Coordinator for Region 6 Forest Service, BLM OR/WA in Portland, Oregon, via the Interagency Special Status and Sensitive Species Program website at http://www.fs.fed.us/r6/sfpnw/issssp/contactus/

EXECUTIVE SUMMARY

Species: Pygmy shrew (*Sorex hoyi hoyi*)

Taxonomic Group: Mammal

Management Status: This species is given a conservation status of "least concern" by the IUCN, and it has no Federal status in the United States. NatureServe (2012) ranks this species as a G5, indicating the species is secure globally. However, the Washington Natural Heritage Program ranks the species as S2S3 for the state, classifying the species as rare or uncommon, imperiled and very vulnerable to extirpation. Based on this state rank, the species is considered a Sensitive species for the Bureau of Land Management (BLM) and Forest Service in Washington State. The species is considered to be documented on Spokane BLM lands, and the Colville National Forest suspects this species to occur on their lands. In Washington, there are approximately 120 records of this species' occurrence (e.g., Stinson and Reichel 1985, Stinson 1987, Hallett and O'Connell 1997, O'Connell et al. 2000, Hawkes 2010). One hundred specimens have been deposited at the Conner Museum at Washington State University, Pullman (D. W. Stinson, WA Department of Fish and Wildlife, personal communication).

Range: This species is made up of five recognized subspecies (Diersing 1980). The overall range extends from Alaska through much of Canada in the northern boreal forest belt, and south and east into eastern Washington, northern Idaho, northern Montana (Hendricks and Lenard 2014), the eastern Dakotas, Minnesota, northern Iowa, Michigan, New York, and New England, and southwards along the Appalachians to northern Georgia. There is an isolated population made up of a distinct subspecies in Wyoming and Colorado (*S. h. montanus*, Diersing 1980, Beauvais and McCumber 2006, Figure 1). In Washington, where the subspecies *S. h. hoyi* occurs, records are currently reported from Pend Oreille and Stevens Counties (Stinson 1987, Hallett and O'Connell 1997, Johnson and Cassidy 1997, O'Connell et al. 2000, Hawkes 2010, Burke Museum of Natural History and Culture 2014), although pygmy shrews are likely to occur in Spokane County also based on GAP analysis. The species does not occur in Oregon.

Specific Habitat: The species occurs in a wide variety of habitats, although some researchers believe that the subspecies differ somewhat from each other in their requirements (Beauvais and McCumber 2006). *S. h. hoyi* in Washington has been found in Douglas-fir (*Pseudotsuga menziesii*), ponderosa (*Pinus ponderosa*) and lodgepole (*Pinus contorta*) forest (Stinson and Reichel 1985, O'Connell et al. 2000). It has also been found under canopies of grand-fir (*Abies grandis*), western red cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), larch (*Larix occidentalis*) and alder (*Alnus* spp., O'Connell et al. 2000). Pygmy shrews in Washington have been trapped in closed-canopy, regenerating, and clear-cut stands (Hallett and O'Connell 1997), and at varying distances from riparian areas under different management regimes (O'Connell et al. 2000, Hawks 2010). A substantial litter layer, woody debris, and thick understory/shrub layer vegetation appear to be general requirements (Hallett and O'Connell 1997).

Threats: Threats are most likely to come from activities that disturb habitat or soil, including logging, grazing, farming, or road building. In addition, changes to hydrology that result in drying of wetland areas may lead to a loss of habitat.

Management Considerations: The range of this species may be more extensive than currently described (e.g., Jung et al. 2007). Given how little is known of this species in Washington or even in adjacent areas in Idaho, more surveys to better delineate the range and habitat may be helpful. Otherwise, management actions that preserve the leaf-litter layer, vegetative cover, and hydrology of areas thought to harbor this species should be considered over management actions that do not.

Inventory, Monitoring, and Research Opportunities: If a better understanding of the limits of the range in Washington is desired, additional surveys may be necessary. Surveys may also help clarify which habitats this subspecies utilizes.

I. INTRODUCTION

Goal

The pygmy shrew, *Sorex hoyi*, is widely distributed throughout Canada and the United States (Fig. 1). A disjunct subspecies (*S. hoyi montanus*) occupies a limited range in Colorado and southern Wyoming (Beauvais and McCumber 2006). The subspecies *Sorex hoyi hoyi* is the most widespread of the five subspecies of *Sorex hoyi*, and is the only subspecies found in Washington (Diersing 1980, Beauvais and McCumber 2006). Despite its broad range, its presence in Washington is confirmed only in Stevens and Pend Oreille Counties (Stinson and Reichel 1985, Stinson 1987, Hallett and O'Connell 1997, Johnson and Cassidy 1997, O'Connell et al. 2000, Hawkes 2010, Burke Museum of Natural History and Culture 2014, Fig. 2). The goal of this conservation assessment is to summarize existing knowledge across the range of the species to better inform management of the species and its habitat in eastern Washington.

Scope

Because information regarding the species in Washington is quite limited, I draw on data published for the species throughout the entire range. The limitation to this approach is that differences among the subspecies in terms of habitat use, diet, and behavior are necessarily lost, as noted previously (Beauvais and McCumber 2006). This work should not be considered complete, as unpublished reports of occurrence or ecological information are very likely to exist beyond what was found for this assessment.

Management Status

The pygmy shrew is assigned the category of "least concern" by the IUCN because it is widespread, relatively numerous, there are no major threats to the species' persistence, and no evidence of widespread declines (http://www.iucnredlist.org/details/41400/0, accessed April 30, 2014). It has no protection at the federal level in the United States or Canada, although it is listed as a Sensitive Species by both the USDA Forest Service and Bureau of Land Management in Washington as well as by Region 2 of the Forest Service (Beauvais and McCumber, 2006). Although two subspecies exist in USDA Forest Service Region 2, *S. hoyi hoyi* and *S. h. montanus*, the subspecies *montanus* is likely the reason for the species-level designation because of its limited range and disjunct distribution (Beauvais and McCumber 2006). NatureServe (2012) ranks this species as G5, indicating that the species is secure globally. However, the Washington Natural Heritage Program ranks the species as S2S3 for the state, identifying the species as considered rare or uncommon, imperiled and very vulnerable to extirpation.

The species is not known to occur in Oregon. In Washington, it has been recorded in southern Stevens County and Pend Oreille County (Conner Museum, Washington State University, Pullman; D. W. Stinson, Department of Fish and Wildlife, personal communication). Gap analysis predicts the species also occurs in Spokane County (http://www.wdfw.wa.gov/conservation/gap/gapdata/mammals/gifs/soho.gif, accessed April 14, 2014). The species is considered to be documented on Spokane BLM lands, and the Colville National Forest suspects this species to occur on their lands.

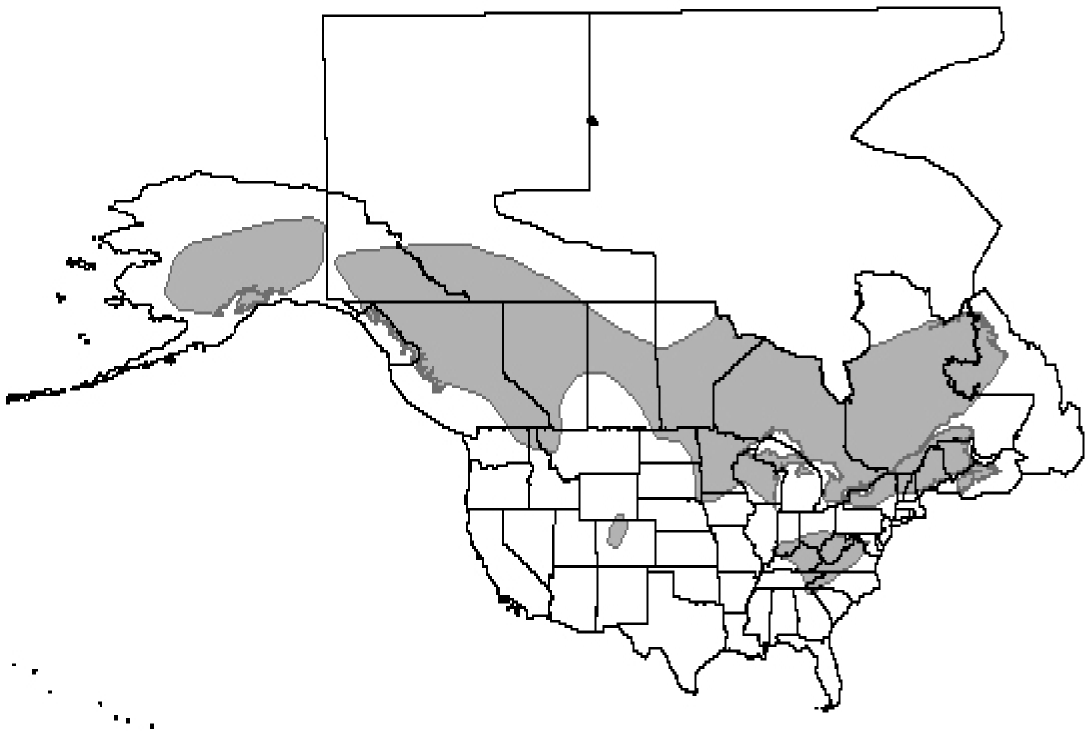
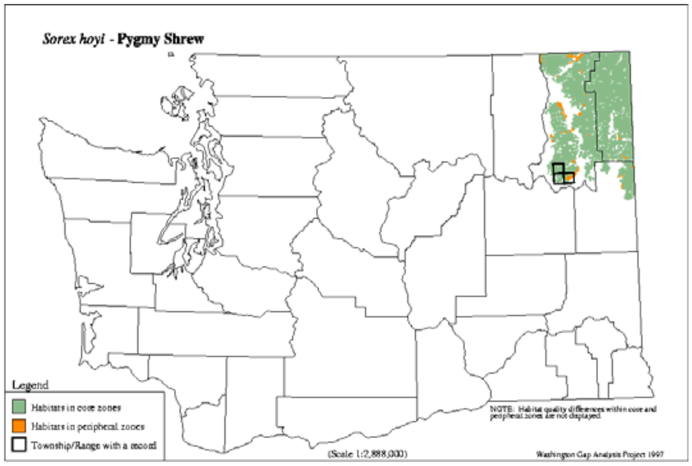


Figure 1. Overall range of *Sorex hoyi*. Image from IUCN website, (http://maps.iucnredlist.org/map.html?id=41400). Note: recent records indicate that the range includes at least northeastern Montana, and likely extends farther south through northern Montana than the IUCN map indicates (Hendricks and Lenard 2014).

A.



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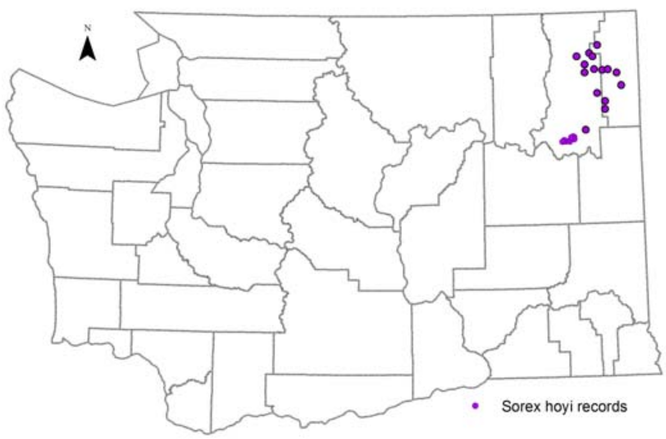

Figure 2. *Sorex hoyi hoyi* range in Washington.
A. The squares represent 1984-1985 trapping records, the shading shows potentially suitable habitat based on Washington GAP Analysis Project (Johnson and Cassidy 1997) (http://wdfw.wa.gov/conservation/gap/gapdata/mammals/gifs/soho.gif).
B. Trapping records reported to the Conner Museum, Washington State University, 1984-2000. Map courtesy of Derek Stinson, Washington Department of Fish and Wildlife. Trapping data are not comprehensive.

II. CLASSIFICATION AND DESCRIPTION

Systematics

Shrews fall in the family Soricidae within the order Soricomorpha. Originally the pygmy shrew was classified under the genus *Microsorex* on the basis of distinct dental characteristics. This was subsequently reconsidered and *Microsorex* was reclassified as a subgenus within the Holarctic genus *Sorex* (e.g., Van Zyll de Jong 1976, see also discussion in Diersing 1980). The genus *Sorex* currently consists of four recognized subgenera, three in North America and one in Europe. The subgenus *Microsorex* contains only *Sorex hoyi* (Diersing 1980, Nowak 1999).

Although the species currently is composed of five (Diersing 1980) or six (Beauvais and McCumber 2006) subspecies, only the subspecies *S. h. hoyi* occurs in Washington and adjacent states (Diersing 1980, Beauvais and McCumber 2006). A presumptive subspecies (*S. h. washingtoni)* was based on a single specimen reported from Loon Lake, Washington; this specimen was later determined to be *S. h. hoyi* (Diersing 1980).

Species Description

The pygmy shrew is among the smallest mammals in the world, weighing 3-8 g (Baker 1983, Beauvais and McCumber 2006). Although measurements of Washington-caught animals were taken (e.g., Hallett and O'Connell 1997), they often were not reported. However, Stinson and Reichel reported measurements for 5 of 6 shrews captured on the Spokane Indian Reservation between late September and late October in 1984. The body length was 81.4 mm (SE= 2.97), the tail length was 26.8 mm (SE = 0.84), and the hind foot was 10 mm (SE = 0.71). Masses of two individuals were reported as 2.8 and 2.3 g (Stinson and Reichel 1985), and Stinson (1987) reported a mean of 2.73±.225 g for 6 shrews captured June-August 1985. Masses of *S. h. hoyi* captured in Stevens and Pend Oreille Counties in mid-May through June during a study of riparian management zones were reported as follows: males 3.6±0.1 g (n=16); immature males: 2.6±0.1 (n=17); females: 3.7±0.1 (n=3); immature females: 2.7±0.1 (n=11, O'Connell et al. 2000).

Rangewide, Diersing (1980) reported measurements of both young of the year and older animals, including detailed measurements of dentition. In those animals, all *S. h. hoyi* trapped from July to August at Attawapiskat Lake, Ontario, the head and body length of younger animals was 60.14 mm (SD = 1.77, n = 21) versus 63.72 mm (SD = 3.21, n = 18) for overwintered (older) animals. Similarly, tail lengths were 34.90 mm (SD = 1.22, n = 21) and 34.53 mm (SD = 1.23, n = 17) and hindfoot lengths were 11.43 mm (SD = 0.51, n = 21) and 11.56 mm (SD = 0.51, n = 18) younger and older animals, respectively. Total lengths ranged from 62-106 mm (Diersing 1980). Measurements of *S. h. hoyi* were apparently taken during a study of small mammal communities in managed forests in Stevens and Pend Oreille Counties, but were not reported (Griffith 1997)

The pelage is brownish dorsally and slightly lighter on the underside, as is typical of species within the genus *Sorex* (Nowak 1999, Foresman 2001, Beauvais and McCumber 2006). The characteristic that reliably distinguishes *S. hoyi* from other species in the genus is the dentition (Carraway 1995). They are the smallest shrew throughout most of their range, although the Alaskan tiny shrew, *S. yukonicus*, is smaller (Dokuchaev 1997, Beauvais and McCumber 2006).

Comparison with Sympatric Species

Ten species of shrew occur in the state of Washington, all within the genus *Sorex* (http://collections.burkemuseum.org/mamwash/soricomorpha.php). Sympatric species include *S. cinereus* (masked shrew), *S. merriami* (Merriam's shrew), *S. monticolus* (dusky shrew), *S. palustris* (water shrew), *S. preblei* (Preble's shrew), and *S. vagrans* (vagrant shrew). All of these species have relatively similar physical appearance, with ears that barely show through the pelage, very small eyes, and a long and flexible snout with conspicuous whiskers (Nowak 1999).

Sorex hoyi is reliably distinguished only based on its dentition, in particular the third upper unicuspid, which is small and disc shaped, and the upper incisor, which has a long median tine (Diersing 1980, Foresman 2001, Beauvais and McCumber 2006). Additional features of the dentition and dentary bone helpful in distinguishing among Sorex species including *S. h. hoyi* are given in Carraway (1995).

III. BIOLOGY AND ECOLOGY

Range, Distribution, and Abundance

The pygmy shrew, *Sorex hoyi*, is widely distributed throughout Canada and extends into the United States in eastern Washington, northern Idaho, northwestern Montana, then down into the eastern Dakotas east through Michigan to western Maine, and south down the Appalachian Mountains into northern Georgia (Fig. 1). A disjunct subspecies (*S. hoyi montanus*) occupies a limited range in Colorado and southern Wyoming (Beauvais and McCumber 2006). *Sorex hoyi hoyi*, is the most widespread of the five subspecies of *Sorex hoyi*, and is the only subspecies found in Washington (Diersing 1980, Beauvais and McCumber 2006).

S. hoyi tends to be the least common and least widely distributed among habitats in multi-species communities of shrews, suggesting a competitive disadvantage with sister species (e.g., Spencer and Pettus 1966, Brown 1967, Beauvais and McCumber 2006). Although no estimates of abundance were found, Long (1972) indicated that 10 pitfall traps placed 10 yards apart in each of four habitats in Wisconsin yielded 15 total shrews, of which only two were *S. h. hoyi*. In Larimer County, Colorado, captures per trap night for *S. h. montanus* ranged from 0.0007 to 0.0011 in 1961-1964. Pygmy shrews made up 47% of all captures in marsh and forest, but as little as zero in clear-cuts (Spencer and Pettus 1966). In Washington, *S. h. hoyi* has been captured far less frequently than other shrew species (Stinson and Reichel 1985, Stinson 1987, Hallett and O'Connell 1997, Johnson and Cassidy 1997, O'Connell et al. 2000, Hawkes 2010). Stinson (1987) recorded one capture per 1,100 pitfall trap nights for *S. h. hoyi*.

Pygmy shrew numbers appear to peak in late summer in several parts of the species' range, and thus this is likely true for more than one of the subspecies (e.g., Spencer and Pettus 1966 for *S. h. montanus*, Feldhamer et al. 1993 for an unidentified subspecies but likely *S. h. winnemana* after Diersing 1980, Long 1972 for *S. h. hoyi* in Wisconsin, Huggard and Klemmer 1998 for *S. h. hoyi* in British Columbia). This pulse is attributed to the recruitment of young of the year, and population numbers are subsequently expected to drop until the following spring when young are born.

Habitat

This species is broadly distributed across a range of habitats, although a greater degree of habitat specificity may exist at the subspecies level (Beauvais and McCumber 2006). Rangewide, *S. hoyi* has been documented in mixed oak/pine and other coniferous-hardwood forests, alder clumps, beech-maple forest, sphagnum swamp, bogs, marshes, and around ponds, lakes, and grassy clearings (Long 1972, Baker 1983, Feldhamer et al. 1993). *S. hoyi* was also positively associated with the presence of larger-diameter downed woody debris and shrub cover (Hallett and O'Connell 1997, Bellows et al. 2001). Thick ground cover and a well-developed leaf litter may provide greater thermal cover, protection from predators, and more abundant prey (Beauvais and McCumber 2006). Shrews in general are associated with the surface of the ground, although *S. hoyi* is an able climber (Prince 1940, Beauvais and McCumber 2006). Other species of *Sorex* and *Blarina* are known to use echolocation (Buchler 1976, Tomasi 1979, Forsman and Malmquist 1988), apparently as a mechanism to assess habitat at short range (Siemers et al. 2009), although it is not known whether *S. hoyi* has this ability. However, taken together, the information available suggests that *S. hoyi* is likely to remain near the surface of the ground, utilizing thick cover both for protection and to find food.

In Washington, *S. h. hoyi* was found during one survey in uneven-aged, second-growth upland conifer forests with overstories of primarily Douglas-fir (*Pseudotsuga menz*iesii) with ponderosa (*Pinus ponderosa*), and lodgepole pine (*Pinus contorta*). The understory included creeping Oregon grape (*Berberis repens*), mountain-lover (*Pachistima myrsinities*), shiny-leaf spirea (*Spirea betulifolia*), and snowberry (*Symphoricarpos albus*), twinflower (*Linnaea borealis*), bluebunch wheatgrass (*Agropyron spicatum*), and pine grass (*Calamagrostis rubescens*). In addition, young grand fir (*Abies grandis*) was in the understory (Stinson and Reichel 1985). A subsequent study in the same area (Stinson 1987) documented ninebark (*Physocarpus malvaceus*), ocean spray (*Holodiscus discolor*), myrtle boxwood (*Pachistma myrsinities*), bunchberry (*Cornus canadensis*) and prince's pine (*Chimaphila umbellata*) in the understory of the grand-fir grids, which also contained western larch (*Larix occidentalis*). The drier Douglas-fir grids also supported serviceberry (*Amelanchier alnifolia*) in addition to the species mentioned above (Stinson 1987). The dry Ponderosa stands did not yield any pygmy shrews, and they were not captured in steppe habitat (Stinson 1987, D. W. Stinson, *personal communication*).

Specific habitat information for locations of capture is not available for the majority of pygmy shrews captured in Washington (Hallett and O'Connell 1997, Johnson and Cassidy 1997, O'Connnell et al. 2000, Hawkes 2010). However, general descriptions of trapping grids (not all of which yielded *S. h. hoyi*) are very similar to descriptions given by Stinson (1987) above.

Some work has indicated that pygmy shrews may use agricultural habitats (Long 1972, Long 1974, Beauvais and McCumber 2006). However, this has never been substantiated for Washington State. Similarly, captures from a long-term study in Idaho and Montana generally were from very similar habitat types of mesic Douglas-fir or drier ponderosa forest, with the exception of one juvenile *S. h. hoyi* caught in sagebrush habitat at Big Hole National Battlefield in Idaho (Foresman 1999). There are currently insufficient data to determine whether *S. h. hoyi* ever uses agricultural lands, sagebrush, shrub-steppe, or land undergoing succession in Washington.

Several studies documented a lack of differentiation among habitats in capture rates of pygmy shrews (Stinson 1987, Hallett and O'Connell 1997, Huggard and Klenner 1998). This may be because stand type or understory species composition is less important than actual structural attributes or microhabitat conditions. One apparent commonality is the presence of water nearby (Long 1972). *Sorex hoyi hoyi* has been most frequently associated with bogs, wetlands, marshy areas, lake margins, along irrigation canals, and habitat that otherwise has abundant cover at ground level in the form of plants or deep leaf litter, and low to mid-story vegetation (Long 1972, Hendricks and Lenard 2014). A common feature across all habitat types recorded is the presence of moist microsites including downed wood, which may be necessary for maintaining osmoregulatory balance, safe resting sites, and for finding sufficient prey (Hallett and O'Connell 1997, Bunnell et al. 2002, Beauvais and McCumber 2006). Interestingly, although *S. h. hoyi* was trapped somewhat less frequently in clear-cuts in a study of forest structure and small mammal communities (Hallett and O'Connell 1997), specimens were trapped in clear-cuts as well as mature and regenerating forest. Specific habitat data for grids that yielded pygmy shrews were not available.

Life History and Breeding Biology

Shrews have long fascinated biologists with the apparent problem of their extremely small size and high basal metabolism. High temperatures may lead to irreplaceable water loss (Genoud 1988). Energy expenditure in the winter may be reduced by the use of nests, which in some species of *Sorex* reduced resting metabolic rate by 30% and overall daily expenditure by 15% (Genoud 1985). *Sorex* shrews apparently do not use torpor as a thermoregulatory strategy, but may reduce their body size, including key organs such as the liver, kidneys, and brain in winter, presumably to reduce energetic demands (e.g, Genoud 1988, Churchfield et al. 2012 and references therein). Overall, other adaptations to seasonal or cold environments include high basal metabolic rates, maintenance of high activity levels, and large home ranges for sufficient resource acquisition (Genoud 1988).

Relatively little is known about reproduction in shrews in general, or about *S. h. hoyi* in particular. *Sorex hoyi* is thought to generally breed only once per year, and few if any individuals survive a second winter in more northern latitudes (Long 1972, Beauvais and McCumber 2006, but see Feldhamer et al. 1993). Thus, the population structure may be one of nearly complete separation between generations. In the southern Appalachians, *S. hoyi* produced two recruitment pulses within a single breeding season, the first in January-early March, and again, although to a lesser extent, in late August-December (Feldhamer et al. 1993). Presumably this smaller second pulse was born to females that had already raised a litter earlier in the season (Feldhamer et al. 1993).

There was no evidence in the literature of shrews breeding as young of the year. In other species of shrews with similar life histories, individual females may have more than one litter in the same breeding season (e.g., Hawes 1977). No information was found regarding the conditions under which *S. hoyi* may breed twice in a single season, although it is noteworthy that second litters have only once been reported from the northern parts of the species' range. Presumably this is most likely to occur when conditions including food availability and weather are optimal and in regions where winter is relatively short and mild. The one exception to this was a report of a capture of a female on June 10 in Idaho with well-developed mammae but only a blastocyst in the womb (Foresman 1986). It is possible that this female had lost her first litter (Foresman 1986). For animals with only one reproductive period per lifetime, the ability to produce a second litter if the first is lost would seem advantageous if energetic needs could be met.

In sites with congeneric shrews, *S. h. winnemana* appears to breed earlier than the conspecifics (Feldhamer et al. 1993, McCay et al. 1998), as did *S. h. montanus* (Spencer and Pettus 1966). The earlier breeding pulse has been attributed to avoiding interspecific competition, but given the nearly complete overlap in breeding seasons documented in McCay et al. (1998) for *S. h. winnemana*, this seems unlikely. Breeding occurred over an extended period from March to November, based on aging specimens using tooth wear (McCay et al. 1998). Although this may simply be an artifact of uncertainty in assigning ages, it seems reasonable for populations at lower latitudes to be able to breed over a longer time period than more northerly ones.

No information was found regarding the timing of breeding of *S. h. hoyi* relative to congenerics, although two Washington specimens taken on June 9th and 11th contained embryos (Conner Museum records, Washington State University, D. W. Stinson, *personal communication*). Although no information on litter size was found, two pregnant specimens of *S. h. hoyi* trapped in Iowa contained 7 and 8 embryos, respectively (Long 1972), and a pregnant shrew captured in Montana in early August carried 3 embryos. If all embryos survive to birth, a range of litter sizes would therefore be 3-8. Lactating *S. h. hoyi* have been captured in late July and early August in Wisconsin and early August in Montana (Long 1974, Foresman 1999). Foresman (1986) reported capturing a pregnant female with well-developed mammae in mid-June. A young animal was captured in early August in Wisconsin (Long 1974). An immature male that had not yet undergone spermatogenesis was taken in early September in Idaho (Foresman 1986). Taken together, it appears that the breeding season in *S. h. hoyi* occurs primarily in July and August, with breeding beginning in June.

In general, shrews of the genus *Sorex* give birth to 4 to 7 young (with a range of 2-12) after a gestation period of roughly 18-28 days. The young are dependent on their mother for 3-5 weeks (Nowak 1999). Although no record of this behavior was found for *S. hoyi*, many *Sorex* young exhibit caravanning behavior upon leaving the nest but before becoming independent. The young shrews will follow each other and their mother by biting and holding the fur of the shrew in front (Nowak 1999).

Movements and Territoriality

Home ranges for shrews are typically on the order of 0.5 ha or often considerably less, with the largest ranges recorded during the breeding season (summarized in Beauvais and McCumber 2006). No data were found for *S. hoyi*. Anecdotal information suggests that individuals of *S. hoyi* utilize different parts of their home range in different seasons, perhaps responding to the rising and falling of the water table. Movements are apparently made to maintain proximity to damp soils (Long 1972, Beauvais and McCumber 2006).

When numbers peak in the fall, younger animals may occupy the core habitat and push shrews born the previous year into marginal habitat (Beauvais and McCumber 2006). Dispersing animals may be captured in less than optimal habitat in late summer, however, biasing habitat inferences from capture data (Huggard and Klenner 1998). Occupancy of what appeared to be drier, lower-quality habitat occurred in pygmy shrews in Wisconsin in late summer, apparently at the height of population densities; ages of animals in peripheral habitat were not given (Long 1972). Hawes (1977) found extensive overlap among territories in the summer among individuals of *S. vagrans and S. obscurus*, near Vancouver, British Columbia, particularly among adults born the previous year and newly independent young. However, as the summer progressed, territorial overlap decreased until by autumn shrews defended exclusive territories, and these individuals tended to survive the winter (Hawes 1977). Similar patterns may exist in *S. h. hoyi*.

Population Trends

Very little can be deduced regarding population trends for this species in Washington or elsewhere based on the current information available. However, very small year-to-year fluctuations in captures were noted in Washington, ranging from 7 to 22 animals (Hallett and O'Connell 1997). There were pronounced seasonal differences in capture rates in British Columbia, but three years differed little overall (Huggard and Klenner 1998).

Elsewhere, one study found that although other conspecific populations of shrews showed considerable variation in numbers trapped from year to year, *S. h. montanus* did not (Spencer and Pettus 1966, but see Baker 1983). Another study noted that *S. hoyi* was not captured during June-August, and speculated that the species spends much of its time underground during the hottest, driest months (Feldhamer et al. 1993). In communities with several species of shrews, *S. hoyi* was considered the least numerous (Buckner 1966, Brown 1967, Baker 1983, Stinson and Reichel 1985, Stinson 1987, Griffith 1997). Combined with the challenges of successfully trapping these animals, these behaviors will make describing population trends particularly difficult.

IV. CONSERVATION

Ecological and Biological Considerations

Sorex hoyi appears to be almost entirely carnivorous. It appears to be willing to consume a wide variety of small invertebrate prey, with an emphasis on non-volant species such as millipedes or life stages such as larvae. Shrews generally eat a wide variety of organisms, including vertebrate carrion (Buckner 1964, Whittaker and French 1984, Nowak 1999). Although a generalist in one sense, the very small size of this animal restricts the range of prey available even within the invertebrate community. They may be able to exert sufficient pressure on the larvae of pest insects such as sawflies to dampen the extent of outbreaks (Buckner 1964).

In Washington, pygmy shrew stomachs contained millipedes (Diplopoda, order Julida), cave crickets (Gryllacrididae, Ceuthophilus), ants, Collembola, Diptera, harvestmen spiders (Phalangida), Hymenoptera, adult and larval Coleoptera, and centipedes (Chilopoda; Stinson 1987, Griffith 1997).

Echolocation, if it occurs in this species, would likely be used for assessing habitat rather than finding food (e.g., Buchler 1976, Tomasi 1979, Forsman and Malmquist 1988, Siemers et al. 2009, Catania 2013).

Where more than one species of shrew occurs, it appears that there is some partitioning in diet among them (Whittaker and French 1984, Stinson 1987, Griffith 1997). Some evidence collected in Washington suggested that shrews narrowed their prey niche breadth in the presence of other species (Griffith 1997). Of four shrew species in northeastern Washington, *S. h. hoyi* had the least dietary overlap compared to any pair of the other three (*S. vagrans*, *S. monticolus*, *S. cinereus*, and *S. h. hoyi*, Stinson 1987).

Although the species' use of other animals' burrows during the summer is speculative, this would suggest that shrews may rely on other, more fossorial to create refuges. Maintaining a diverse assemblage of small animals will likely only enhance conservation efforts.

Although shrews do not consume vegetation, they do rely on vegetative cover for maintaining appropriate microsite conditions and for the support of their food base. It seems plausible that destruction of plant communities via invasion of exotic plant species would have negative impacts on many small animals, not just shrews. Similarly, maintaining hydrological conditions will be important in maintaining appropriate habitat and microsite conditions.

Threats

One threat to *S. h. hoyi* in Washington is habitat loss through anthropogenic activities, either directly through development activities such as logging, road building and clearing of land, or indirectly through alteration as a result of climate change and resulting fire, severe drought, or invasion of exotic species that alter the food web.

For example, grazing appeared to change food availability and consequently the diets of *S. vagrans*; the effects were apparently related to soil compaction (Whitaker et al. 1983) although removal of vegetation could affect prey diversity and abundance as well. Given the importance of cover to *S. hoyi* (Hallett and O'Connell 1997, Bellows et al. 2001), the loss of mesic microsites due to removal of vegetation may also be a factor affecting shrew persistence. Shrews were found to be positively associated with area of medium-tall shrubs and increased woody debris in one study in Washington (Hallett and McConnell 1997). However, *S. h. hoyi* has been captured in regenerating and cut-over stands (Hallett and O'Connell 1997, Huggard and Klenner 1998, Johnson and Cassidy 1997, Hawkes 2010). It is not clear whether these animals were residents that may have been pushed into more open habitat by interspecific competition (Huggard and Klenner 1998), or were dispersing to more favorable habitat.

Fire, either uncontrolled burning or as a fuels-reduction treatment, has the potential to reduce the thickness of the leaf-litter layer, destroy canopy cover, and remove downed woody debris. The reduction in leaf litter has been associated with reductions in shrew populations overall and *S. hoyi* in particular (Greenberg et al. 2007). A follow-up study did not find that mechanical fuel reduction followed by burning affected shrew numbers or community composition after the first year (Matthews et al. 2009). Of five *S. h. hoyi* trapped in a study of the effects of fire on small-mammal communities, one was caught on a trap grid in a burned area (Zwolak and Foresman 2007). Changing fire regimes may therefore alter the habitat suitability and ultimately the range of this species, but much may depend on conditions and regrowth following fire.

Invasive species have the potential to threaten persistence of *S. h. hoyi* populations in many ways. The greatest threat is likely the alteration of habitat, either in a manner that affects the distribution and abundance of prey, or by altering the physical habitat, particularly the surface of the soil and the litter and vegetation directly above it, needed by the shrews themselves. It may also increase the risk of fire and subsequent removal of critical cover resources.

A less-recognized risk may be posed by management actions meant to control invertebrate species that *S. hoyi* may eat. *Sorex cinereus* showed changes in distribution and population structure following the application of *Bacillus thuringiensis* to a jack pine stand relative to untreated stands. Although *B. thuringiensis* is used to control larval lepidopterans and has very low toxicity to other organisms (National Pesticide Information Center, http://npic.orst.edu/factsheets/BTtech.pdf), a side effect is reduced prey abundance. In this study, shrews responded by emigrating from the sprayed areas and altering their diet (Bellocq et al. 1992).

Sorex hoyi is most often associated with habitats that offer mesic microsites. It therefore may be vulnerable to changes in hydrology brought about by climate change and competing demands for water. Conversion of land to agriculture is also considered a threat elsewhere in its range, although *S. h. hoyi* has been associated with irrigated agricultural land uses (Beauvais and McCumber 2006).

Management Considerations

General actions to preserve cover, soil litter, downed dead wood, and invertebrate abundance while minimizing road building or other activities that disturb soil are likely to avoid harm. Specific actions that may be helpful to this species include the following:

- Maintain downed woody debris within harvest units, and if units are logged, leave some unburned slash piles, particularly near wet soils. Given the small size of shrew home ranges, more small piles will be more effective in providing habitat than a few large piles.

- Retaining large logs greater than 20 inches in diameter in harvested units will help provide moist microsites and prey for shrews.

- Mesic microsites appear to be important to *S. h. hoyi*. Protecting these microsites in harvest units by either clumping leave trees around such sites, or excluding them from the unit altogether, may be helpful in maintaining shrew populations.

- Because of the importance of leaf litter in providing both cover and prey, retaining hardwoods in harvest units and using silvicultural treatments to promote growth of additional hardwoods will help maintain appropriate habitat conditions.

- Small mammals may not cross road openings regardless of traffic (e.g., Beauvais and McCumber 2006, McGregor et al. 2008 and references therein), likely because of the vulnerability to predation during the crossing. Shrews in particular are associated with dense, low cover. Therefore, if possible roads should be located away from riparian habitat conservation areas, and existing roads should be removed if possible.

- If relocating or rerouting a proposed road is not feasible, crossing structures may help mitigate the impact not only to shrews, but to other small animals as well.

- Range improvements, timing of grazing, and adaptive management can be used to maintain hydrologic integrity and necessary vegetation cover in grazing allotments within riparian habitat conservation areas.

- Mechanical fuels removal treatment did not alter the leaf litter nor impact pygmy shrew populations in North Carolina (Greenberg et al. 2007).

V. INVENTORY, MONITORING, AND RESEARCH OPPORTUNITIES

Data and Information Gaps

The basic distribution of this species in Washington State needs to be more clearly delineated. It is possible that surveys may lead to the decision that this species is widespread enough even within eastern Washington that it needs no further special consideration. However, there are insufficient data available currently to determine if this might be the case.

Inventory and Monitoring

Delineating where this species occurs will be an important first step in deciding whether any special management actions are necessary. It is highly likely that populations of *S. h. hoyi* in Washington are contiguous with those in Idaho and Montana, and thus occur in Spokane County as well as in Stevens and Pend Oreille Counties. It is also not known whether the species extends west of the Columbia River, although this is a major barrier to dispersal.

Shrews can be difficult to catch, and a great deal of effort is often needed. Furthermore, most captures result in death. A thorough discussion of issues highly relevant to trapping *S. h. hoyi* can be found in Beauvais and McCumber (2006). Of particular importance is that trapping should be conducted by biologists experienced in shrew biology and during late summer when shrew numbers are thought to peak. These factors will increase the likelihood of detection of these often cryptic animals. All specimens should be saved for definitive identification using dental characteristics, and careful records kept not only on the locations of all traps, but the characteristics of surrounding habitat.

Lethal trapping is required to identify shrews. Although trapping will be necessary to determine where in Washington the species is distributed, any monitoring should be conducted with well-defined, carefully planned prior objectives to ensure the data collected will be adequate to address the conservation or management need. The potential to remove a critical proportion of a population and thus jeopardize its persistence is a risk that should be considered during planning.

Research

Some research may be helpful in exploring the effects of management activities on shrews. For example, roads are hypothesized to be a barrier to the movements of *S. hoyi* (Beauvais and McCumber 2006), but there are no data to evaluate this. Road building may become more necessary as the risk of fire increases with climate change, and understanding the potential risks to sensitive fauna may help guide management decisions so that negative effects are minimized.

Little is understood regarding the population dynamics of this species. Although *S. hoyi* appears to have little overlap between generations, there is evidence of two breeding pulses within a summer in at least some parts of the range. Understanding whether *S. hoyi* is capable of increasing reproductive output in optimal conditions will help in assessing just how vulnerable this species may be to disturbances that may create high mortality in a population. A better understanding of movement potential will also be helpful to determining whether biological corridors such as riparian zones will facilitate persistence.

Acknowledgements

This review was vastly improved by reviews and information supplied particularly by Derek W. Stinson, Wildlife Biologist, Washington Department of Fish and Wildlife. I also thank Chris Loggers, West Zone Wildlife Biologist, Colville National Forest, USFS, Michael A. Borysewicz, East Zone Wildlife Biologist, Colville National Forest, USFS, and John Chatel, Threatened, Endangered, and Sensitive (TES) Program Manager, USFS Region 6, for their thoughtful reviews and comments that also greatly improved this Assessment’s earlier drafts.

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