Shrews in Managed Northern Hardwood Stands in the Allegheny Mountains of West Virginia

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Abstract: Shrews are an abundant and important component of the mammalian fauna in central and southern Appalachian forested habitats. Because most soricids are small, cryptic, and difficult to survey, they typically have been underrepresented in research examining effects of forest management on small mammals. To assess shrew response to clearcutting northern hardwood forests in the Allegheny Mountains of West Virginia, we conducted a pitfall trapping survey during the late spring and early summer of 1998 and 1999 across a chronosequence of northern hardwood stand-ages from recently clearcut to those >60 years old. Capture frequency of masked shrews *(Sorex cinereus),* smoky shrews *(S. fumeus),* and northern short-tailed shrews *(Blarina brevicauda)* did not differ among stand-ages. Shrew captures were influenced more by differences in weather conditions between years and pitfall type. Masked shrew and smoky shrew captures were correlated positively with daily precipitation and negatively with maximum daily temperature in 1999, a severe drought year. Pitfalls placed along natural cover such as downed woody debris and emergent rock captured more masked shrews and smoky shrews than did pitfalls placed in the open forest floor. Rock shrews *(S. dispar)* and pygmy shrews *(S. hoyi),* both habitat specialists that our survey did not target, were collected only in pitfalls placed near cover.

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Although levels of active forest management on public lands continue to decline throughout most of the central and southern Appalachians (Ford et al. 2002), large areas of corporate lands in West Virginia, western Maryland, southeastern Ohio, and eastern Kentucky are devoted to industrial forest management with intensive harvesting (DiGiovanni 1990, Castleberry et al, 2001). This is particularly true in the Allegheny Mountain subsection of the central Appalachians where extensive stands of high-value black cherry *(Prunus serotina)* and northern red oak *(Quercus rubra)* sawtimber occur (Adams et al. 2000). Despite being one of the most heavily forested landscapes in eastern North America, present levels of forest harvest in the region approximate the record timbering that occurred at the turn of the 20th Century (Adams

1999). Moreover, forest management impacts to most non-game wildlife groups are poorly known in the region (Ford and Rodrigue 2001). Forest certification programs for private and corporate forests in this region such as the Sustainable Forest Initiative require the development of wildlife and biodiversity monitoring efforts to quantify both positive and negative forest management impacts (Am. For. and Pap. Assoc. 2002).

The family Soricidae represents a relatively rich mammalian group (6-8 species) in the central and southern Appalachians for which little data linked to forest management exist (Ford et al. 1997). All shrew species that occur in the central and southern Appalachians are considered sensitive, rare, threatened, or endangered from a conservation standpoint in 1 or more states in the region (Laerm et al. 2000). Shrews rarely have been studied as a primary focus due to their cryptic nature and difficulty in collection (Kalko and Handley 1993, Ford et al. 1997). Accordingly, most studies report shrew captures as infrequent or incidental and at relative abundance levels where habitat-relationship inferences are uncertain (Kirkland 1990, Kirkland and Sheppard 1994). However, increased use of pitfall-trapping methodologies over the last decade, particularly in the central and southern Appalachians, has allowed wildlife researchers to begin examining soricid ecology in conjunction with forest management activities (Ford and Rodrigue 2001). Except for the water shrew *(S. palustris),* regionally extant soricids display low vagility and are most closely linked to habitat conditions such as emergent rock or conditions associated with mature forests, such as abundant coarse woody debris and moist micro-sites (Getz 1961, Ford et al. 1994, Pagels et al. 1994, Ford et al. 1997). Therefore, shrews potentially could serve as good barometers of current environmental conditions in managed forests and elsewhere.

In the southern Appalachians of northern Georgia, smoky shrews and northern short-tailed shrews were found to be more abundant in mature (>80 years old) and old-growth cove-hardwood forests at mid-elevations than in stands aged 15, 25, and 50 years post-harvest (Ford et al. 1997). Conversely, in high elevation northern red oak-northern hardwood transition communities in western North Carolina and owing to marked increases in precipitation and decreases in overall mean temperature, masked shrew abundance was not different between recently clearcut group-selection stands and uncut, mature stands (Ford et al. 2000). Similarly, immediate post-harvest effects were not noted after partial overstory removals occurred following diameter-limit harvest in northern hardwood forests in West Virginia because most micro-site habitat measures did not change or had actually improved (increased amounts of downed woody debris) for shrews (Ford and Rodrigue 2001). Therefore, the primary objective of our study was to examine shrew abundance in 3 ages of clearcut northern hardwood forest stands and uncut mature stands in an industrial forest setting in the Allegheny Mountains of West Virginia. As a secondary effort, we assessed how daily precipitation and temperature influenced shrew capture and we examined collection variation in 2 different pitfall trapping methodologies.

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Methods

We surveyed the relative abundance of shrews across 4 stand-ages in northern hardwood forests in May–June 1998 and 1999 at the MeadWestvaco Wildlife and Ecosystem Research Forests (MWERF). The MWERF is a 3,360-ha area in the Unglaciated Allegheny Mountain and Plateau physiographic province of West Virginia (Fenneman 1938) in southwestern Randolph County (38˚42'N, 80˚03'W). Established by the former Westvaco Corporation in 1994, the area is reserved for the study of industrial forestry impacts on ecosystems and ecological processes in an Appalachian setting. Elevations range from 740 to 1200 m and topography consists of steep side-slopes, broad plateau-like ridges, and narrow valleys with small, high-gradient streams. The climate is cool and moist with average annual precipitation exceeding 198 cm, much of which occurs as snow from November through March (NOAA 2002). Forest cover primarily is an Allegheny hardwood-northern hardwood type (Strausbaugh and Core 1977) dominated by beech *(Fagus grandifolia),* yellow birch *(Betula alleghaniensis),* sugar maple *(Acer saccharum),* red maple *(A. rubrum),* black cherry, and Fraser's magnolia *(Magnolia fraseri).* Species from the cove hardwood or mixed mesophytic associations such as yellow-poplar *(Liriodendron tulipifera),* basswood *(Tilia americana),* sweet birch *(Betula lenta)* and northern red oak are present at lower elevations on the MWERF, whereas eastern hemlock *(Tsuga canadensis)* and red spruce *(Picea rubens)* are present at the highest elevations and along sheltered riparian areas. Throughout the MWERF, dense shrub layers of striped maple *(A. pensylvanicum)* and rosebay rhododendron *(Rhodendendron maximum)* are present. An artifact of past forest harvesting and excessive white-tailed deer herbivory, a dense layer of hay-scented fern *(Dennastaedtia punctiloba)* occurs where the shrub layer is absent and the overstory canopy is not continuous (Ford and Rodrigue 2001).

Oldest forest stands on the MWERF are second-growth stands established by natural regeneration following wide-scale railroad logging that occurred in this portion of West Virginia in the 1900–1920s (Clarkston 1993). Currently, MWERF forest stands are managed on 40- to 80-year rotations depending on site characteristics and quality. Harvest methods on site include diameter-limit to remove valuable sawtimber and clearcut and deferment harvests for stand regeneration (Ford and Rodrigue 2001). In 1998, as part of an ongoing ruffed grouse *(Bonasa umbellus)*-arthropod prey ecology study (Dobony 2000), we installed a series of pitfall trapping stations in 3 mature northern hardwood stands (>60 years old), 3 sapling northern hardwood stands (6–15 years post-harvest), 3 newly-regenerated northern hardwood stands (2–5 years post harvest), and 3 recently clearcut northern hardwood stands (≤2 years post-harvest). Harvested stands were approximately 15–20 ha in size. We chose stands to survey by randomly selecting stands within corresponding age classes from all available on the MWERF as indicated by MeadWestvaco FRIS inventory maps.

Within each stand and using a randomly selected GPPS point with that stand as a starting point, we placed 3 trapping stations located 25 m apart (Dobony 2000). At each station, we placed 2 pitfall traps, 1 along a cover object such as downed coarse woody debris or emergent rock and 1 in the forest floor unassociated with cover following the methodologies of Morrill (1975) as modified by McCay et al. (1998). For pitfall traps, we used 943 cm^3 plastic cups filled with a 5% formalin solution to fix and preserve specimens (Handley and Kalko 1993, Ford et al. 1994). We opened pitfall traps from late May through early July in 1998 and 1999. We checked traps daily and removed captured specimens. Pitfall trapping was conducted under the auspices of West Virginia Division of Natural Resources Scientific Collection Permit No. 01-1998 and No. 06-1999. We identified shrews to species based on external morphology and unicuspid dentition patterns (Laerm et al. 1999, Ford and Rodrigue 2001).

Across the MWERF in 1998 and 1999, we maintained a series of 6 portable data loggers (Hobo, StowAway Temperature, Onset Computer Corp., Bourn, Mass.) to record daily high and low temperatures and 12 rain gauges to record daily precipitation (Tru-Check Rain Gauges, Albert Lea, Minn.). We averaged daily temperature and precipitation values over the entire MWERF. Capture frequencies of shrews were compared among forest age-classes and between years using a 2-way ANOVA on ranked data. Kolomogorov D statistics indicated that our shrew collection data were not normally distributed and our efforts to transform data were unsuccessful. We used Scheffe's Test to separate mean ranks of capture frequencies among forest age-classes and years when significant effects ($\alpha = 0.05$) were detected (SAS Inc. 1991). We used Spearman's Rank Correlation (Steel and Torrie 1980) to examine temperature and precipitation influences from the previous 24 hour on daily soricid collections for each species in 1998 and 1999. We also performed the same correlation analysis on shrew captures by year and species with Julian date to determine if there were cumulative effects within year from shrew removal. We examined effect of pitfall type (nature cover and no cover) on total shrew captures for 1998 and 1999 for each species using Wilcoxon 2-sample tests (Steel and Torrie 1980), and we tested for independence between pitfall type and proportional species assemblages in the captures for 1998 and 1999 using Fisher's Exact Test (SAS Inc. 1999).

Results

We sampled 6,600 pitfall trapnights and collected 932 shrews during 1998 and 1999. Soricids were collected on the MWERF were: masked shrew ($N = 644$), rock shrew ($N = 2$), smoky shrew ($N = 238$), pygmy shrew ($N = 5$), and northern short-tailed shrew ($N = 43$). We removed the small numbers of rock shrews, a colluvial talus specialist (Laerm t al. 1997), and pygmy shrews, a species rarely encountered in mesic habitats locally (Ford and Rodrigue 2001) from stand-age comparisons, correlation analyses, and pitfall type comparisons. Capture frequency of masked shrews, smoky shrews, and northern short-tailed shrews did not differ among northern hardwood stand-ages on the MWERF (Table 1). Year effect was not apparent for masked shrews or smoky shrews (Table 1). However, we collected more northern short-tailed

Table 1. Mean capture frequencies of soricids in 3 mature (>60 years), 3 sapling (6–15 years), 3 regeneration (2–5 years) and 3 recently clearcut (≤2 years) northern hardwood stands on the MeadWestvaco Wildlife and Ecosystem Research Forest, Randolph County, West Virginia, 1998–1999.

Species		Mature		Sapling		Regeneration		Clearcut	
		$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Masked shrew[a,b]									
	1998	29.3	7.51	36.0	4.16	22.0	7.21	14.7	4.37
	1999	12.0	3.05	32.7	4.06	42.0	7.21	26.0	11.72
Smoky shrew[a,b]									
	1998	8.7	5.70	17.3	12.45	5.3	2.90	2.7	0.67
	1999	3.3	1.33	17.3	5.45	11.3	5.69	13.3	1.76
Northern short-tailed shrew[a,c]									
	1998	2.0	1.15	1.3	1.30	0.0	0.00	0.7	0.67
	1999	2.7	0.88	3.0	2.52	3.0	1.15	1.7	0.33

a. Forest stand-age effects on ranked data not significant ($P > 0.05$).

b. Year effect not significant on ranked data ($P > 0.05$).

c. Year effect significant on ranked data ($F = 5.83$, *d.f.* = 1, $P = 0.032$) with 1999 >1998.

shrews in 1999 than 1998 (Table 1). No stand-age by year interaction was significant for any species collected.

The 1998 daily collections of masked shrews, smoky shrews, and northern short-tailed shrews were not correlated with total daily rainfall ($\bar{x}$ = 0.6 cm, SE = 0.18, range = 0 to 8.3 cm), whereas captures of these species were correlated positively with total daily rainfall ($\bar{x}$ = 0.3 cm, SE = 0.12, range = 0 to 4.3 cm) in 1999 (Table 2). The 1998 daily collections of masked shrews, smoky shrews, and northern short-tailed shrews were not correlative with maximum daily temperature ($\bar{x}$ = 24.6 C, SE = .67, range = 10.8 to 31.4 C), whereas captures of masked shrews and northern short-tailed shrews were correlated negatively with maximum daily temperature ($\bar{x}$ = 26.5 C, SE = 0.69, range = 14.0 to 35.9 C) in 1999 (Table 2). The 1998 daily captures of masked shrews, smoky shrews, and northern short-tailed shrews were not correlated with minimum daily temperature in 1998 ($\bar{x}$ = 12.8 C, SE = 0.44, range = 4.5 to 18.5 C) or 1999 ($\bar{x}$ = 11.6 C, SE = 0.62, range = 3.1 to 19.8 C) (Table 2). Julian date was not correlated with daily captures of masked shrews, smoky shrews, or northern short-tailed shrews in 1998 or 1999 (Table 2).

More masked shrews and smoky shrews were captured in pitfalls along natural cover objects than those pitfalls placed in the open in both 1998 and 1999 (Table 3). There were no differences in the number of northern short-tailed shrews captured among pitfall type in 1998 or 1999 (Table 3). Observed species assemblages of shrews by the 2 pitfall trap types did not differ in 1998 (Fisher's exact test, $P = 0.32$) or 1999 (Fisher's exact test, $P = 0.49$).

Table 2. Spearman's Rank Correlation coefficients between daily soricid captures and previous 24-hour rainfall, maximum daily temperature, minimum daily temperature, and Julian date on the MeadWestvaco Wildlife and Ecosystem Research Forest, Randolph County, West Virginia, 1998–1999.

	Masked shrew		Smoky shrew		Northern short-tailed shrew	
	r_s	*P*	r_s	*P*	r_s	*P*
Rainfall (cm)						
1998 (*N* = 50)	0.09	0.52	0.16	0.23	0.17	0.21
1999 (*N* = 45)	0.40	0.01	0.44	0.002	0.46	0.001
Maximum temp. (c)						
1999 (*N* = 52)	-0.21	0.12	-0.26	0.06	-0.07	0.62
1999 (*N* = 50)	-0.30	0.03	-0.26	0.06	-0.37	0.01
Minimum temp. (c)						
1998 (*N* = 52)	-0.25	0.07	-0.11	0.42	0.04	0.75
1999 (*N* = 50)	0.04	0.73	0.10	0.48	-0.14	0.39
Julian date						
1998 (*N* = 52)	-0.17	0.21	-0.26	0.06	-0.07	0.62
1999 (*N* = 50)	0.01	0.96	-0.04	0.73	-0.21	0.15

Table 3. Mean capture frequencies of soricids between pitfall trapping stations placed along natural cover and those in the open forest floor in 12 northern hardwood stands on the MeadWestvaco Wildlife and Ecosystem Research Forest, Randolph County, West Virginia, 1998–1999.

	Natural cover		*No cover*			
Species	$\bar{x}$	SE	$\bar{x}$	SE	*Z*[a]	*P*
Masked shrew						
1998	16.5	2.33	9.0	1.89	2.20	0.02
1999	18.2	3.5	10.0	2.23	1.74	0.04
Smoky shrew						
1998	6.3	2.44	2.2	1.14	1.68	0.05
1999	7.8	1.73	3.5	1.32	1.87	0.03
Northern short-tailed shrew						
1998	0.7	0.28	0.3	0.22	0.88	0.18
1999	1.6	0.04	1.0	0.41	1.18	0.12

a. Comparison of ranked data between pitfall trapping stations with cover and without cover.

Discussion

Although the small replication and low power in our study design limits the definitive conclusions we can infer from our study, we found trends that would suggest no long-term biological impact or meaningful change to masked shrew, smoky shrew, and northern short-tailed shrew captures across a series of northern hardwood stands that originated from clearcutting. These responses are unlike negative impacts noted for other biotic groups such as spring ephemeral herbs (Duffy and Meier 1992), moths (Buford et al. 1999), or woodland salamanders (Ford et al. 2002) in central and southern Appalachian forests. Our work targeted towards shrews provides the missing elements to previous research in the central and southern Appalachians that did not employ pitfall methodologies in northern hardwood stands of various ages (Kirkland 1977, Kirkland 1978*a*, Healy and Brooks 1988). Moreover, our "long-view" chronosequence study compliments shrew research that only examined short-term harvesting impacts in northern hardwoods (Ford et al. 2000, Ford and Rodrigue 2001). We believe that our work and that preceding this study show that forest management activities in the central and southern Appalachians are compatible with the conservation of soricid communities.

Masked shrews can respond favorably to forest disturbance in northern hardwoods (Kirkland 1977, Ford et al. 2000) and other high elevation communities in the central and southern Appalachians (Mitchell et al. 1997). Pagels et al. (1994) hypothesized that optimal masked shrew habitat varies across wide soil moisture, soil pH, and overstory vegetation conditions, as well as with wide variations in downed woody debris and emergent rock, so long as the shaded, moist conditions described by Getz (1961) are present. Following deferment or "leave-tree" timber harvests on the MWERF, there were decreases in measured levels of micro-habitat variables such as canopy cover and leaf litter. Conversely, these decreases probably were ameliorated somewhat by tremendous increases in downed woody debris that served as refuge and feeding substrates for masked shrews and other soricids (Ford and Rodrigue 2001). The rapid growth of new hardwood regeneration quickly shades the forest floor within 2–3 growing seasons and keeps light penetration to the forest floor at a minimum until the late pole stage of growth (Kirkland 1978*a*, Beck and Hooper 1986). Additionally, the MWERF is located within a portion of the Allegheny Mountains in West Virginia that typically receives the highest annual amounts of precipitation and has the lowest maximum mean temperatures in the growing season.

From the southern terminus of the Appalachians in Georgia and north to New England, smoky shrews show marked increases in relative abundance as forest stands age (DeGraaf et al. 1991, Ford et al. 1997). Nonetheless, efforts to link smoky shrew abundance with micro-habitat variables, such as downed woody debris amounts, in the central and southern Appalachians have proven inconclusive (Ford et al. 1994, Menzel et al. 1999, Ford and Rodrigue 2001). Impacts of forest harvesting in northern hardwoods on the largely fossorial northern short-tailed shrews also have been difficult to interpret. Ford et al. (1997) reported significantly higher relative abundances in cove hardwood stands >25 years old than in younger stands, whereas in nearby northern hardwood forests, no difference between recently cut and uncut stands was detected (Ford et al. 2000). DeGraaf et al, (1991) believed that northern short-tailed shrew abundance is not tied to forest stand-age per se, but rather is linked to a complex set of micro-habitat conditions that promote high relative humidity levels in subsurface burrows (Pruitt 1959, Getz 1961). In the Allegheny Mountains of West Virginia, Kirkland (1978*b*) only failed to find northern short-tailed shrews in a handful of recent clearcuts on xeric aspects that had diminished leaf litter, desiccated soils, and poor post-harvest herbaceous growth and woody regeneration.

The link between soricid abundance and cool, moist micro-habitat conditions clearly has been shown for masked shrews, smoky shrews, and northern short-tailed shrews (Getz 1961, DeGraaf et al. 1991). However, we believe our study was the first to examine daily precipitation and temperature data in conjunction with ongoing pitfall trapping activity in eastern North America. Although we hesitate to label late spring and early summer of 1998 as climatically normal at the MWERF, the late spring and early summer of 1999 was regarded by the U.S. Department of Agriculture as a severe drought period in the mid-Atlantic, including all of the Allegheny Mountain subsection (USDA 1999). We recorded approximately twice as much precipitation and the minimum and maximum temperature ranges were approximately 4 C less in 1998 than in 1999. In the cooler and moister conditions of 1998, correlations between daily weather data and shrew captures were not noted. However, the opposite was true in 1999 as shrew captures (and by implications shrew activity) were correlated positively with periods of greater precipitation and were correlated negatively with warmer temperatures. Accordingly, weather-related effects on soricid captures should be accounted for in future research efforts, especially when sampling occurs during periods of aberrant or extreme weather patterns. Summer drought impacts to northern short-tailed shrew reproductive success probably are minimal, but drought conditions do appear to reduce summer survival of the post-reproductive overwintered adults (Getz 1994). It is plausible that we collected more northern short-tailed shrew in 1999 because below-ground conditions during the drought were not optimal for the species.

Pitfalls placed along drift-fences or natural cover items take advantage of the fact that many small mammal species show a proclivity for drifting behavior (Brillhart and Kaufman 1991). Our data demonstrated this with greater captures of masked shrews and smoky shrews in pitfalls placed along natural cover than those placed in the open. All of our captures of rock shrews and pygmy shrews also occurred at covered pitfalls. Similar to the finding of McCay et al. (1998), we found that northern short-tailed shrews were not captured at a greater rate in covered pitfalls. George et al. (1986) noted that northern short-tailed shrews probably do not move aboveground on the forest floor as much as members of the genus *Sorex*, and thus are less likely to be more susceptible to covered rather than open pitfall traps. Despite collecting rock shrews and pygmy shrews only along cover, our analyses showed reduced captures of soricids in open pitfalls still approximated the same species assemblage as captures in covered pitfalls. From a biological inventory survey standpoint, this is a significant finding as the effort and time required to install an open pitfall trap in the forest floor is substantially less than that required to place pitfalls along downed woody debris or emergent rock. Also, pitfalls placed in the open might be more suitable for survey standardization purposes with less inherent bias than subjectively choosing natural cover for pitfall locations.

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