Virginia Journal of Science
Volume 66, Issue 3
Fall 2015

Virginia's Land Mammals: Past and Present, with Some Thoughts About Their Possible Future

John F. Pagels[1,2] and Nancy D. Moncrief [*2]

[1]Department of Biology, Virginia Commonwealth University, Richmond, Virginia 23284,
[2]Virginia Museum of Natural History, Martinsville, VA 24112

ABSTRACT

Mammals encountered today in Virginia's forests and fields include native and nonnative species, feral populations, and free-ranging pets. We examine factors that have influenced Virginia's terrestrial mammal fauna since the arrival of European colonists in the 1600s and some of the factors that are shaping the fauna today. We look in depth at changes since Handley and Patton's (1947) first complete monograph on Virginia mammals and augment Linzey's (1998) book, *The Mammals of Virginia*. We include current nomenclature, baseline information, and references to comprehensive literature. We discuss some of the current and developing anthropogenic factors that have impacted, or that likely will impact, our native land mammals as well as factors that bode well for many species, especially in areas of conservation of habitat.

BACKGROUND

Approximately 115 species of mammals live in or frequent Virginia; of these, about 28 are marine mammals (e.g., porpoises, whales, seals, and manatees) that are known from its shores, bays, and tidal rivers (Handley and Patton 1947; Linzey 1998). Including extirpated species, 77 species of native land mammals (those species that occurred here or reached here without purposeful or accidental introduction by humans) have been recorded since Europeans arrived in Virginia (Table 1). The diversity of Virginia's land mammals reflects a complex history of evolution, adaptation, and migration that has occurred over millions of years on a varied land surface and under changing climatic conditions (Woodward and Hoffman 1991). With elevations ranging from sea level to more than 1,500 m, the east-west orientation of the long axis of the state intersects five physiographic regions (Fig. 1), which results in a wide variety of habitats. As detailed by Handley (1992), most (42 of 74 extant species) Virginia land mammals have boreal (northern) affinities and the rest have austral (southern) affinities (Table 1). As a general rule, boreal species either occur statewide or in the west. By contrast, austral species tend to occur only in the east or south if their distributions are not statewide. As a result of its latitudinal position, Virginia is near the northern edge of the distributions of about a dozen austral species and the southern edge of

* - Corresponding author -- nancy.moncrief@vmnh.virginia.gov

TABLE 1. Land mammals native to Virginia, including species present at the time of European contact and those that have naturally colonized Virginia since that time. Common or vernacular name (as suggested by Wilson and Reeder 2005) is indicated for each species, along with current classification, current distribution, distributional affinity (distrib. affinity, after Handley 1992), habitat in Virginia, and the citation for a comprehensive monograph or review of the biology of that species. Virginia's Eastern Shore is comprised of Accomack and Northampton counties, at the southern end of the Delmarva Peninsula. For bats (Chiroptera), habitat describes roost sites, which may change seasonally. The following denote special circumstances that are detailed in text: E= extirpated; ER= extirpated (or nearly so), restoration attempted; EE = extirpated (or nearly so), range expansion from nearby states; A = augmented to increase populations and/or restore regionally.

Scientific name	Common name	Family	Order	Distribution	Distrib. affinity	Habitat	Citation
Didelphis virginiana	Virginia opossum	Didelphidae	Didelphimorphia	statewide	austral	generalist	McManus 1974
Sorex cinereus	cinereus shrew	Soricidae	Soricomorpha	mountains and Eastern Shore	boreal	generalist	Whitaker 2004
Sorex dispar	long-tailed shrew	Soricidae	Soricomorpha	mountains	boreal	forest, rocks and boulders	Kirkland 1981
Sorex fumeus	smoky shrew	Soricidae	Soricomorpha	mountains	boreal	forest	Owen 1984
Sorex hoyi	American pygmy shrew	Soricidae	Soricomorpha	statewide except Eastern Shore	boreal	generalist	Long 1974
Sorex longirostris	southeastern shrew	Soricidae	Soricomorpha	statewide except Eastern Shore	austral	oldfield, early succession	French 1980
Sorex palustris	American water shrew	Soricidae	Soricomorpha	mountains	boreal	mountain headwater streams	Beneski and Stinson 1987

TABLE 1. Continued.

Scientific name	Common name	Family	Order	Distribution	Distrib. affinity	Habitat	Citation
Blarina brevicauda	northern short-tailed shrew	Soricidae	Soricomorpha	statewide except south-central and parts of east	austral	generalist	George et al. 1986
Blarina carolinensis	southern short-tailed shrew	Soricidae	Soricomorpha	south-central and parts of east except Eastern Shore	austral	generalist	McCay 2001
Cryptotis parva	North American least shrew	Soricidae	Soricomorpha	statewide	austral	oldfield, early succession	Whitaker 1974
Parascalops breweri	hairy-tailed mole	Talpidae	Soricomorpha	mountains	boreal	generalist	Hallett 1978
Scalopus aquaticus	eastern mole	Talpidae	Soricomorpha	statewide	boreal	generalist	Yates and Schmidly 1978
Condylura cristata	star-nosed mole	Talpidae	Soricomorpha	statewide	boreal	near water	Petersen and Yates 1980
Myotis austroriparius	southeastern myotis	Vespertilionidae	Chiroptera	east except Eastern Shore	austral	buildings	Jones and Manning 1989

TABLE 1. Continued.

Scientific name	Common name	Family	Order	Distribution	Distrib. affinity	Habitat	Citation
Myotis grisescens	gray myotis	Vespertilionidae	Chiroptera	mountains, southwest	austral	caves	Decher and Choate 1995
Myotis leibii	eastern small-footed myotis	Vespertilionidae	Chiroptera	mountains	boreal	caves and rocky outcrops	Best and Jennings 1997
Myotis lucifugus	little brown myotis	Vespertilionidae	Chiroptera	statewide	boreal	caves and buildings, hollow trees, under tree bark	Fenton and Barclay 1980
Myotis septentrionalis	northern myotis	Vespertilionidae	Chiroptera	statewide	boreal	caves and buildings, hollow trees, under tree bark	Caceres and Barclay 2000
Myotis sodalis	Indiana myotis	Vespertilionidae	Chiroptera	mountains	austral	caves, hollow trees, under tree bark	Thomson 1982
Lasiurus borealis	eastern red bat	Vespertilionidae	Chiroptera	statewide	austral	tree foliage	Shump and Shump 1982a

TABLE 1. Continued.

Scientific name	Common name	Family	Order	Distribution	Distrib. affinity	Habitat	Citation
Lasiurus cinereus	hoary bat	Vespertilionidae	Chiroptera	statewide	austral	tree foliage	Shump and Shump 1982b
Lasiurus intermedius	northern yellow bat	Vespertilionidae	Chiroptera	southeast (one record)	austral	tree foliage	Webster et al. 1980
Lasiurus seminolus	Seminole bat	Vespertilionidae	Chiroptera	southeast (one record)	austral	tree foliage	Wilkins 1987
Lasionycteris noctivagans	silver-haired bat	Vespertilionidae	Chiroptera	statewide	boreal	tree foliage, under tree bark	Kunz 1982
Perimyotis subflavus	tri-colored bat	Vespertilionidae	Chiroptera	statewide	austral	caves, tree foliage, and buildings	Fujita and Kunz 1984
Eptesicus fuscus	big brown bat	Vespertilionidae	Chiroptera	statewide	boreal	caves, hollow trees, and buildings	Kurta and Baker 1990
Nycticeius humeralis	evening bat	Vespertilionidae	Chiroptera	primarily east of Blue Ridge	austral	hollow trees and buildings	Watkins 1972

TABLE 1. Continued

Scientific name	Common name	Family	Order	Distribution	Distrib. affinity	Habitat	Citation
Corynorhinus rafinesquii	Rafinesque's big-eared bat	Vespertilionidae	Chiroptera	southeast except Eastern Shore	austral	hollow trees and buildings	Jones 1977
Corynorhinus townsendii	Townsend's big-eared bat	Vespertilionidae	Chiroptera	mountains	boreal	caves and rocky outcrops	Kunz and Martin 1982
Tadarida brasiliensis	Brazilian free-tailed bat	Molossidae	Chiroptera	statewide except Eastern Shore	austral	buildings	Wilkins 1989
Sylvilagus floridanus	eastern cottontail	Leporidae	Lagomorpha	statewide	austral	oldfield, forest edge	Chapman et al. 1980
Sylvilagus obscurus	Appalachian cottontail	Leporidae	Lagomorpha	mountains	boreal	forest	Chapman 2007a
Sylvilagus palustris	marsh rabbit	Leporidae	Lagomorpha	southeast except Eastern Shore	austral	marsh,wet areas	Chapman and Willner 1981
Lepus americanus ***ER***	snowshoe hare	Leporidae	Lagomorpha	mountains	boreal	forest, dense understory	Chapman 2007b
Tamias striatus	eastern chipmunk	Sciuridae	Rodentia	statewide	boreal	generalist, wooded	Snyder 1982
Marmota monax	woodchuck	Sciuridae	Rodentia	statewide	boreal	generalist	Kwiecinski 1998

TABLE 1. Continued.

Scientific name	Common name	Family	Order	Distribution	Distrib. affinity	Habitat	Citation
Sciurus carolinensis	eastern gray squirrel	Sciuridae	Rodentia	statewide	boreal	forest	Koprowski 1994a
Sciurus niger ***A***	eastern fox squirrel	Sciuridae	Rodentia	west and southeast and Eastern Shore	austral	forest	Koprowski 1994b
Tamiasciurus hudsonicus	red squirrel	Sciuridae	Rodentia	mountains and upper Piedmont	boreal	mixed forest	Steele 1998
Glaucomys sabrinus	northern flying squirrel	Sciuridae	Rodentia	mountains	boreal	forest, northern hardwood, spruce/fir	Wells-Gosling and Heaney 1984
Glaucomys volans	southern flying squirrel	Sciuridae	Rodentia	statewide	austral	forest	Dolan and Carter 1977
Castor canadensis ***ER***	American beaver	Castoridae	Rodentia	statewide	boreal	forest, near water	Jenkins and Busher 1979
Oryzomys palustris	marsh oryzomys	Cricetidae	Rodentia	lower Piedmont and east	austral	near water	Wolfe 1982

TABLE 1. Continued.

Scientific name	Common name	Family	Order	Distribution	Distrib. affinity	Habitat	Citation
Reithrodontomys humulis	eastern harvest mouse	Cricetidae	Rodentia	statewide except Eastern Shore	austral	oldfield	Stalling 1997
Peromyscus gossypinus	cotton deermouse	Cricetidae	Rodentia	east except Eastern Shore	austral	lowland forests, swamps	Wolfe and Linzey 1977
Peromyscus leucopus	white-footed deermouse	Cricetidae	Rodentia	statewide	boreal	generalist	Lackey et al. 1985
Peromyscus maniculatus	North American deermouse	Cricetidae	Rodentia	mountains and upper Piedmont	boreal	forest and oldfield	Laerm and Castleberry 2007
Ochrotomys nuttalli	golden mouse	Cricetidae	Rodentia	southern half of state except Eastern Shore	austral	disturbed areas in forests, forest edges	Linzey and Packard 1977
Sigmodon hispidus	hispid cotton rat	Cricetidae	Rodentia	extreme southwest; Blue Ridge to east except Eastern Shore	austral	oldfield	Cameron and Spencer 1981

TABLE 1. Continued.

Scientific name	Common name	Family	Order	Distribution	Distrib. affinity	Habitat	Citation
Neotoma magister	Allegheny woodrat	Cricetidae	Rodentia	mountains	austral	caves, outcrops with boulders	Castleberry et al. 2006
Myodes gapperi	southern red-backed vole	Cricetidae	Rodentia	mountains	boreal	mesic forest, coarse woody debris, rocks	Merritt 1981
Microtus chrotorrhinus	rock vole	Cricetidae	Rodentia	mountains	boreal	mesic forest, rocks, logs, roots	Kirkland and Jannett 1982
Microtus pennsylvanicus	meadow vole	Cricetidae	Rodentia	statewide	boreal	oldfield, grasslands	Reich 1981
Microtus pinetorum	woodland vole	Cricetidae	Rodentia	statewide	austral	brushy, orchards	Smolen 1981
Ondatra zibethicus	common muskrat	Cricetidae	Rodentia	statewide	boreal	near water	Willner et al. 1980
Synaptomys cooperi	southern bog lemming	Cricetidae	Rodentia	mountains and southeast except Eastern Shore	boreal	bogs, wet meadows	Linzey 1983

TABLE 1. Continued.

Scientific name	Common name	Family	Order	Distribution	Distrib. affinity	Habitat	Citation
Zapus hudsonius	meadow jumping mouse	Dipodidae	Rodentia	statewide	boreal	oldfield	Whitaker 1972
Napaeozapus insignis	woodland jumping mouse	Dipodidae	Rodentia	mountains	boreal	forest	Whitaker and Wrigley 1972
Erethizon dorsatum ***EE***	North American porcupine	Erethizontidae	Rodentia	mountains	boreal	generalist	Woods 1973
Canis latrans	coyote	Canidae	Carnivora	statewide	boreal	generalist	Bekoff 1977
Canis lupus ***E***	wolf	Canidae	Carnivora	not present	boreal	not present	Mech 1974
Vulpes vulpes	red fox	Canidae	Carnivora	statewide	boreal	oldfield, open woodlands	Larivière and Pasitschniak -Arts 1996
Urocyon cinereoargenteus	gray fox	Canidae	Carnivora	statewide	austral	forest, brushy woodlands	Fritzell and Haroldson 1982
Ursus americanus	American black bear	Ursidae	Carnivora	statewide except Eastern Shore	boreal	forests primarily	Larivière 2001

TABLE 1. Continued.

Scientific name	Common name	Family	Order	Distribution	Distrib. affinity	Habitat	Citation
Procyon lotor	raccoon	Procyonidae	Carnivora	statewide	austral	generalist	Lotze and Anderson 1979
Pekania pennanti ***EE***	fisher	Mustelidae	Carnivora	mountains	boreal	forest	Powell 1981
Mustela frenata	long-tailed weasel	Mustelidae	Carnivora	statewide	austral	generalist	Sheffield and Thomas 1997
Mustela nivalis	least weasel	Mustelidae	Carnivora	statewide except Eastern Shore	boreal	generalist	Sheffield and King 1994
Neovison vison	American mink	Mustelidae	Carnivora	statewide	boreal	near water	Larivière 1999
Lontra canadensis ***A***	North American river otter	Mustelidae	Carnivora	statewide	boreal	near water	Larivière and Walton 1998
Spilogale putorius	eastern spotted skunk	Mephitidae	Carnivora	west	austral	forest	Kinlaw 1995
Mephitis mephitis	striped skunk	Mephitidae	Carnivora	statewide	boreal	generalist	Wade-Smith and Verts 1982

TABLE 1. Continued.

Scientific name	Common name	Family	Order	Distribution	Distrib. affinity	Habitat	Citation
Lynx rufus	bobcat	Felidae	Carnivora	statewide	boreal	generalist, much cover	Larivière and Walton 1997
Puma concolor ***E***	cougar	Felidae	Carnivora	not present	boreal	not present	Currier 1983
Odocoileus virginianus ***A***	white-tailed deer	Cervidae	Artiodactyla	statewide	austral	generalist	Smith 1991
Cervus canadensis ***ER***	wapiti	Cervidae	Artiodactyla	extreme southwest	boreal	clearings in high-elevation forests	Maehr et al. 2007
Bison bison ***E***	American bison	Bovidae	Artiodactyla	not present	boreal	not present	Meagher 1986

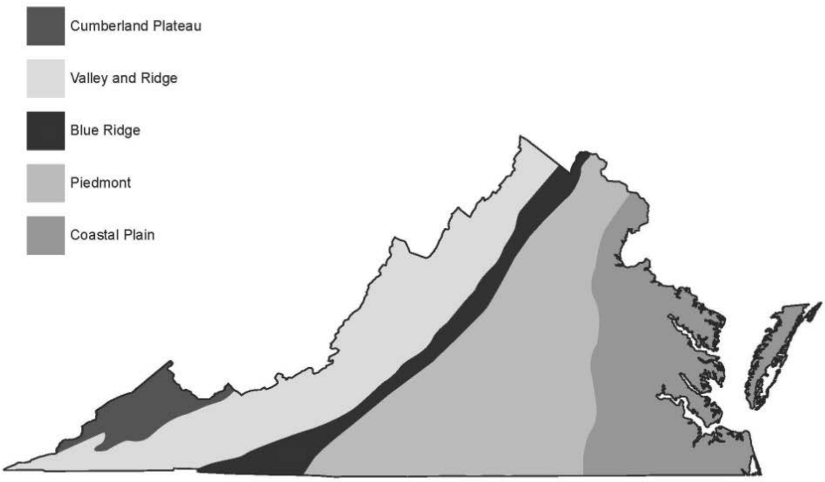

FIGURE 1. The physiographic provinces of Virginia.

distribution for about as many boreal species (Hall 1981). Ranges and statuses of several boreal species were the subject of a recent study by Campbell et al. (2010), motivated in part by Dobson et al.'s (1997) identification of the central and southern Appalachian mountains as a "hot spot of threatened biodiversity." The central and southern Appalachians have many specialized habitats, including caves, cliffs, talus, bogs, and boreomontane forests, that support populations of 7 of the 11 extant species listed in Virginia as threatened or endangered (Tables 1 and 2).

In this review, we summarize current information about the distribution and species composition of Virginia's native land mammals, with emphasis on studies that documented changes in the land mammal fauna since Handley and Patton's 1947 monograph. We also discuss long-term and ongoing threats to native species in the state. In doing so, we cite key literature that directs present and future students of Virginia mammals to pertinent resources.

HISTORICAL OVERVIEW

The history of the study of land mammals in Virginia was summarized recently by Linzey (1998) and Rose (2013). Although many mammals, especially game species, were documented and described by the earliest European explorers, and later by colonists, in the late 1500s and early 1600s, Rose (2013) credits C. H. Merriam with conducting the first systematic studies of Virginia's mammals in the late 1800s. Both Linzey (1998) and Rose (2013) characterize Handley and Patton's (1947) book *Wild Mammals of Virginia* as being the seminal work for chronicling the mammal fauna of the state. Therefore, we use that book as a basis for comparison throughout this review.

Rose (2013) acknowledged contributions in recent decades by a number of researchers that increased our understanding of mammals in particular regions of

TABLE 2. Special legal status (as of 13 April 2016) of native land mammals extant in Virginia (USFWS 2016, VDGIF 2016). The common, or vernacular, names are those used by the Virginia Department of Game and Inland Fisheries.

Scientific name	Common name	State legal status	Federal legal status
Sorex palustris	American water shrew	endangered	
Myotis grisescens	gray bat	endangered	endangered
Myotis lucifugus	little brown bat	endangered	
Myotis septentrionalis	northern long-eared bat	threatened	threatened
Myotis sodalis	Indiana bat	endangered	endangered
Perimyotis subflavus	tri-colored bat	endangered	
Corynorhinus rafinesquii macrotis	Rafinesque's eastern big-eared bat	endangered	
Corynorhinus townsendii virginianus	Virginia big-eared bat	endangered	endangered
Lepus americanus	snowshoe hare	endangered	
Glaucomys sabrinus coloratus	Carolina northern flying squirrel	endangered	endangered
Microtus chrotorrhinus	rock vole	endangered	

Virginia. To Rose's (2013) list we add W. M. Ford and J. L. Orrock, especially for their work in western Virginia, R. E. Eckerlin for work on mammals and their parasites, and J. C. Mitchell for his collaborative studies.

Handley and Patton (1947) described mammals known to occur in the state, those that were already extirpated by the early 1900s, and species from nearby states not yet recorded in Virginia. Subsequent publications of Handley (1979a, 1991) summarized information about Virginia's threatened and endangered mammal species. In addition to detailing changes in species composition since the Pleistocene, Handley (1992) commented on destruction of habitat, climate change, and other ongoing threats to mammals. Linzey's (1998) book, which included a comprehensive bibliography, summarized information for all mammals in Virginia.

NATIVE TAXA OVER TIME

Taxonomic changes since 1947 – In the nearly 70 years since Handley and Patton (1947), revisions in systematics and taxonomy reflect changes in our understanding of the evolutionary relationships of many mammals that inhabit Virginia (Table 3). We use the nomenclature for scientific names and vernacular, or common, names recognized by authors of taxonomic accounts in Wilson and Reeder (2005), with a few

TABLE 3. Current scientific name, scientific name (synonym) for the same taxon used by Handley and Patton (1947), if the names differ between publications, and citation(s) that documents our reason(s) for using a different name.

Current scientific name	Scientific name in Handley and Patton (1947)	Citation
Sorex hoyi	*Microsorex hoyi*	George 1988
Blarina brevicauda	*Blarina telmalestes*	George et al. 1986
Blarina carolinensis	*Blarina brevicauda carolinensis*	Genoways and Choate 1972; Tate et al. 1980
Myotis leibii	*Myotis subulatus leibii*	Glass and Baker 1968; Herd 1987
Myotis septentrionalis	*Myotis keenii septentrionalis*	van Zyll de Jong 1979
Perimyotis subflavus	*Pipistrellus subflavus*	Menu 1984; Hoofer and Van Den Bussche 2003; Hoofer et al. 2006
Corynorhinus rafinesquii	*Corynorhinus macrotis*	Jones 1977; Tumlison and Douglas 1992; Hoofer and Van Den Bussche 2001
Sylvilagus obscurus	*Sylvilagus transitionalis*	Chapman et al. 1992
Ochrotomys nuttalli	*Peromyscus nuttalli*	Blair 1942; Carleton 1980
Myodes gapperi	*Clethrionomys gapperi*	Kretzoi 1964; Carleton et al. 2014
Microtus pinetorum	*Pitymys pinetorum*	Conroy and Cook 2000; Conroy et al. 2001
Ondatra zibethicus	*Ondatra zibethica*	misspelling/gender issue
Vulpes vulpes	*Vulpes fulva*	Larivière and Pasitschniak-Arts 1996
Pekania pennanti	*Martes pennanti*	Li et al. 2014; Samuels and Cavin 2013; Koepfli et al. 2008
Mustela nivalis	*Mustela rixosa*	Sheffield and King 1994; Abramov and Baryshnikov 1999
Neovison vison	*Mustela vison*	Abramov 1999; Kurose et al. 2000
Lontra canadensis	*Lutra canadensis*	van Zyll de Jong 1972; Bininda-Edmonds et al. 1999
Puma concolor	*Felis concolor*	Pocock 1917; Kratochvil 1982

exceptions. We follow the recommendations of Hoofer and Van Den Bussche (2003) and Hoofer et al. (2006) for the tri-colored bat (*Perimyotis subflavus*), and those of Koepfli et al. (2008), Samuels and Cavin (2013), and Li et al. (2014) for the fisher (*Pekania pennanti*). For the wapiti (*Cervus canadensis*), we have followed the recommendations of Ludt et al. (2004), Pitra et al. (2004), and Skog et al. (2009) in recognizing it as a species that is distinct from the elk (*Cervus elaphus*). Handley and Patton (1947) also used the name *Cervus canadensis* for the wapiti, although *Cervus elaphus* was the name applied to this taxon by many subsequent workers (e.g., Hall 1981, Maehr et al. 2007).

Changes in the number of taxa documented since 1947 – The documentation of native taxa of land mammals in Virginia has changed since 1947 due to the collection of specimens and to changes in mammalian systematics (Table 4). One species, the Dismal Swamp short-tailed shrew (*Blarina telmalestes*), was judged to be conspecific with the northern short-tailed shrew (*Blarina brevicauda*), and we have removed it from the list. We have added the southern short-tailed shrew (*Blarina carolinensis*), which was formerly named *Blarina brevicauda carolinensis* (Tables 3 and 4), also because of systematic and taxonomic revisions.

Another taxon, the Maryland shrew (*Sorex cinereus fontinalis*), has been collected in Virginia (Moncrief and Dueser 1998). The systematic status of this shrew is in need of study. Based on morphology, Kirkland (1977) and others (e.g., Van Zyll de Jong 1991) assigned specimens they examined to *Sorex cinereus fontinalis.* On the basis of allozymic evidence, George (1988) recognized *Sorex fontinalis* as a distinct species. A subsequent study that examined mitochondrial DNA (mtDNA) diversification within the *Sorex cinereus* group (Demboski and Cook 2003) seemed to support George's (1988) findings, and another study of relationships within the genus *Sorex* (Hope et al. 2012) reported high mtDNA divergence of eastern populations of *Sorex cinereus* that is also consistent with George's (1988) conclusion. However, Hope et al. (2012) also reported variation at nuclear loci that places all specimens they examined from eastern localities within *Sorex cinereus* (*sensu stricto*). Neither Demboski and Cook (2003) nor Hope et al. (2012) examined specimens from Pennsylvania, Maryland, Delaware, or Virginia, where *Sorex cinereus fontinalis* has been documented. Additionally, as noted by Stewart et al. (1993), George's (1988) analysis included only a few specimens (n = 7) of *Sorex cinereus fontinalis* and may have been subject to sampling error. In the absence of additional, convincing evidence to the contrary, we take a conservative approach and treat this taxon as a subspecies of the cinereus shrew (*Sorex cinereus*). Further, we suggest that additional collections and analyses of specimens of *Sorex* from northern Virginia may reveal the Maryland shrew to have a broader distribution than is now considered to be the case.

Another taxon that requires additional study in Virginia is the wolf (or gray wolf, *Canis lupus*). We note that Linzey (1998) included 2 species of wolves, *Canis lupus* and *Canis rufus* (the red wolf), in his accounts of Virginia mammals. Since the publication of Linzey's book in 1998, numerous morphologic and genetic studies (reviewed by Chambers et al. 2012) have been conducted on *Canis* in North America in order to determine how many different species should be recognized in this genus and to determine the historic distributions of species of *Canis* on this continent. All studies of taxa in eastern North America have been hampered by a scarcity of museum

TABLE 4. Changes in documentation of native taxa of land mammals in Virginia since 1947 (Handley and Patton 1947), with citations that provide details about these changes.

Scientific name	Change	Reason for change	Citation
Sorex dispar	added to list	specimens collected	Handley 1956; Holloway 1957; Pagels 1987
Sorex palustris	added to list	specimens collected	Pagels and Tate 1976; Pagels et al. 1991; Pagels et al. 1998
Blarina telmalestes	removed from list	taxonomic revision	George et al. 1986; Handley 1979b; Webster et al. 2011
Blarina carolinensis	added to list	taxonomic revision	Handley 1971; Genoways and Choate 1972; Ellis et al. 1978; Tate et al. 1980
Myotis austroriparius	added to list	specimens collected	Hobson 1998
Myotis grisescens	added to list	specimens collected	Holsinger 1964; Decher and Choate 1995
Myotis leibii	added to list	specimens collected	Johnson 1950
Lasiurus intermedius	added to list	specimen collected	Rageot 1955; Webster et al. 1980
Lasiurus seminolus	added to list	specimen collected	Padgett 1987; Padgett and Rose 1991
Corynorhinus townsendii	added to list	specimens reported	Handley et al. 1979
Tadarida brasiliensis	added to list	specimens reported	Cranford and Fortune 1994; Reynolds and Fernald 2015
Glaucomys sabrinus	added to list	specimens collected	Handley 1979a; Reynolds et al. 1999
Peromyscus maniculatus bairdii	added to list	specimens collected	Peacock and Peacock 1962; Pitts and Kirkland 1987
Microtus chrotorrhinus	added to list	specimens collected	Pagels 1990; Orrock et al. 1999
Canis latrans	added to list	specimens collected	Hill et al. 1987; Bozarth et al. 2011

specimens, which has resulted in substantial chronological and geographic gaps in the data. None of these studies, including Nowak's (2002) widely cited work on the historical distribution of the red wolf, examined material from Virginia. Nevertheless, Nowak (2002) and Chambers et al. (2012) included the entire state of Virginia in the historical distribution of the red wolf and considered it to have been the only species present in Virginia at the time of European contact.

Wolves were extirpated from Virginia and most of North America east of the Mississippi River by the early 1900s (Handley and Patton 1947, Linzey 1998, Nowak 2002). Linzey (1998) reported that no wolf specimens from Virginia (of either *Canis lupus* or *Canis rufus*) are known to exist in collections. Our searches of collections records and our literature review for this project revealed specimens identified as *Canis* sp. in prehistoric deposits from Virginia (Eshelman and Grady 1986, FAUNMAP Working Group 1994). Until this material, or other evidence from Virginia, can be analyzed, we take a conservative approach and recognize a single species, *Canis lupus*, which, as defined by Wilson and Reeder (2005), includes specimens referable to *rufus*.

Species known to occur in nearby states in 1947 – Thirteen taxa have been recorded as new to Virginia since 1947 (Table 4), although many of them were known from adjacent states, and Handley and Patton (1947) speculated that seven of these species did, in fact, occur here. For example, the eastern small-footed myotis (*Myotis leibii*) and the gray myotis (*Myotis grisescens*) were known from West Virginia and Tennessee, respectively, in 1947, and Handley and Patton (1947) encouraged work to document these species in Virginia.

In several cases, the first individuals collected in Virginia were only captured by intensive survey efforts and/or by using methods that were not common in the past. Snap traps, live traps, and mist nets are often used for mammal studies. However, such trapping can be labor- and time-intensive, may not be legally permitted, or may be ineffective for detection of some species. Pitfall traps have been especially useful in studies of shrews (Handley and Kalko 1993, Padgett and Rose 1994), including the American water shrew (*Sorex palustris;* Pagels and Tate 1976, Pagels 1987). Also, largely with the use of pitfall traps, Rose (2006) found that a thought-to-be-extinct subspecies of the southern bog lemming (*Synaptomys cooperi*) was widespread in southeastern Virginia. Nest boxes attached to trees are often the most effective method for capturing arboreal squirrels (Pagels et al. 1990). Technological advances have revolutionized our ability to detect and identify species of mammals. For example, polymerase-chain-reaction analysis of DNA may only require the "capture" of hairs (Moncrief et al. 2008) or scat (Bozarth et al. 2011) to document the presence of a species. Remotely triggered digital game cameras, such as those used in the observations of the fisher and porcupine (*Erethizon dorsatum*), as discussed below, are often now used in surveys in combination with other trap types (i.e., Chupp et al. 2013). Such cameras can document species that would go undetected using traditional traps and permit broadscale survey efforts that would otherwise be cost-prohibitive (Erb et al. 2012). Similarly, increasingly sophisticated ultrasonic detectors are now used for bat surveys (Britzke et al. 2011).

Among the 13 new taxa collected since 1947 (Table 4) are the American water shrew, northern flying squirrel (*Glaucomys sabrinus*), and rock vole (*Microtus chrotorrhinus*). These species are largely confined to high elevation sites (i.e., mountain-top "islands" or nearly so) in the western part of the state (Table 1), and all are considered boreal Ice Age relicts (Handley 1992). Habitat specialization, limited geographical distributions, and apparent small population sizes of these species in Virginia reflect characteristics of threatened and endangered species (Yu and Dobson 2000).

The American water shrew lives in high-elevation moist, cool, largely undisturbed shaded habitats, which have likely prevailed throughout historic time (Pagels et al. 1991). Known from five sites in Bath and Highland counties along nearly pristine headwater streams (Pagels and Tate 1976, Pagels et al. 1998), the American water shrew is endangered in Virginia (Table 2).

The Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*), known only from Highland County, was recently delisted from federal endangered status (USFWS

2008, 2013b), and it was subsequently removed from the state endangered species list (B. Gwynn, pers. comm.). We disagree with the DGIF's actions to delist this taxon in Virginia. The Virginia northern flying squirrel occurs at only a few sites in Highland County, and its habitat (high elevation northern hardwood and northern conifer) is very rare in Virginia, as detailed below. For these reasons, we contend that this taxon is in danger of extirpation in Virginia, and therefore, warrants protection under the Virginia Endangered Species Act. A second subspecies, the Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*) is federal and state endangered (Table 2). Populations of the northern flying squirrel in southwestern Virginia (Grayson and Smyth counties) are considered intergrades of the Virginia and Carolina forms (Fies and Pagels 1991, Sparks 2005) and are listed as federal endangered. According to Payne et al. (1989), habitat of the northern flying squirrel in the southern Appalachians is high elevation, mesic forest characterized by northern hardwood and northern conifer species [i.e., red spruce (*Picea rubens*) or Fraser fir (*Abies fraseri*)]. These forests in Virginia are now largely restricted to Whitetop and Mount Rogers in Grayson and Smyth counties, and to a few sites in Highland County (Pagels et al. 1990, Reynolds et al. 1999). Recent studies by Ford and collaborators provide habitat models and new information on the Virginia (Menzel et al. 2006, Ford et al. 2010) and Carolina northern flying squirrels (Ford et al. 2015), respectively. They found that except for increasingly higher elevations to the south (i.e., southwest Virginia and North Carolina), habitat of the northern flying squirrel in the mid- to southern Appalachians is high elevation, cool, moist forest characterized by montane conifers [such as red spruce, Fraser fir, or eastern hemlock (*Tsuga canadensis*)], and a northern hardwoods component [such as yellow birch (*Betula alleghaniensis*), sugar maple (*Acer saccharum*) and black cherry (*Prunus serotina*)]. Desirable areas for the northern flying squirrel have few, if any, hard-mast-producing trees, such as American beech (*Fagus grandifolia*) or oak species (*Quercus* spp.), which are more favorable habitat components for southern flying squirrels (*Glaucomys volans*).

The rock vole is known from sites in Highland and Bath counties (Pagels 1990, Orrock et al. 1999) in mixed mesophytic habitats characterized by yellow birch, with abundant large, often moss-covered rocks (Orrock and Pagels 2003). Rock voles were also captured among rocks along a roadway in Highland County where the rocks appeared to have been placed for road stabilization (W. Bulmer, R. Eckerlin, and A. Gardner, pers. comm.). That site also had abundant yellow birch. Mixed mesophytic forests (Orrock et al. 2000, McShea et al. 2003), or montane mesic forests in general (Ford et al. 2006b), are important to many small mammals, and localized areas of moss-covered rocks and associated microhabitat in these forests seem to be critical to the rock vole in Virginia. One of us (JFP) and collaborators conducted surveys for the rock vole and the American water shrew in the late 1980s and 1990s at many sites in what appeared to be prime habitat in southwestern Virginia, notably the Whitetop, Mount Rogers and Clinch Mountain areas. Despite these surveys, neither the rock vole nor American water shrew has been found there to date, indicative of their localized distribution.

The long-tailed shrew (*Sorex dispar*), first reported from the Mountain Lake area of Giles County (Handley 1956, Holloway 1957), was later found in several other counties in western Virginia (Pagels 1987). Often associated with talus or boulder areas, the long-tailed shrew has a more continuous distribution than the American water shrew, northern flying squirrel, and rock vole (Table 1).

Handley and Patton (1947) stated that neither the coyote (*Canis latrans*) nor the red fox (*Vulpes vulpes*) occurred in Virginia in pre-colonial days, although Rose (1986) later reported red fox from Woodland Period archeological sites, which dated to approximately 2,000 years before European settlement. Both of these species now occur statewide (Linzey 1998). These species characteristically inhabit open woods, grasslands, and overgrown fields. However, coyotes often occupy a broader array of habitats (including inner cities; Gehrt et al. 2009) than do red foxes.

There has been debate over the source of eastern populations of both of these species. For many years, it was believed that red foxes in the eastern United States were of European origin, introduced to the American colonies for sport hunting (Churcher 1959, Linzey 1998, Kamler and Ballard 2002). Kasprowicz et al. (2016) recently presented genetic findings that European red foxes were, in fact, introduced to the mid-Atlantic region of North America. However, Kasprowicz et al. (2016) and Statham et al. (2012) also presented genetic evidence that red foxes were indigenous to the eastern United States at the time of European contact. As we noted above, red foxes were present at Woodland Period archeological sites in Virginia (Rose 1986).

Frey (2013) suggested that early naturalists in eastern North America probably believed red foxes were exotic because the colonists observed rapid range expansions and increases in abundance of this species in areas of the Southeast where, because of lack of suitable habitat, the red fox had been uncommon at the time of European settlement. Frey (2013) also provided historical information on population fluctuations of the red fox and the gray fox (*Urocyon cinereoargenteus*). Colonial-era clearing for agriculture and extensive deforestation increased abundance of red fox prey (e.g., rabbits and voles), whereas subsequent reforestation in some areas favored the gray fox, a woodland species, and its prey (e.g., insects, birds, and small mammals). The red fox possibly also benefitted from mesopredator release after wolves were reduced in numbers, and then extirpated in the Southeast (Frey 2013). However, the absence of wolves also likely played a role in the coyote's eastward range expansion. Red fox populations in the eastern United States may be suppressed again, but this time by coyotes (Frey 2013; Newsome and Ripple 2015).

Handley and Patton (1947) noted that coyotes had been collected in several western counties. They went on to comment that they "hesitate to recognize [the coyote] as an authentic Virginia species because many coyote pups are brought by tourists from the west and are released or escape when they reach maturity" (Handley and Patton 1947, page 140). Linzey (1998) reported a 1965 record of the coyote from Rockingham County, a record unknown at the time of the first symposium on Virginia's Rare and Endangered Species (Linzey 1979), when the coyote was said to be on the verge of entering Virginia (Pagels 1979). Mastro (2011) reported that prior to 1983, only eight coyotes had been recorded from Virginia. Mastro's (2011) review of literature on coyotes includes a time-line of range expansion into the mid-Atlantic states, observations on life history and ecology, and information about hybridization with other canids. Bozarth et al. (2011) provided mtDNA evidence that coyotes expanded their range into Virginia from northern and southern fronts, and they and Mastro (2011) observed that the mid-Atlantic states are the terminus of coyote range expansion in the continental US. Translocation by humans cannot be ruled out for spotty coyote introductions (Hill et al.1987, Linzey 1998); however, like others, we suggest habitat alteration and the extirpation of wolves were dominant factors in the colonization of Virginia by coyotes. We consider the coyote to be part of Virginia's native fauna and its presence in the state to be the result of natural range expansion. The coyote is an opportunistic feeder and known to predate white-tailed deer (*Odocoileus virginianus*); Montague (2014) found deer to be the most frequent food item of coyotes during all months of the year in western Virginia. Perhaps the abundance of white-tailed deer since the 1970s has played a complementary role in the rapid range expansion of the coyote in the state, including (as in other regions, see Gehrt et al. 2009), suburban and urban areas.

Range expansions of species not included in Handley and Patton (1947) – Six taxa not mentioned by Handley and Patton (1947) have naturally expanded their ranges into Virginia since 1947 (Table 4). Bats added to the list include the Brazilian free-tailed bat (*Tadarida brasiliensis*), which may be a very recent arrival. It was first reported by Cranford and Fortune in 1994 based on two specimens captured in Giles County, far north of its published geographic limits in North Carolina at the time, where it was considered a recent arrival (Wilkins 1989). Reynolds and Fernald (2015) reported on a specimen from southeastern Virginia in the 1990s and a pup collected in Charlottesville in 2014. More recently, R. Reynolds (pers. comm.) learned of an additional record from southeast Virginia and another from the Richmond area. This species has a surprisingly broad distribution in the state, given its recent range expansion.

Two species of bats are known from single records in the southeast: the Seminole bat (*Lasiurus seminolus*) from the Great Dismal Swamp (Padgett 1987) and the northern yellow bat (*Lasiurus intermedius*) from what is now the City of Norfolk (Rageot 1955). The southeastern myotis (*Myotis austroriparius*) was first recorded in the Great Dismal Swamp in 1998 (Hobson 1998), but it is now known to also occur at inland sites in the upper Coastal Plain (Reynolds and Fernald 2015). Virginia is at the northern edge of the range of each of these species. Another bat, Townsend's big-eared bat (*Corynorhinus townsendii*), occurs only in westernmost, mountainous portions of the state (Table 1). The subspecies of Townsend's big-eared bat that occurs here, *Corynorhinus townsendii virginianus*, is on the state and federal endangered lists (Table 2).

A subspecies of the North American deermouse (*Peromyscus maniculatus*), the prairie deermouse (*Peromyscus maniculatus bairdii*), was first collected in northern Virginia in 1960 (Table 4; Peacock and Peacock 1962). Another subspecies (*Peromyscus maniculatus nubiterrae*), which was included in Handley and Patton (1947), is a long-tailed mouse that is abundant in mountainous areas of Virginia at relatively high elevations and typically occupies mesic forests (McShea et al. 2003). In contrast, the prairie deermouse is a short-tailed mouse that is abundant in the Midwestern US. It is found in early successional and agricultural habitats and has been recorded in the Shenandoah Valley as far south as Harrisonburg (Hensley 1976). Francl and Meikle (2009) included the North American deermouse and white-footed mouse (*Peromyscus leucopus*) among other species captured with the hispid cotton rat (*Sigmodon hispidus*) at an early successional, relatively low-elevation site, 510 m, in Montgomery County in southwestern Virginia. Specimens were assigned to species based on tail length; the long-tailed specimens were identified as deermice and those with shorter tails as white-footed mice (K. Powers, pers. comm.). They did not assign the deermice to subspecies. The forest subspecies of deermouse (*Peromyscus maniculatus nubiterrae*), is usually found above 800 m (Handley and Patton 1947). Except for a Rockbridge County record (Pitts and Kirkland 1987), we know of no other efforts to document the presence of the prairie deer mouse in Virginia. However, we suspect *Peromyscus maniculatus bairdii* has a broader and more southerly distribution in the Shenandoah Valley than is indicated by published records.

Augmentation, regional translocations, undetected occurrence, and natural range expansions within Virginia since 1947 – Handley and Patton (1947) indicated that several species were absent from one or more regions of Virginia. In some cases, the Virginia Department of Game and Inland Fisheries (VDGIF) translocated animals from other regions of Virginia and from other parts of North America, in an attempt to restore populations of those species. In other cases, we believe natural range expansion has occurred, and we provide details and explanations for these expansions. The white-tailed deer was restricted to far southeastern Virginia and a few counties in the mountains by the early 1900s (Handley and Patton 1947). Between 1930 and 1950, more than 2000 animals from Florida, Michigan, North Carolina, Pennsylvania, and Wisconsin were released in Virginia (Linzey 1998). The augmentation efforts were successful. By the 1990s their numbers had rebounded to the point that the VDGIF sold some "limitless" tags to reduce populations and curtail damage to crops and ornamental plantings (Thompson and Francl-Powers 2013).

In 1947, Handley and Patton reported that the northern river otter (*Lontra canadensis*) was rare in the mountains. In the late 1980s, to supplement natural re-expansion of its range, VDGIF translocated animals from the Coastal Plain of Virginia and from Louisiana to areas west of the Blue Ridge (Handley 1991), and the northern river otter again occurs statewide (Linzey 1998).

Handley and Patton (1947) indicated that the eastern fox squirrel (*Sciurus niger*) was rare and localized in most regions of the state in 1947. More recently, Fies (1993) provided evidence that populations of eastern fox squirrels west of the Blue Ridge may be naturally expanding eastward. Although this species occurs in the Coastal Plain, its distribution is highly fragmented and population densities are low (Linzey 1998). In an effort to restore this species to Virginia's Eastern Shore (where it was listed as federal endangered until December 2015, USFWS 2015a), the US Fish and Wildlife Service translocated animals from Maryland to Accomack County between 1968 and 1971, and then from Accomack to Northampton County in 1982 and 1983 (Handley 1991).

Handley and Patton (1947) reported very restricted distributions for several taxa that are now known to be more widespread. Their records indicated that a subspecies of the southeastern shrew (*Sorex longirostris*), the Dismal Swamp southeastern shrew (*Sorex longirostris fisheri*), was restricted to the historic Dismal Swamp of extreme southeastern Virginia and extreme northeastern North Carolina. This taxon subsequently was found to occur throughout the Coastal Plain of North Carolina and well west of the Dismal Swamp in Virginia (Webster et al. 2009). Handley and Patton (1947) also reported the star-nosed mole (*Condylura cristata*) was unknown from most of the Piedmont and that the hoary bat (*Lasiurus cinereus*) had only been recorded at three localities. These three species now have statewide distributions (Linzey 1998), and it is likely they occurred statewide in 1947, but had gone undetected. Handley and Patton (1947) also reported that the American pygmy shrew (*Sorex hoyi*) was rare and known from only two localities. Because of extensive studies using pitfall traps (Pagels 1987), this species is now known to occur statewide (Linzey 1998), and it is sometimes locally abundant (Bellows et al. 2001).

The hispid cotton rat, a species that inhabits oldfields, was first collected in southern Virginia in 1941 (Patton 1941), then in Chesterfield County (Pagels and Adleman 1971), and later at many sites in southcentral Virginia (Pagels 1979). It has been reported from many locations across the southern half of the state: the Great Dismal Swamp (Rose 1999), Buckingham County (Pagels et al. 1992), a Blue Ridge site in Nelson County (Francl and Meikle 2009), sites in Botetourt and Montgomery counties (Francl and Meikle 2009), and Lee County in southwestern Virginia (Pagels 1979). It is likely that more northerly expansion will ensue in the Great Appalachian Valley (which includes the Shenandoah Valley) and in portions of the Piedmont and Coastal Plain.

The least weasel (*Mustela nivalis*) was only known from Montgomery and Rockingham counties in 1947, but Handley and Patton (1947) suggested that it probably occurred in all montane counties. More recently, the species was recorded from scattered mountain localities and two sites in the upper Piedmont (Handley 1991), and it was subsequently captured in the Coastal Plain (Bellows et al. 1999). Sheffield and King (1994) noted reports of many range extensions by the least weasel. Unlike several of the aforementioned species that have demonstrated range expansions, the least weasel is not a habitat specialist, but it is a predator specialist of small mammals, especially voles and other mice (Sheffield and King 1994).

The bobcat (*Lynx rufus*) was absent from the lower Piedmont and Coastal Plain, except it occurred in the Dismal Swamp and was "common in the mountains" (Handley and Patton 1947). Similarly, at the time of Handley and Patton's (1947) publication, the distribution of the black bear (*Ursus americanus*) was restricted to montane counties and the Dismal Swamp. Although still most abundant in those areas, both species now have statewide distributions (Linzey 1998); these reestablishments are likely the result of management and enforcement of game regulations by VDGIF.

Extirpations without reintroductions – At least three species of native land mammals present in Virginia at the time of the establishment of Jamestown were extirpated between 1607 and 1947 (Table 1) and remain absent today: wolf, cougar (also known as puma or mountain lion, *Puma concolor*) and American bison (*Bison bison*). Wolves and the cougar were eliminated from most of eastern North America by the early 1900s because of their reputation as predators of livestock. Handley and Patton (1947) stated that the last wolf was killed in the winter of 1909-1910 in Tazewell County, and the last known cougar was killed in Washington County in 1882. Linzey (1998) summarized what he considered to be reliable reports of cougars in Virginia between 1979 and 1998, but none of these were accompanied by verified physical evidence (specimens, hair, scat, or photographs). Our searches of museum databases (see Acknowledgments) returned one record of a *Puma concolor* specimen at the US National Museum (USNM, catalog number 270142) collected in 1940 at an archeological deposit (Keyser Farm site) in Page County, and another specimen at the Museum of Comparative Zoology (catalog number BOM-7120) of unknown date from Lee County. The US Fish and Wildlife Service (McCollough 2011) recently reviewed evidence of cougars in the eastern United States and recommended delisting the eastern cougar (*Puma concolor couguar*) because it is extinct. Most biologists consider the cougar to be extirpated in Virginia (Kocka and McShea 2011).

Handley and Patton (1947) reported that American bison were common in the early 1600s. William Byrd II in his 1728 survey of the "dividing line" between Virginia and North Carolina reported that a member of his party shot a two-year-old male American bison on 11 November (Rose 2013). Byrd wrote an extensive description of the massive shoulders of the animal, as well its legs, horns, hair, and herding behavior (Rose 2013). American bison were also reported in other early historical accounts of Virginia (Rose 1986). Skeletal remains of the American bison have been reported from archaeological deposits from one site in extreme southwestern Pennsylvania (Gilmore 1946). However, none have ever been reported from Virginia (E. Moore, pers. comm.). Although herds of the American bison were certainly present east of the Mississippi by the 18th Century, the lack of archaeological evidence in Virginia suggests they occurred in this region irregularly (if at all) prior to European colonization (E. Moore, pers. comm.). Handley and Patton (1947) cite Coues (1871) in reporting that the last remaining American bison in this region was killed in western Virginia (possibly what is now eastern West Virginia or eastern Kentucky) in the late 1790s.

Reintroductions and range expansions following extirpations and near extirpations – Several native species were extirpated, or nearly so, following arrival of Europeans; efforts have been made to restore most of these species to their former ranges through translocation of individuals (Table 1). Handley and Patton (1947) indicated that the snowshoe hare (*Lepus americanus*) probably occurred at high elevations throughout the mountains of Virginia, but by 1947 it was restricted to Highland County. Between 1961 and 1978, hundreds of animals from New Brunswick, Canada were released at several sites in Virginia; however, these attempts to establish populations of snowshoe hares failed (Fies 1991). In 1989, 26 animals captured in West Virginia were released in Highland County (Fies 1992), but by 1991 hares were absent in some previously occupied areas (Fies 1991). Fies (1991) noted that lack of understory threatened the remaining populations of snowshoe hares in Virginia, and Handley (1991) predicted that snowshoe hares could not survive in Virginia without appropriate habitat management. Our searches of museum databases (see Acknowledgments) returned electronic records of three specimens (skulls only) of *Lepus americanus* (USNM catalog numbers 448849-448851) collected in 1986 from Highland County. Also, a road-killed specimen (VMNH 134967, formerly VCU 4968) was collected in 1986 in extreme eastern Pocahontas County, West Virginia, near the Virginia border. The portion of the George Washington-Jefferson National Forest in northwestern Highland County where the hare was last seen currently is managed as the US Forest Service's Laurel Fork Special Management Area. This designation generally prohibits habitat alteration that otherwise could benefit the snowshoe hare. Although extant populations are present nearby in West Virginia within a few km of the state line, the conservation status of the snowshoe hare in Virginia is questionable, and this species may be extirpated.

The American beaver (*Castor canadensis*) is among the species that were extirpated and later successfully reintroduced (Table 1). Handley and Patton (1947) reported that American beavers were absent from Virginia by 1910, due to overtrapping. Linzey (1998) provides details of the restocking program implemented by VDGIF in the 1930s and 1940s. The American beaver is now considered to be a pest or nuisance species in some locations in the state (Linzey 1998).

The presence (or not) of the North American porcupine in Virginia at the time of European contact and recent evidence that it now occurs here present an enigma. Handley and Patton (1947) considered the porcupine to be "vanished" (extirpated) from Virginia's fauna, based on an anecdotal account from the 1730s. In the late 1800s, credible reports of live porcupines in West Virginia and Maryland were published in the Proceedings of the National Museum of Natural History; Goode (1878) described a live specimen from West Virginia, and Lugger (1881) provided details of specimens, including a live and a recently killed animal, from three localities in Maryland. Harman and Thoerig (1968) and Feldhamer et al. (1981) reported on porcupines killed by hunters in western Maryland, and Paradiso (1969) stated that the porcupine had been extirpated from Maryland, even though he mentioned "records and reports of the porcupine in the western part of Maryland right up to the present time." More recently, Linzey (1998) cited literature of occasional reports of animals in western Maryland, West Virginia, and Virginia through the late 1980s.

Our searches of museum databases returned one record (USNM catalog number 570136) of a porcupine found by D.E. Carr in 2006; it was dead on a road on North Mountain in Frederick County. M. Fies also reported (pers. comm.) a roadkill porcupine in 2010 near Swoope in Augusta County and two animals that were killed between September 2010 and July 2011 near I-81 in Frederick County. Joseph and Janet Trout used game cameras on Stone Mountain (in western Frederick County) to obtain numerous photographs of porcupines during 2008-2011. Among the photographs (which were examined by M. Fies, J. Pagels, and S. Roble, in litt.) were adults with young that apparently represent the first breeding records of the porcupine for Virginia. M. Fies (pers. comm.) also reported photos of porcupines from game cameras in western Shenandoah County (adjacent to Frederick County) in 2010 and 2013. More recently, a porcupine that had been hit by an automobile in western Frederick County in September 2014 was rehabilitated and released (Fies, pers comm.). Almost all recent evidence of the porcupine in the state was from areas near the border with West Virginia and Maryland. This is consistent with a statement in October 2015 by B. Sargent (pers. comm.) that the porcupine is "becoming more commonly reported in northeastern West Virginia." While we concede that it is possible that some animals have been accidentally transported to Virginia and nearby states on logging trucks heading south through Pennsylvania (Handley 1991), we concur with M. Fies (pers. comm.) that most of the porcupines recently observed in Virginia likely are the result of dispersal from expanding populations in West Virginia and Maryland. Regardless of origin and political boundaries, there is a breeding population of porcupines in western Maryland, northeastern West Virginia, and portions of northwest Virginia; the porcupine is once again part of our mammal fauna.

The fisher probably was present in western Virginia before being extirpated in the late 1800s (Handley and Patton 1947), although no specimen from Virginia was reported in a museum collection until very recently (Moncrief and Fies 2015). In 1969, the West Virginia Division of Natural Resources released 23 animals from New Hampshire at two sites in eastern West Virginia; at the time, no fisher population was known within 460 km of West Virginia (Pack and Cromer 1981). Periodic observations of fishers in Virginia, which Handley (1979a, 1991) considered to be reliable, were reported between 1969 and 1990, including one by JFP in 1989. However, none of these reports were accompanied by verified physical evidence of fishers (specimens, hair, scat, or photographs). In 2008, personnel from VDGIF examined and photographed two taxidermy mounts of fishers that were killed by hunters in Frederick Co., Virginia during 2006 and 2007 (Moncrief and Fies 2015). Trail cameras provided photographic evidence that documented fishers in five western counties between 2009 and 2015 (Moncrief and Fies 2015). In addition, four animals were collected in two of those counties between 2011 and 2015, and these specimens were deposited in the Mammal Collection of the Virginia Museum of Natural History (Moncrief and Fies 2015). According to Moncrief and Fies (2015), fishers that are now present in Virginia almost certainly dispersed from expanding populations in eastern West Virginia and western Maryland. Based on fisher sightings nearly 25 years ago, as well as the more recent specimens and photographic evidence, it is likely there will be documentation of reproduction in Virginia fishers in the near future.

The wapiti was hunted to extinction in Virginia by 1855 (Handley and Patton 1947). In 1917, animals from Yellowstone National Park were released into several western counties, and the population was estimated at about 300 individuals by 1922 (Handley 1979a). However, after a nematode parasite [*Pneumostrongylus* (syn. *Parelaphostrongylus*) *tenuis*] lethal to the wapiti was introduced by translocated white-tailed deer, the wapiti again disappeared (Handley 1979a). Another attempt to restore the wapiti in Virginia has been made within the past decade. A total of 71 animals from Kentucky was released from 2012 to 2014 in Buchanan County (part of the three-county restoration area that also includes Dickenson and Wise counties). Each year, the animals (16 in 2012, 10 in 2013, and 45 in 2014) were held for quarantine and disease testing before they were released. Including individuals that have entered Virginia from Kentucky on their own, the estimated population size was 150 to 200 animals following the 2016 calving season (D. Kalb, pers. comm.).

ONGOING AND NEW LONG-TERM THREATS TO VIRGINIA'S NATIVE LAND MAMMALS

Clearing for agriculture and other purposes, roadways, invasive plants, nonnative mammals, disease, climate change, and wind turbines are among the threats to native land mammals in Virginia. Before humans arrived, natural forces such as floods, wind, ice storms, and landscape-level wildfires (c.f. Francl and Small 2013), initiated or retarded succession. Both Native Americans and Europeans often used burning and clear cutting to prepare the land for crops and to manage habitat for early successional wildlife. Changes in land-use patterns since the arrival of Europeans have undoubtedly affected the distributions and abundances of our mammals, and some of these changes threaten continued existence of some species. Forests have been alternately cleared for agriculture and replanted. Networks of roadways have been established to move goods and people. Some introduced plants and animals have become invasive, compete with native organisms, or spread diseases to other mammals, including humans. Reliance on fossil fuels and the resultant climate change are altering distributions of species. These and other factors will continue to impact Virginia's land mammals. In the following sections, we provide details of the current status of these threats and efforts to mitigate them.

Virginia's landscape today – In western Virginia, as a result of reforestation after extensive early timbering and the abandonment of small farms, plus many years of control of natural fires, there is less early successional habitat than in the past. Forest abundance may be returning to pre-Colonial times, although tree species composition has been altered (e.g., American chestnut, *Castanea dentata,* is almost absent, Stephenson et al. 1992). Old-growth forests and forest types critical to uncommon plants and animals must be preserved, and connectivity must be encouraged in our mountainous areas. However, well-planned wildlife "openings," regardless of how they are produced, and continued USFS burning at previous fire intervals will benefit forest species and nongame and game species of mammals and birds.

In eastern Virginia, land use changes, increased urbanization, and changes in agricultural practices have decreased abundance of early successional habitats that benefit many species of wildlife. In most agricultural areas, early successional habitat is nearly non-existent because fields are cultivated, mowed or bush-hogged to the forest edge, the fields and pastures are of great acreage, and the fence rows, which provided cover and food in the past, are now nearly non-existent. Fies et al. (1992) described effects of changing land-use patterns on habitat for northern bobwhite (*Colinus virginianus)*, including the impact of "clean farming" methods. The same effects and impacts apply to numerous old field and generalist mammals.

Nearly all human activities lead to fragmentation of habitat far beyond the levels caused by natural factors such as fires and floods. Studies in landscape ecology have demonstrated that habitat fragmentation and the resultant size, shape, and isolation of patches and the inter-patch matrices have far-reaching effects on populations of organisms (Watling et al. 2011). Regardless of scale, habitat fragmentation will have lasting impacts on earth's ecosystems (Haddad et. al 2015). Whether viewed positively or negatively, managed forests, agroforestry, deforestation, reforestation, agricultural development, urbanization, suburbanization and exurbanization (low density rural development) all impact many of the state's 10.2 million ha. In 1630, about 9.9 million ha was forested. About 800,000 ha of reforestation followed extensive timbering in the early 1900s, so that a total of about 6.4 million ha, including plantation forests or otherwise highly managed sites, are forested today (VDOF 2015a,b). More than 3.3 million ha, or about 33% of Virginia's area, is agricultural land (VDACS 2015). In a nutshell, Virginia's landscape has become increasingly fragmented in modern times.

Roadways – Roadways are a major part of our environment and can affect both the biotic and the abiotic components of landscapes by changing the dynamics of populations of plants and animals, introducing exotic elements, and changing levels of available resources, such as water, light and nutrients (Coffin 2007). Virginia maintains more than 14,000 km of interstate and primary roads and 77,000 km of secondary roads (VDOT 2015). Among the most obvious, negative impacts are dead animals on or along roadways. Romin and Bissonette (1996) estimated the number of deer (all species) killed on US roadways to be at least 500,000 in 1991. In the mid-1980s, Pagels and French (1987) estimated that about 24 small mammals, primarily shrews, were entrapped in discarded bottles per km of Virginia's secondary roads. Forman (2000), who earlier coined the phrase "road ecology" (Forman and Alexander 1998), estimated one-fifth of the land area in the United States is affected by the cumulative effects of public road systems. Beckmann et al. (2010) encouraged road engineers and planners to consider impacts on animal movement in their design of new roadways. Methods are available for reducing wildlife mortality on roads. One solution includes fencing that directs wildlife to existing culverts or specially constructed underpasses. Sparks and Gates (2012) found that at least 57 wildlife species used culverts in western Maryland. In a novel approach, Kelly et al. (2013) installed gliding posts (modified wooden utility poles) that allowed successful gliding by the northern flying squirrel across a scenic byway in the mountains of North Carolina. In brief, many management tools are available to reduce the carnage of wildlife on our highways.

Invasive plants – Habitats in Virginia and elsewhere are becoming increasingly altered by invasive plants, which disrupt ecosystem processes and alter plant community composition and structure (Vilà et al. 2011). Some plants (e.g., *Elaeagnus umbellata*, autumn olive) were introduced in an attempt to benefit wildlife, yet they are now known for their negative impact on native habitats. Japanese stilt grass (*Microstegium vimineum)* is spreading rapidly in much of Virginia, including sites in the Coastal Plain, Piedmont, Blue Ridge, and Ridge and Valley provinces (JFP, pers. obs.). This invasive species can dominate ground-level habitats and shade out important native plants, and its high allelopathic potential (Pisula and Meiners 2010) is perhaps the reason for the large monocultures seen in many areas. A non-native form of common reed (*Phragmites australis*), which forms 2-m tall thickets where few native biota can coexist, dominates edges of salt and freshwater marshes and other damp places in the Coastal Plain and undoubtedly impacts many organisms, including mammals. Further, cold season fescue grasses (*Festuca arundinacea* varieties), of European origin, are often planted along roadsides, stream embankments, pastures, and cultural areas (including battlefield parks). The thick, matted growth form of fescue grass nearly prevents the germination of warm-season grasses and forbs, and severely limits movement of ground-nesting and ground-feeding wildlife (IDFW 2006). Allelopathic compounds produced by fescue grass also inhibit germination and establishment of native herbaceous species, and fescue grass often has a high occurrence of an endophytic fungus (*Acermonium coenophialium*) that produces alkaloids toxic to many organisms, including certain insects, wildlife, and many domestic animals (Conover 1998, IDFW 2006). These are but a few examples of the invasive plants and the damage caused by them in Virginia (VDCR 2015a). Some of the fescue fields are being reconverted to animal- and plant- friendly warm-season grasses and herbs. In general, some of the best efforts for countering loss of old-field habitats are found in groups working for recovery of game species (e.g., northern bobwhite quail), which benefits numerous other bird species and mammals, including the eastern cottontail (*Sylvilagus floridanus*).

Wildlife diseases and parasites – In recent decades, several diseases that affect free-living wildlife have been labeled emerging infectious diseases (EIDs), which can be placed into three broad categories: 1) diseases that "spill-over" to domestic animals and wildlife living nearby; 2) diseases resulting from human translocation of hosts and/or parasites; and 3) diseases with no obvious direct involvement of domestic animals or humans (Daszak et al. 2000). Emerging infectious diseases are frequently associated with changes in the ecology of the host, the pathogen, or both. These ecological changes are, in turn, often caused by anthropogenic habitat modification (e.g., deforestation, habitat fragmentation, agricultural development; Colwell et al. 2011, Gottdenker et al. 2014).

Wildlife diseases sometimes threaten the health of humans or domestic animals (Sleeman 2006, Joseph et al. 2013). Sleeman (2006) provided a comprehensive review of potential risks and instructions to prevent or reduce exposure to several notable wildlife diseases, including hantavirus pulmonary syndrome, tularemia, and tick-borne diseases such as Lyme disease and Rocky Mountain spotted fever.

Rabies, which can infect any mammal and is nearly always fatal, provides an example of a disease that was rapidly, and unintentionally, spread to Virginia by translocation (Smith et al. 1984). In the late 1970s, an outbreak of raccoon rabies occurred on the border of Virginia and West Virginia. It was later attributed to the interstate translocation of infected raccoons (*Procyon lotor*) that were captured in the southeastern United States and relocated to the mid-Atlantic region as part of an effort by hunting clubs to restock dwindling raccoon populations in this region (Guerra et al. 2003).

Another disease associated with raccoons is caused by the ascariid roundworm parasite *Baylisascaris procyonis*. This parasite has been documented in Virginia (Davidson 2006), and it has been described as an emerging zoonosis (Sorvillo et al. 2002) because of the increasing abundance and proximity of raccoons, its primary host, to humans. The ingestion of *Baylisascaris procyonis* eggs from soil or materials contaminated by raccoon feces, although very rare, may be fatal in humans. The parasite is also known to impact many wild mammals and some birds (Sorvillo et al. 2002), and it has been implicated in the extirpation of the Allegheny woodrat (*Neotoma magister*) in New York and New Jersey (LoGiudice 2003, Page 2013). In a study of Allegheny woodrats in the mid-Atlantic Highlands of Maryland, Virginia, and West Virginia, Ford et al. (2006a) indicated that, although the status of *Baylisascaris procyonis* throughout this region is uncertain, the parasite has been documented from raccoon feces in northern West Virginia and much of Maryland. These authors (Ford et al. 2006a) also cautioned that raccoons have been observed in rock outcrops with Allegheny woodrats in this region, so that a potential transfer mechanism is in place if *Baylisascaris procyonis* becomes a common enzootic in the mid-Atlantic Highlands, as may already be occurring north of the Potomac River.

Another parasite, *Toxoplasma gondii*, is a protozoan that can infect all birds and mammals. It relies on felids to complete its life cycle, and it is an emerging threat from free-roaming domestic cats (*Felis catus*). A recent study (Ballash et al. 2015) concluded that feral cats are likely the primary cause of white-tailed deer infections of *Toxoplasma gondii i*n northeastern Ohio. Feces of a single cat can deposit hundreds of millions of oocysts that may remain infectious for up to 18 months (Tenter et al. 2000). The implication for humans for the disease, which has been linked to schizophrenia, miscarriages, blindness, memory loss, and death (Torrey and Yolken 2013, Gajewski et al. 2014), is that humans can acquire toxoplasmosis from cysts in venison of undercooked white-tailed deer, a situation that may be exacerbated by the close association of humans, cats and deer in urban and suburban areas.

Although many studies of diseases in wildlife are motivated by concerns related to the health of humans and livestock, a number of diseases mainly or only affect wild mammals. Hemorrhagic disease, which is the most important infectious disease of white-tailed deer in the southeastern United States and in Virginia (VDGIF 2015c), seems to be in this category. Chronic wasting disease (CWD) is another disease that seems to naturally occur only in wild mammals, including white-tailed deer and wapiti

(Davidson 2006, VDGIF 2015a). In this case, the disease agent appears to be abnormally shaped proteins called prions that affect the central nervous system and lymphatic tissues (Davidson 2006). The first Virginia case of CWD was confirmed in Frederick County in 2009 (VDGIF 2015a).

In some instances, EIDs may lead to extirpation and/or extinction (Daszak et al. 2000, Joseph et al. 2013). For example, white-nose syndrome, which is caused by the fungal pathogen *Pseudogymnoascus destructans*, has been documented in numerous cave-dwelling bats, including species that occur in Virginia (Zukal et al. 2014, Powers et al. 2015). This pathogen is responsible for killing millions of bats in North America; it may alter the structure of bat communities and change ecosystem function (Jachowski et al. 2014), and it may extirpate one or more species of bats (listed in Table 2) that inhabit Virginia (Thogmartin et al., 2013). Additional parasites and diseases that cause mortality in native land mammals of Virginia are described in Davidson (2006).

Introduced and feral mammals — Ten species of mammals have been introduced intentionally or accidentally since the arrival of Europeans in Virginia, and many of these negatively impact our native environment. The house mouse (*Mus musculus*), the brown rat (*Rattus norvegicus*), and the roof rat (*Rattus rattus*) accompanied Europeans and remain commensals of humans (Table 5). Efforts to control these rodents and their damage to stored grains and foods result in great economic costs. However, their impact on native mammals, though largely unmeasured, probably is slight. More recent, and intentional, introductions were those of the sika (*Cervus nippon*) to Assateague Island (Accomack County) and the black-tailed jackrabbit (*Lepus californicus*) to Cobb Island (Northampton County). Introduced for hunting around 1960 (Linzey 1998), both species survive on their respective islands. The coypu (or nutria, *Myocastor coypus*) is a semiaquatic rodent native to South America. It was held in captivity for its fur in the 1930s, but animals escaped or were released when the fur market collapsed, and populations have become established on the Coastal Plain (Klopfer and St. Germain 2012). The coypu consumes large amounts of aquatic vegetation, can damage earthen dams, and likely competes with, and displaces, the (native) muskrat (*Ondatra zibethicus*, USFWS 2013a). Klopfer and St. Germain (2012) provide details about the distribution of the coypu in Virginia and adjacent states, and recent collaborative efforts to eradicate this invasive species.

Free-ranging and feral domestic mammals in Virginia (Table 5) include the horse (*Equus caballus*), the wild boar (pig or hog, *Sus scrofa*), the domestic cat, and the domestic dog (C*anis lupus familiaris*). Feral horses are restricted to Assateague Island (Accomack County) and Mount Rogers (Grayson and Smyth counties). The herd of horses on Assateague Island (the "Chincoteague ponies") is maintained at 150 head, and it is managed by local and federal guidelines. A goal of the 2013 Interim Chincoteague Pony Management Plan is to ensure the horses remain healthy and do not detract from the island's diverse natural resources (USFWS 2013c). Similarly, there are about 120 horses on the grassy balds near Mount Rogers (two herds on the Mount Rogers National Recreational Area with about 90 animals and one herd on Grayson Highlands State Park of about 30 animals) that are maintained by the Wilburn Ridge Pony Association (H. Thompson, pers. comm.). Such grassy, high elevation balds as those at Mount Rogers are being lost to encroachment by weedy vegetation and surrounding forests in the US and elsewhere. Weigl and Knowles (2014) hypothesized these areas owe their origin and persistence to past climatic extremes and activities of

TABLE 5. Land mammals introduced to Virginia, either accidentally or intentionally. Common or vernacular name (as suggested by Wilson and Reeder 2005) is indicated for each taxon, along with current classification and the citation for a comprehensive monograph or review of the biology of that taxon. Asterisks denote taxa with feral and/or free-ranging individuals.

Scientific name	Common name	Family	Order	Citation
Lepus californicus	black-tailed jackrabbit	Leporidae	Lagomorpha	Best 1996
Mus musculus	house mouse	Muridae	Rodentia	Laerm and Webster 2007a
Rattus norvegicus	brown rat	Muridae	Rodentia	Laerm and Webster 2007b
Rattus rattus	roof rat	Muridae	Rodentia	Laerm and Webster 2007c
Myocastor coypus	coypu	Myocastoridae	Rodentia	Woods et al. 1992
*Canis lupus familiaris**	domestic dog	Canidae	Carnivora	Serpell 1995
*Felis catus**	domestic cat	Felidae	Carnivora	Turner and Bateson 2013
*Equus caballus**	horse	Equidae	Perissodactyla	Mills and McDonnell 2005
*Sus scrofa**	wild boar	Suidae	Artiodactyla	Chapman and Trani 2007
Cervus nippon	sika	Cervidae	Artiodactyla	Feldhamer 1980

large mammalian herbivores, many of which are now extinct or extirpated. The horses largely fulfill that maintenance role today.

Feral wild boars consume wildlife and plants, destroy food caches of small mammals, compete with native wildlife for hard mast, and often severely damage plant communities and habitats (Campbell and Long 2009). Although populations of feral wild boars are localized in Virginia, they seem to be increasing and are being monitored by the VDGIF (2015b).

The literature is voluminous on the negative impact of domestic cats on native wildlife. Loss et al. (2013) estimated that free-ranging pets and feral cats kill 1.4-3.7 billion birds and 6.9 to 20.7 billion mammals annually in the US. Loss et al. (2013) also found that the majority of mortality is caused by truly feral cats and un-owned, stray cats (i.e., those without habitation but perhaps being fed). However, even house pets that spend only part of the day or night outside kill large numbers of small, native animals. A study that used "kittycams" to monitor hunting by such house pets in a suburban area of the southeastern USA found that almost half of them hunted wildlife, with an average of 2.4 kills per week (Loyd et al. 2013). These authors also showed that domestic cats brought home fewer than one in four kills, a finding that greatly increases earlier mortality estimates (e.g., Mitchell and Beck 1992). Loss et al. (2013) suggested that free-ranging pets and feral cats likely are the greatest source of anthropogenic mortality for US birds and mammals. Further, abundance of native predators typically reflects prey numbers and habitat quality of prey, and crashes of prey populations are followed by crashes of predator populations. In contrast, predation by free-ranging pet or feral cats (including those in trap, neuter, release programs) occurs regardless of prey numbers. Even those cats fed by humans continue to hunt, to the detriment of native wildlife (see Hawkins et al. 2004, among others).

The domestic dog has a long history in North America, perhaps as long as that of Native Americans. Companion, hunter, protector, herder, guide, and law enforcement describe some of the roles of modern dogs. Dogs also can adversely affect wildlife, but differ from cats in a number of ways, including mechanisms of disturbance, numbers of prey individuals consumed, and prey size. Free-ranging dogs, even when accompanied by their owners, often disturb and harass wildlife species (see Hughes and Macdonald 2013). Leashed dogs jumping after squirrels or depositing scent (that of a predator) while on a casual walk provide familiar examples of such harassment, potential or real.

Climate change – In the past 50 years, human-induced modification of climate has caused temperatures to rise, precipitation regimes to change, and icecaps to melt (Duffy and Tebaldi 2012, Abatzoglou and Barbero 2014, McCain and King 2014). Handley (1992) noted that regional disasters such as the gypsy moth (*Lymantria dispar*), acid rain, and the chestnut blight fungus (*Cryphonectria parasitica*) can have long-lasting or permanent impacts on the environment, but that all of these pale in comparison to the destructive potential of climate change. Handley (1992) and many others (e.g., Lawler et al. 2009) predicted a shift in the distributional ranges of some flora and a concomitant shift in the range of some mammals in response to climate change. Such shifts will change the composition, but not necessarily change the species richness, of mammal communities in Virginia (Handley 1992).

Recent models (McCain and King 2014) have identified factors (body size and activity time) that may mediate response of individual mammal species to climate change. We suggest that in the short-term, several species isolated in high elevation habitats in Virginia (e.g., American water shrew, northern flying squirrel, and rock vole) face the greatest threat of local extirpation due to climate change. Despite certain, often political, arguments that climate change is part of a natural cycle, we note extinction is also natural, but that both extinction and climate change are exacerbated by human activities. There is no evidence that Virginia is being spared the effects of climate change. In fact, the state has recently taken an active role to address climate change by developing a strategy to safeguard species of greatest concern (VDGIF et al. 2009). In addition, Kane et al. (2013) recently conducted a suite of climate modeling and species vulnerability assessments. Although their models did not explicitly include any mammals, we deem the animals used in that study to be appropriate surrogates for Virginia's mammals.

Wind energy and wind turbines — Large numbers of bats and other wildlife are killed by wind turbines each year (Kunz et al. 2007, Arnett et al. 2008). For years, arguments in support of wind energy development noted that wind is free, that fossil fuel costs are high, oil production is subject to political disruption in other countries, and the US is exhausting its coal deposits. More often now we hear from promoters of wind energy that wind is (still) free and that turbines produce zero greenhouse gas emissions and hence do not promote climate change. These arguments of the American Wind Energy Association and the American Wind Wildlife Institute can be compelling. However, wind turbines are substantial potential threats to Virginia bats, especially the hoary bat, the eastern red bat (*Lasiurus borealis*), and the silver-haired bat (*Lasionycteris noctivagans*; R. Reynolds, pers. comm.).

WILDLIFE MANAGEMENT AND HABITAT PROTECTION

Thompson and Francl-Powers (2013) recently summarized the history of wildlife management in Virginia. Between 1607 and the early 1900s, many species of mammals were hunted or trapped for sustenance, for sport, or for their pelts and other body parts. By 1916, the VDGIF was established to conserve, protect, and manage wildlife and non-marine fishes of the state. This mission continues today, and this state agency is charged with managing all land mammals, whether game or non-game species.

Over time, the mandate of the VDGIF has expanded to include management and conservation of land and habitat as well as the wildlife species themselves (Thompson and Francl-Powers 2013). In 2015, VDGIF maintained 41 management areas totaling more than 82,000 ha (VDGIF 2015d). Two other state agencies, Virginia Department of Conservation and Recreation (VDCR) and Virginia Department of Forestry (VDOF), also conserve natural resources and manage land for wildlife. In 2015, VDOF managed 22 state forests that total more than 27,000 ha (VDOF 2015c), and VDCR maintained more than 48,000 ha, including 36 state parks and 62 natural areas and preserves (VDCR 2015b).

In 2015, federal lands under management for wildlife and habitat conservation in Virginia included the George Washington and Jefferson National forests, which comprised more than 647,000 ha in Virginia (USDA 2015), 14 USFWS National Wildlife Refuges, which protected more than 52,000 ha of habitat (USFWS 2015b), and 21 national parks and other sites totaling more than 80,000 ha that are administered by the National Park Service (NPS 2015). In addition, the federal Department of Defense (DOD) properties in Virginia comprised 104,814 ha (Gorte et al. 2012), and most undeveloped area on DOD sites is managed as habitat for local wildlife. In 2015, the Virginia Outdoor Foundation (VOF) administered conservation easements on more than 300,000 ha of private land, including some of the highest-quality forests, cleanest waterways, and richest wildlife habitat in the state (VOF 2015). In sum, about 16.7 percent (about 1.7 million ha) of the estimated total land area of Virginia is protected in 2015 (VDCR 2015c).

SUMMARY

Although species richness, abundance and distribution of Virginia's land mammals reflect natural processes, the consequences of long-term human activities are also evident. As we described above, the recent range expansion of the hispid cotton rat provides an example of how humans have influenced the roles of habitat availability and habitat contiguity, in part through climate change. Further, with continued warming, we predict subsequent expansion of the ranges of additional species and contraction of the ranges of others. This will change species composition, but not necessarily species richness, as certain boreal species are lost from Virginia's fauna and replaced by austral species.

We suggest early successional habitats are more abundant now in much of the Piedmont and Coastal Plain than at the time of European settlement. In those same regions, future land use patterns may cause those early successional associations to persist, except in areas where cover is removed (e.g., modern clearing of vacant land and "clean farming"). In western Virginia, especially on large expanses of public lands, reforestation has reduced the amount of early successional habitat, and creation of additional openings would benefit certain wildlife.

Invasive plants will increasingly alter our native communities, degrading and eliminating habitats suitable for native mammals and other organisms. Feral and free-ranging cats and dogs will continue to harass and kill native wildlife. Lessening the impact of these non-native predators will require measures that evoke emotional reactions and cause contentious situations; it is unlikely this problem will be solved anytime in the near future. The public must be educated regarding the potential negative consequences (e.g., habitat destruction, competition with native species, new diseases) of introductions of exotic species, translocated game species, and the free rein given to domestic species.

The quest for alternative, renewable energy sources is urgent and includes capturing solar and wind energy. We caution that wind energy is not a panacea to the ills of fossil fuels. Animals may be killed by turbines, and habitat destruction on ridgetops, somewhat akin to surface mining, must be considered in the siting of wind facilities. We urge decision makers to seek information from qualified biologists and from refereed journals and to otherwise be aware of conflicts of interests when considering sources of information regarding the effects of wind turbines on wildlife.

Demands placed on our environment by an ever-increasing human population and the ongoing perturbations of natural systems portend that protection, management, and conservation of our natural resources will continue to be major challenges. Most of the lands under management for wildlife and habitat conservation in Virginia, especially east of the mountains, are not contiguous. Moreover, much of the habitat in the matrices surrounding managed areas is unsuitable for many species. Challenges will be greatest for maintenance of viable populations of species considered to be habitat specialists, whether in mesic forests, overgrown fields, swamps, marshes, or clear, 1st-2nd order headwater streams. Despite these and other ongoing challenges, many of Virginia's land mammals have demonstrated resilience in their ability to persist during the more than 400 years since European contact. With the combined efforts of state and federal agencies and non-governmental organizations, most species should continue to be a part of our natural heritage well into the future.

ACKNOWLEDGMENTS

We thank R. Groover for the opportunity to participate in the symposium on Virginia's environment and W. Wieland for shepherding this manuscript through the editorial process. We especially thank M. Fies, W. M. Ford, K. Powers, and R. Rose for their many helpful comments on an earlier draft of this manuscript. M. Fies, B. Gwynn, D. Kalb, E. Moore, R. Reynolds, B. Sargent, B. Stinson, and H. Thompson quickly provided helpful information related to their areas of expertise. J. Davenport drafted the Figure, and K. Davis and L. Hightower provided editorial assistance. To obtain details for museum records, we sent information requests to Academy of Natural Sciences of Philadelphia on 11 August 2014 and Carnegie Museum of Natural History on 27 August 2014. We also searched the following institutions through the VertNet portal on 16 August 2014 and 9 January 2015: American Museum of Natural History, California Academy of Sciences, Centennial Museum, Charles R. Conner Museum, Cheadle Center for Biodiversity and Ecological Restoration, Cincinnati Museum Center, Cornell University Museum of Vertebrates, Delaware Museum of Natural History, Denver Museum of Nature & Science, Field Museum of Natural History, Florida Museum of Natural History, Georgia Southern University, Humboldt State University Wildlife Department, James R. Slater Museum of Natural History, John Wesley Powell-Dale Birkenholz Natural History Collections, University of Kansas Biodiversity Institute, Louisiana State University Museum of Natural Science, Michigan State University Museum, Milwaukee Public Museum, Moore Laboratory of Zoology, Museum of Comparative Zoology Harvard University, Museum of Southwestern Biology, Museum of Texas Tech University, Museum of Vertebrate Zoology University of California at Berkeley, United States National Museum of Natural History Smithsonian Institution, Natural History Museum of Los Angeles County, New Mexico Museum of Natural History and Science, New York State Museum, North Carolina Museum of Natural Sciences, Ohio State University, Oregon State University, Perot Museum of Nature and Science, Royal Ontario Museum, Sam Noble Oklahoma Museum of Natural History, San Diego Natural History Museum, Santa Barbara Museum of Natural History, Schmidt Museum of Natural History Emporia State University, Tall Timbers Research Station and Land Conservancy, Texas A&M University Biodiversity Research and Teaching Collections, The University of Texas at Austin Natural History Collections, Tulane University, University of Alabama Biodiversity and Systematics, University of Alaska Museum, University of Arkansas Collections Facility, University of British Columbia Beaty Biodiversity Museum, University of Colorado Museum of Natural History, University of Michigan Museum of Zoology, University of Nevada at Reno, University of Washington Burke Museum, University of Wyoming Museum of Vertebrates, Western Foundation of Vertebrate Zoology, Western New Mexico University.

LITERATURE CITED

Abatzoglou, J. T. and R. Barbero. 2014. Observed and projected changes in absolute temperature records across the contiguous United States. Geophysical Research Letters 42:650-658.

Abramov, A. V. 1999. A taxonomic review of the genus *Mustela* (Mammalia, Carnivora). Zoosystematica Rossica 8:357-364.

Abramov, A. V. and G. F. Baryshnikov. 1999. Geographic variation and intraspecific taxonomy of weasel *Mustela nivalis* (Carnivora, Mustelidae). Zoosystematica Rossica 8:365-402.

Arnett, E. B., W. Brown, W. P. Erickson, J. K. Fiedler, B. L. Hamilton, T. H. Henry, ... and R. D. Tankersley. 2008. Patterns of bat fatalities at wind energy facilities in North America. The Journal of Wildlife Management 72:61-78.

Ballash, G. A., J. P. Dubey, O. C. H. Kwok, A. B. Shoben, T. L. Robison, T. J. Kraft, and P. M. Dennis. 2015. Seroprevalence of *Toxoplasma gondii* in white-tailed deer (*Odocoileus virginianus*) and free-roaming cats (*Felis catus*) across a suburban to urban gradient in northeastern Ohio. EcoHealth 12:359-367.

Beckmann, J. P., A. P. Clevenger, M. Huijser, and J. A. Hilty (eds.). 2010. Safe Passages: Highways, Wildlife, and Habitat Connectivity. Island Press, Washington, D.C. 424 pp.

Bekoff, M. 1977. Canis latrans. Mammalian Species 79:1-9.

Bellows, A. S., J. F. Pagels, and J. C. Mitchell. 1999. First record of the least weasel, *Mustela nivalis* (Carnivora: Mustelidae), from the Coastal Plain of Virginia. Northeastern Naturalist 6:238-240.

Bellows, A. S., J. C. Mitchell, J. F. Pagels, and H. N. Mansfield. 2001. Mammals of Fort AP Hill, Caroline County, Virginia and vicinity. Virginia Journal of Science 52:163-226.

Beneski, J. T. and D. W. Stinson. 1987. Sorex palustris. Mammalian Species 296:1-6.

Best, T. L. 1996. Lepus californicus. Mammalian Species 530:1-10.

Best, T. L and J. B. Jennings. 1997. Myotis leibii. Mammalian Species 547:1-6.

Bininda-Edmonds, O. R. P., J. L. Gittleman, and A. Purvis. 1999. Building large trees by combining phylogenetic information: a complete phylogeny of the extant Carnivora (Mammalia). Biological Reviews 74:143-175.

Blair, W. F. 1942. Systematic relationships of *Peromyscus* and several related genera as shown by the baculum. Journal of Mammalogy 23:196-204.

Bozarth, C. A., F. Hailer, L. L. Rockwood, C. W. Edwards, and J. E. Maldonado. 2011. Coyote colonization of northern Virginia and admixture with Great Lakes wolves. Journal of Mammalogy 92:1070-1080.

Britzke, E. R., J. E. Duchamp, K. L. Murray, R. K. Swihart, and L. W. Robbins. 2011. Acoustic identification of bats in the eastern United States: a comparison of parametric and nonparametric methods. The Journal of Wildlife Management 75:660-667.

Caceres, M. C. and R. M. R. Barclay. 2000. Myotis septentrionalis. Mammalian Species 634:1-4.

Cameron, G. N. and S. R. Spencer. 1981. Sigmodon hispidus. Mammalian Species 158:1-9.

Campbell, T. A. and D. B. Long. 2009. Feral swine damage and damage management in forested ecosystems. Forest Ecology and Management 257:2319-2326.

Campbell, J. W., M. T. Mengak, S. B. Castleberry, and J. D. Mejia. 2010. Distribution and status of uncommon mammals in the southern Appalachian mountains. Southeastern Naturalist 9:275-302.

Carleton, M. D. 1980. Phylogenetic relationships in neotomine-peromyscine rodents (Muroidea) and a reappraisal of the dichotomy within New World Cricetinae. Miscellaneous Publications, Museum of Zoology, University of Michigan, 157:1-146.

Carleton, M. D., A. L. Gardner, I. Y. Pavlinov, and G. G. Musser. 2014. The valid generic name for red-backed voles (Muroidea: Cricetidae: Arvicolinae): restatement of the case for *Myodes* Pallas, 1811. Journal of Mammalogy 95:943-959.

Castleberry, S. B., M. T. Mengak, and W. M. Ford. 2006. Neotoma magister. Mammalian Species 789:1-5.

Chambers, S. M., S. R. Fain, B. Fazio, and M. Amaral. 2012. An account of the taxonomy of North American wolves from morphological and genetic analyses. North American Fauna 77:1-67.

Chapman, B. R. 2007a. Appalachian cottontail *Sylvilagus obscurus* (Chapman, Cramer, Dippenaar, and Robinson, 1992). Pages 243-246 *in* M. K. Trani, W. M. Ford, and B. R. Chapman (eds.), The Land Manager's Guide to Mammals of the South. The Nature Conservancy, Southeastern Region, Durham, NC. 546 pp.

Chapman, B. R. 2007b. Snowshoe hare *Lepus americanus* (Erxleben, 1777). Pages 226-229 *in* M. K. Trani, W. M. Ford, and B. R. Chapman (eds.), The Land Manager's Guide to Mammals of the South. The Nature Conservancy, Southeastern Region, Durham, NC. 546 pp.

Chapman, B. R. and M. K. Trani. 2007. Feral pig *Sus scrofa* (Linnaeus, 1758). Pages 540-544 *in* M. K. Trani, W. M. Ford, and B. R. Chapman (eds.), The Land Manager's Guide to Mammals of the South. The Nature Conservancy, Southeastern Region, Durham, NC. 546 pp.

Chapman, J. A. and G. R. Willner. 1981. Sylvilagus palustris. Mammalian Species 153:1-3.

Chapman, J. A., K. L. Cramer, N. J. Dippenaar, and T. J. Robinson. 1992. Systematics and biogeography of the New England cottontail, *Sylvilagus transitionalis* (Bangs, 1895), with the description of a new species from the Appalachian mountains. Proceedings of the Biological Society of Washington 105:841-866.

Chapman, J. A., J. G. Hockman, and M. M. Ojeda C. 1980. Sylvilagus floridanus. Mammalian Species 136:1-8.

Chupp, A. D., A. M. Roder, L. L. Battaglia, and J. F. Pagels. 2013. A case study of urban and peri-urban mammal communities: implications for the management of National Park Service areas. Northeastern Naturalist 20:631-654.

Churcher, C. S. 1959. The specific status of the New World red fox. Journal of Mammalogy 40:513-520.

Coffin, A. W. 2007. From roadkill to road ecology: a review of the ecological effects of roads. Journal of Transport Geography 15:396-406.

Colwell, D. D., F. Dantas-Torres, and D. Otranto. 2011. Vector-borne parasitic zoonoses: emerging scenarios and new perspectives. Veterinary Parasitology 182:14-21.

Conover, M. R. 1998. Impact of consuming tall fescue leaves with the endophytic fungus, *Acremonium coenophialum*, on meadow voles. Journal of Mammalogy 79:457-463.

Conroy, C. J. and J. A. Cook. 2000. Molecular systematics of a Holarctic rodent (*Microtus*: Muridae). Journal of Mammalogy 81:344-359.

Conroy, C. J., Y. Hortelano, F. A. Cervantes, and J. A. Cook. 2001. The phylogenetic position of southern relictual species of *Microtus* (Muridae: Rodentia) in North America. Mammalian Biology/Zeitschrift fur Saugetierkunde 66:332-344.

Coues, E. 1871. Former eastward range of the buffalo. American Naturalist 5:719-720.

Cranford, J. A. and D. S. Fortune. 1994. Mexican free-tailed bats at Mt. Lake Biological Station. Virginia Journal of Science 45:111.

Currier, M. J. P. 1983. Felis concolor. Mammalian Species 200:1-7.

Daszak, P., A. A. Cunningham, and A. D. Hyatt. 2000. Emerging infectious diseases of wildlife--threats to biodiversity and human health. Science 287:443-449.

Davidson, W. R. (ed.). 2006. Field Manual of Wildlife Diseases in the Southeastern United States. Third Edition. Southeastern Cooperative Wildlife Disease Study. 448 pp.

Decher, J. and J. R. Choate. 1995. Myotis grisescens. Mammalian Species 510:1-7.

Demboski, J. R. and J. A. Cook. 2003. Phylogenetic diversification within the *Sorex cinereus* group (Soricidae). Journal of Mammalogy 84:144-158.

Dobson, A. P., J. P. Rodriguez, W. M. Roberts, and D. S. Wilcove. 1997. Geographic distribution of endangered species in the United States. Science 275:550-553.

Dolan, P. G. and D. C. Carter. 1977. Glaucomys volans. Mammalian Species 78:1-6.

Duffy, P. B. and C. Tebaldi. 2012. Increasing prevalence of extreme summer temperatures in the US. Climatic Change 111:487-495.

Ellis, L. S., V. E. Diersing, and D. F. Hoffmeister. 1978. Taxonomic status of short-tailed shrews (*Blarina*) in Illinois. Journal of Mammalogy 59:305-311.

Erb, P. L., W. J. McShea, and R. P. Guralnick. 2012. Anthropogenic influences on macro-level mammal occupancy in the Appalachian trail corridor. PloS one 7:e42574.

Eshelman, R., and F. Grady. 1986. Quaternary vertebrate localities of Virginia and their avian and mammalian fauna. Pages 43-70 *in* J. N. McDonald and S. O. Bird (eds.), The Quaternary of Virginia – a symposium volume. Virginia Division of Mines and Mineral Resources. Publication 75. Charlottesville, VA. 137 pp.

FAUNMAP Working Group. 1994. FAUNMAP: A database documenting late quaternary distributions of mammal species in the United States. Illinois State Museum Scientific Papers 25:1-690.

Feldhamer, G. A. 1980. Cervus nippon. Mammalian Species 128:1-7.

Feldhamer, G. A., D. R. Gillespie, and W. B. Taliaferro. 1981. Recent record of a porcupine in western Maryland. Proceedings of the Pennsylvania Academy of Science 55:199.

Fenton, M. B. and R. M. R. Barclay. 1980. Myotis lucifugus. Mammalian Species 142:1-8.

Fies, M. L. 1991. Snowshoe hare. Pages 576-578 *in* K. Terwilliger (coordinator), Virginia's Endangered Species. The McDonald and Woodward Publishing Company, Blacksburg, VA. 672 pp.

Fies, M. L. 1992. Survival and movement of relocated snowshoe hares (*Lepus americanus*) in western Virginia. Virginia Journal of Science 43:230.

Fies, M.L. 1993. Fox squirrels (*Sciurus niger*) in Virginia: a review of historical collection records and information from recent populations surveys. Pages 37-49 *in* N. D. Moncrief, J. W. Edwards and P. A. Tappe (eds.). Proceedings of the Second Symposium on Southeastern Fox Squirrels, *Sciurus niger*. Virginia Museum of Natural History Special Publication Number 1. 84 pp.

Fies, M. L. and J. F. Pagels. 1991. Northern flying squirrel. Pages 583-584 *in* K. Terwilliger (coordinator), Virginia's Endangered Species. The McDonald and Woodward Publishing Company, Blacksburg, VA. 672 pp.

Fies, M. L., I. L. Kenyon Jr, and J. V. Gwynn. 1992. Effects of changing land use patterns on bobwhite quail habitat in Virginia. Virginia Journal of Science 43:143-156.

Ford, W. M., S. B. Castleberry, M. T. Mengak, J. L. Rodrigue, D. J. Feller, and K. R. Russell. 2006a. Persistence of Allegheny woodrats *Neotoma magister* across the mid Atlantic Appalachian Highlands landscape, USA. Ecography 29:745-754.

Ford, W. M., T. S. McCay, M. A. Menzel, W. D. Webster, C. H. Greenberg, J. F. Pagels, and J. F. Merritt. 2006b. Influence of elevation and forest type on community assemblage and species distribution of shrews in the central and southern Appalachian Mountains. Pages 303-315 *in* J. F. Merritt, S. Churchfield, R. Hutterer, and B. A. Sheftel (eds.) Advances in the Biology of Shrews, II. International Society of Shrew Biologists, Carnegie Museum of Natural History, Pittsburgh, PA. 458 pp.

Ford, W. M., K. R. Moseley, C. W. Stihler, and J. W. Edwards. 2010. Area occupancy and detection probabilities of the Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*) using nest-box surveys. Pages 37-47 *in* J. S. Rentch and T. M. Schuler (eds.), Proceedings from the Conference on the Ecology and Management of High Elevation Forests in the Central and Southern Appalachian Mountains. USDA Forest Service General Technical Report NRS-P-64. 242 pp.

Ford, W. M., A. M. Evans, R. H. Odom, J. L. Rodrigue, C. A. Kelly, N. Abaid, C. A. Diggins, and D. Newcomb. 2015. Predictive habitat models derived from nest-box occupancy for the endangered Carolina northern flying squirrel in the southern Appalachians. Endangered Species Research 27:131-140, doi: 10.3354/esr00662.

Forman, R. T. 2000. Estimate of the area affected ecologically by the road system in the United States. Conservation Biology 14:31-35.

Forman, R. T. and L. E. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29:207-231.

Francl, K. E. and D. Meikle. 2009. A range extension of the hispid cotton rat, *Sigmodon hispidus*, in Virginia. Banisteria 33:54-55.

Francl, K. E. and C. J. Small. 2013. Temporal changes and prescribed-fire effects on vegetation and small-mammal communities in central Appalachian forest, creek, and field habitats. Southeastern Naturalist 12:11-26.

French, T. W. 1980. Sorex longirostris. Mammalian Species 143:1-3.

Frey, J. K. 2013. Re-evaluation of the evidence for the importation of red foxes from Europe to colonial America: origins of the southeastern red fox (*Vulpes vulpes fulva*). Biological Conservation 158:74-79.

Fritzell, E. K. and K. J. Haroldson. 1982. Urocyon cinereoargenteus. Mammalian Species 189:1-8.

Fujita, M. S. and T. H. Kunz. 1984. Pipistrellus subflavus. Mammalian Species 228:1-6.

Gajewski, P. D., M. Falkenstein, J. G. Hengstler, and K. Golka. 2014. *Toxoplasma gondii* impairs memory in infected seniors. Brain, Behavior, and Immunity 36:193-199.

Gehrt, S. D., C. Anchor and L. A. White. 2009. Home range and landscape use of coyotes in a metropolitan landscape: conflict or coexistence? Journal of Mammalogy 90:1045-1057.

Genoways, H. H. and J. R. Choate. 1972. A multivariate analysis of systematic relationships among populations of the short-tailed shrew (genus *Blarina*) in Nebraska. Systematic Zoology 21:106-116.

George, S. B. 1988. Systematics, historical biogeography, and evolution of the genus *Sorex*. Journal of Mammalogy 69:443-461.

George, S. B., J. R. Choate, and H. H. Genoways. 1986. Blarina brevicauda. Mammalian Species 261:1-9.

Gilmore, R. M. 1946. Mammals in archeological collections from southwestern Pennsylvania. Journal of Mammalogy 27:227-234.

Glass, B. P. and R. J. Baker. 1968. The status of the name *Myotis subulatus* Say. Proceedings of the Biological Society of Washington 81:257-260.

Goode, G. B. 1878. The occurrence of the Canada Porcupine in West Virginia. Proceedings of the United States National Museum 1:264-265.

Gorte, R. W., C. H. Vincent, L. A. Hanson, and M. R. Rosenblum. 2012. Federal land ownership: overview and data. Congressional Research Service 42346.

Gottdenker, N. L., D. G. Streicker, C. L. Faust, and C. R. Carroll. 2014. Anthropogenic land use change and infectious diseases: a review of the evidence. EcoHealth 11:619-632.

Guerra, M. A., A. T. Curns, C. E. Rupprecht, C. A. Hanlon, J. W. Krebs, and J. E. Childs. 2003. Skunk and raccoon rabies in the eastern United States: temporal and spatial analysis. Emerging Infectious Diseases 9:1143–1150, doi:10.3201/eid0909.020608.

Haddad, N. M., L. A. Brudvig, J. Clobert, K. F. Davies, A. Gonzalez, R. D. Holt, ... and J. R. Townshend. 2015. Habitat fragmentation and its lasting impact on Earth's ecosystems. Science Advances 1:e1500052.

Hall, E. R. 1981. Mammals of North America. Second ed. John Wiley and Sons, New York, NY 1:1-600+90.

Hallett, J. G. 1978. Parascalops breweri. Mammalian Species 98:1-4.

Handley, C. O., Jr. 1956. The shrew *Sorex dispar* in Virginia. Journal of Mammalogy 37:435.

Handley, C. O., Jr. 1971. Appalachian mammalian geography – Recent epoch. Pages 263-303 *in* P. C. Holt, R. A. Patterson, and J. P. Hibbard (eds.), The Distributional History of the Biota of the Southern Appalachians, Part III, Vertebrates. Virginia Polytechnic Institute and State University, Research Division Monograph 4. 306 pp.

Handley, C. O., Jr. 1979a. Mammals. Pages 483-621 *in* D. W. Linzey (ed.), Proceedings of the Symposium on Endangered and Threatened Plants and Animals of Virginia. Virginia Polytechnic Institute and State University, Blacksburg, VA. 665 pp.

Handley, C. O, Jr. 1979b. Mammals of the Dismal Swamp: a historical account. Pages 297-357 *in* P. W. Kirk, Jr. (ed.), The Great Dismal Swamp. University Press Virginia, Charlottesville, VA. 427 pp.

Handley, C. O., Jr. 1991. Mammals. Pages 539-616 *in* K. Terwilliger (coordinator), Virginia's Endangered Species. The McDonald and Woodward Publishing Company, Blacksburg, VA. 672 pp.

Handley, C. O., Jr. 1992. Terrestrial mammals of Virginia: trends in distribution and diversity. Virginia Journal of Science 43:157-160.

Handley, C. O., Jr. and E. K. V. Kalko. 1993. A short history of pitfall trapping in America, with a review of methods currently used for small mammals. Virginia Journal of Science 44:19-26.

Handley, C. O., Jr. and C. P. Patton. 1947. Wild Mammals of Virginia. Commonwealth of Virginia Commission of Game and Inland Fisheries. 220 pp.

Handley, C. O., Jr., G. Tipton, and A. Tipton. 1979. *Plecotus townsendii virginianus*. Pages 497-500 *in* D. W. Linzey (ed.), Proceedings of the Symposium on Endangered and Threatened Plants and Animals of Virginia. Virginia Polytechnic Institute and State University, Blacksburg, VA. 665 pp.

Harman, D. M. and T. Thoerig. 1968. Occurrence of the porcupine *Erethizon dorsatum* and the nutria *Myocastor coypus bonariensis* in western Maryland. Chesapeake Science 9:138-139.

Hawkins, C. C., W. E. Grant, and M. T. Longnecker. 2004. Effect of house cats, being fed in parks, on California birds and rodents. Pages 164-170 *in* W. W. Shaw, L. K. Harris, and L. Vandruff (eds.), Proceedings of the 4th International Urban Wildlife Symposium, School of Natural Resources, College of Agriculture and Life Science, University of Arizona, Tucson, AZ. 368 pp.

Hensley, M. S. 1976. Prevalence of cuterebrid parasitism among wood mice in Virginia. Journal of Wildlife Diseases 12:172-179.

Herd, R. M. 1987. Electrophoretic divergence of *Myotis leibii* and *Myotis ciliolabrum* (Chiroptera: Vespertilionidae). Canadian Journal of Zoology 65:1857-1860.

Hill, E. P., P. W. Sumner, and J. B. Wooding. 1987. Human influences on range expansion of coyotes in the Southeast. Wildlife Society Bulletin 15:521-524.

Hobson, C. S. 1998. Bat records from southeastern Virginia, including a new resident species, *Myotis austroriparius* (Chiroptera: Vespertilionidae). Banisteria 12:18-23.

Holloway, H. L. 1957. *Sorex dispar* at Mountain Lake, Virginia. Journal of Mammalogy 38:406.

Holsinger, J. R. 1964. The gray myotis in Virginia. Journal of Mammalogy 45:151-152.

Hoofer, S. R. and R. A. Van Den Bussche. 2001. Phylogenetic relationships of plecotine bats and allies based on mitochondrial ribosomal sequences. Journal of Mammalogy 82:131-137.

Hoofer, S. R. and R. A. Van Den Bussche. 2003. Molecular phylogenetics of the chiropteran family Vespertilionidae. Acta Chiropterologica 5:1-63.

Hoofer, S. R., R. A. Van Den Bussche, and I. Horáček. 2006. Generic status of the American pipistrelles (Vespertilionidae) with description of a new genus. Journal of Mammalogy 87:981-992.

Hope, A. G., K. A. Speer, J. R. Demboski, S. L. Talbot, and J. A. Cook. 2012. A climate for speciation: rapid spatial diversification within the *Sorex cinereus* complex of shrews. Molecular Phylogenetics and Evolution 64:671-684.

Hughes, J. and D. W. Macdonald. 2013. A review of the interactions between free-roaming domestic dogs and wildlife. Biological Conservation 157:341-351.

[IDFW] Indiana Division of Fish and Wildlife [Internet]. 2006. Fescue Eradication: Habitat Management Fact Sheet. [accessed 28 Aug. 2015]. Available from www.in.gov/dnr/fishwild/files/fescue.pdf

Jachowski, D. S., C. A. Dobony, L. S. Coleman, W. M. Ford, E. R. Britzke, and J. L. Rodrigue. 2014. Disease and community structure: white nose syndrome alters spatial and temporal niche partitioning in sympatric bat species. Diversity and Distributions 20:1002-1015.

Jenkins, S. H. and P. E. Busher. 1979. Castor canadensis. Mammalian Species 120:1-8.

Johnson, D. H. 1950. *Myotis subulatus leibii* in Virginia. Journal of Mammalogy 31:197.

Jones, C. 1977. Plecotus rafinesquii. Mammalian Species 69:1-4.

Jones, C. and R. W. Manning. 1989. Myotis austroriparius. Mammalian Species 332:1-3.

Joseph, M. B., J. R. Mihaljevic, A. L. Arellano, J. G. Kueneman, D. L. Preston, P. C. Cross, and P. T. Johnson. 2013. Taming wildlife disease: bridging the gap between science and management. Journal of Applied Ecology 50:702-712.

Kamler, J. F. and W. B. Ballard. 2002. A review of native and nonnative red foxes in North America. Wildlife Society Bulletin 30:370-379.

Kane, A., T. C. Burkett, S. Klopfer, and J. Sewall. 2013. Virginia's climate modeling and species vulnerability assessment: how climate data can inform management and conservation. National Wildlife Federation, Reston, VA. 63 pp.

Kasprowicz, A. E., M. J. Statham, and B. N. Sacks. 2016. Fate of the other redcoat: remnants of colonial British foxes in the eastern United States. Journal of Mammalogy 97:298-309.

Kelly, C. A., C. A. Diggins, and A. J. Lawrence. 2013. Crossing structures reconnect federally endangered flying squirrel populations divided for 20 years by road barrier. Wildlife Society Bulletin 37:375-379.

Kinlaw, A. 1995. Spilogale putorius. Mammalian Species 511:1-7.

Kirkland, G. L., Jr. 1977. A re-examination of the subspecific status of the Maryland shrew, *Sorex cinereus fontinalis* Hollister. Proceedings of the Pennsylvania Academy of Sciences 51:43-46.

Kirkland, G. L., Jr. 1981. Sorex dispar and Sorex gaspensis. Mammalian Species 155:1-4.

Kirkland, G. L., Jr. and F. J. Jannett, Jr. 1982. Microtus chrotorrhinus. Mammalian Species 180:1-5.

Klopfer, S. D. and M. St. Germain. 2012. Final report: support for a nutria eradication program in Virginia. Conservation Management Institute, College of Natural Resources and Environment, Virginia Tech, Blacksburg, VA. 19 pp.

Kocka, D. and W. J. McShea. 2011. Big cats in Virginia: the facts ain't lion. Virginia Wildlife February 18-21.

Koepfli, K. P., K. A. Deere, G. J. Slater, C. Begg, K. Begg, L. Grassman, ... and R. K. Wayne. 2008. Multigene phylogeny of the Mustelidae: resolving relationships, tempo and biogeographic history of a mammalian adaptive radiation. BMC Biology 6:10, doi:10.1186/1741-7007-6-10

Koprowski, J. L. 1994a. Sciurus carolinensis. Mammalian Species 480:1-9.

Koprowski, J. L. 1994b. Sciurus niger. Mammalian Species 479:1-9.

Kratochvil, J. 1982. Karyotyp und system der familie Felidae (Carnivora, Mammalia). Folia Zoologica 31:289-304.

Kretzoi, M. 1964. Uber einige homonyme und synonyme Saugetiernamen. Vertebrata Hungarica 6:131-138.

Kunz, T. H. 1982. Lasionycteris noctivagans. Mammalian Species 172:1-5.

Kunz, T. H. and R. A. Martin. 1982. Plecotus townsendii. Mammalian Species 175:1-6.

Kunz, T. H., E. B. Arnett, W. P. Erickson, A. R. Hoar, G. D. Johnson, R. P. Larkin, ... and M. D. Tuttle. 2007. Ecological impacts of wind energy development on bats: questions, research needs, and hypotheses. Frontiers in Ecology and the Environment 5:315-324.

Kurose, N., A. V. Abramov, and R. Masuda. 2000. Intrageneric diversity of the cytochrome b gene and phylogeny of Eurasian species of the genus *Mustela* (Mustelidae, Carnivora). Zoological Science Tokyo 17:673-679.

Kurta, A. and R. H. Baker. 1990. Eptesicus fuscus. Mammalian Species 356:1-10.

Kwiecinski, C. G. 1998. Marmota monax. Mammalian Species 591:1-8.

Lackey, J. A., D. G. Huckaby, and B. G. Ormiston. 1985. Peromyscus leucopus. Mammalian Species 247:1-10.

Lawler, J. J., S. L. Shafer, D. White, P. Kareiva, E. P. Maurer, A. R. Blaustein, and P. J. Bartlein. 2009. Projected climate-induced faunal change in the Western Hemisphere. Ecology 90:588-597.

Laerm, J. and S. B. Castleberry. 2007. Deer mouse *Peromyscus maniculatus* (Wagner, 1845). Pages 337-341 *in* M. K. Trani, W. M. Ford, and B. R. Chapman (eds.), The Land Manager's Guide to Mammals of the South. The Nature Conservancy, Southeastern Region, Durham, NC. 546 pp.

Laerm, J. and W. D. Webster. 2007a. House mouse *Mus musculus* (Linnaeus, 1758). Pages 293-296 *in* M. K. Trani, W. M. Ford, and B. R. Chapman (eds.), The Land Manager's Guide to Mammals of the South. The Nature Conservancy, Southeastern Region, Durham, NC. 546 pp.

Laerm, J. and W. D. Webster. 2007b. Norway rat *Rattus norvegicus* (Berkenhout, 1769). Pages 350-353 *in* M. K. Trani, W. M. Ford, and B. R. Chapman (eds.),The Land Manager's Guide to Mammals of the South. The Nature Conservancy, Southeastern Region, Durham, NC. 546 pp.

Laerm, J. and W. D. Webster. 2007c. Black rat *Rattus rattus* (Linnaeus, 1758). Pages 354-357 *in* M. K. Trani, W. M. Ford, and B. R. Chapman (eds.), The Land Manager's Guide to Mammals of the South. The Nature Conservancy, Southeastern Region, Durham, NC. 546 pp.

Larivière, S. 1999. Mustela vison. Mammalian Species 608:1-9.

Larivière, S. 2001. Ursus americanus. Mammalian Species 647:1-11.

Larivière, S. and M. Pasitschniak-Arts. 1996. Vulpes vulpes. Mammalian Species 537:1-11.

Larivière, S. and L. R. Walton. 1997. Lynx rufus. Mammalian Species 563:1-8.

Larivière, S. and L. R. Walton. 1998. Lontra canadensis. Mammalian Species 587:1-8.

Li, B., M. Wolsan, D. Wu, W. Zhang, Y. Xu, and Z. Zeng. 2014. Mitochondrial genomes reveal the pattern and timing of marten (*Martes*), wolverine (*Gulo*), and fisher (*Pekania*) diversification. Molecular Phylogenetics and Evolution 80:156-164.

Linzey, A.V. 1983. Synaptomys cooperi. Mammalian Species 210:1-5.

Linzey, D. W. (ed.). 1979. Proceedings of the symposium on endangered and threatened plants and animals of Virginia. Virginia Polytechnic Institute and State University, Blacksburg, VA. 665 pp.

Linzey, D. W. 1998. The Mammals of Virginia. McDonald and Woodward Publishing Company, Blacksburg, VA. 459 pp.

Linzey, D. W. and R. L. Packard. 1977. Ochrotomys nuttalli. Mammalian Species 75:1-6.

LoGiudice, K. 2003. Trophically transmitted parasites and the conservation of small populations: raccoon roundworms and the imperiled Allegheny woodrat. Conservation Biology 17:258-266.

Long, C. A. 1974. Microsorex hoyi and Microsorex thompsoni. Mammalian Species 33:1-4.

Loss, S. R., T. Will, and P. P. Marra. 2013. The impact of free-ranging domestic cats on wildlife of the United States. Nature Communications 4:1396.

Lotze, J. H. and S. Anderson. 1979. Procyon lotor. Mammalian Species 119:1-8.

Loyd, K. A. T., S. M. Hernandez, J. P. Carroll, K. J. Abernathy, and G. J. Marshall. 2013. Quantifying free-roaming domestic cat predation using animal-borne video cameras. Biological Conservation 160:183-189.

Ludt, C. J., W. Schroeder, O. Rottmann, and R. Kuehn. 2004. Mitochondrial DNA phylogeography of red deer (*Cervus elaphus*). Molecular Phylogenetics and Evolution 31:1064-1083.

Lugger, O. 1881. The occurrence of the Canada porcupine in Maryland. Proceedings of the United States National Museum 4:161-162.

Maehr, D. S., J. J. Cox, and J. L. Larkin. 2007. Elk *Cervus elaphus* (Linnaeus, 1758). Pages 526-532 *in* M. K. Trani, W. M. Ford, and B. R. Chapman (eds.), The Land Manager's Guide to Mammals of the South. The Nature Conservancy, Southeastern Region, Durham, NC. 546 pp.

Mastro, L. L. 2011. Life history and ecology of coyotes in the Mid-Atlantic states: a summary of the scientific literature. Southeastern Naturalist 10:721-730.

McCain, C. M. and S. R. King. 2014. Body size and activity times mediate mammalian responses to climate change. Global Change Biology 20:1760-1769.

McCay, T. S. 2001. Blarina carolinensis. Mammalian Species 673:1-7.

McCollough, M. 2011. Eastern puma (=cougar) *(Puma concolor couguar)* 5-year review: summary and evaluation. Retrieved from http://ecos.fws.gov/docs/five_year_review/doc3611.pdf P:\TE\Recovery\5-Year Reviews\eastern cougar\Eastern cougar 5-year review-final-111610.doc. 106 pp.

McManus, J. J. 1974. Didelphis virginiana. Mammalian Species 40:1-6.

McShea, W. J., J. Pagels, J. Orrock, E. Harper, and K. Koy. 2003. Mesic deciduous forest as patches of small-mammal richness within an Appalachian mountain forest. Journal of Mammalogy 84:627-643.

Meagher, M. 1986. Bison bison. Mammalian Species 266:1-8.

Mech, L.D. 1974. Canis lupus. Mammalian Species. 37:1-6.

Menzel, J. M., W. M. Ford, J. W. Edwards, and L. J. Ceperley. 2006. A habitat model for the Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*) in the central Appalachian Mountains. USDA Forest Service Research Paper-NE-729. 10 pp.

Menu, H. 1984. Revision du statut de *Pipistrellus subflavus* (F. Cuvier, 1832). Proposition d'un taxon generique nouveau: *Perimyotis* nov. gen. Mammalia 48:409-416.

Merritt, J. F. 1981. Clethrionomys gapperi. Mammalian Species 146:1-9.

Mills, D. S. and S. M. McDonnell (eds.). 2005. The Domestic Horse: the Origins, Development and Management of Its Behaviour. Cambridge University Press. 264 pp.

Mitchell, J. C. and R. A. Beck. 1992. Free-ranging domestic cat predation on native vertebrates in rural and urban Virginia. Virginia Journal of Science 43:197-207.

Moncrief, N. D. and R. D. Dueser. 1998. First record of a shrew of the genus *Sorex* on the eastern shore of Virginia. Banisteria 12:40-41.

Moncrief, N. D. and M. L. Fies. 2015. Report of first specimens of *Pekania pennanti* (fisher) from Virginia. Northeastern Naturalist 22:N31-N34.

Moncrief, N. D., R. A. Van Den Bussche, R. D. Dueser, D. Loftis, N. E. Cockett, and M. Culver. 2008. Diagnostic genetic marker that differentiates eastern fox squirrels from eastern gray squirrels. The Journal of Wildlife Management 72:320-323.

Montague, D. M. 2014. Diet and feeding ecology of coyotes, black bears, and bobcats in western Virginia and preliminary assessment of coyote parasites. M.S. Thesis, Virginia Tech, Blacksburg. 182 pp.

[NPS] National Park Service [Internet]. 2015. Virginia Parks. [updated 28 Aug. 2015; accessed 28 Aug. 2015]. Available from www.nps.gov/state/va/index.htm.

Newsome, T. M. and W. J. Ripple. 2015. A continental scale trophic cascade from wolves through coyotes to foxes. Journal of Animal Ecology 84:49-59.

Nowak, R. M. 2002. The original status of wolves in eastern North America. Southeastern Naturalist 2:95-130.

Orrock, J. L. and J. F. Pagels. 2003. Tree communities, microhabitat characteristics, and small mammals associated with the endangered rock vole, *Microtus chrotorrhinus*, in Virginia. Southeastern Naturalist 2:547-558.

Orrock, J. L., E. K. Harper, J. F. Pagels, and W. M. McShea. 1999. Additional records of the rock vole, *Microtus chrotorrhinus* (Miller) (Mammalia: Rodentia: Muridae) in Virginia. Banisteria 14:36-38.

Orrock, J. L., J. F. Pagels, W. J. McShea, and E. K. Harper. 2000. Predicting habitat suitability and quality for a small mammal: the effect of scale and resolution. Ecological Applications 10:1356-1366.

Owen, J. G. 1984. Sorex fumeus. Mammalian Species 215:1-8.

Pack, J. C. and J. I. Cromer. 1981. Reintroductions of fisher in West Virginia. Pages 1431-1442 *in* J. A. Chapman, A. K. Fuller, and D. Pursley (eds.), Proceedings of the First Worldwide Furbearer Conference, Volume 2. Worldwide Furbearer Conference, Inc., Frostburg, MD. 2056 pp.

Padgett, T. M. 1987. The first record of the seminole bat, *Lasiurus seminolus* (Chiroptera: Vespertilionidae), from Virginia. Virginia Journal of Science 38:253.

Padgett, T. M. and R. K. Rose. 1991. Bats (Chiroptera: Vespertilionidae) of the Great Dismal Swamp of Virginia and North Carolina. Brimleyana 17:17-26.

Padgett, T. M. and R. K. Rose. 1994. The pygmy shrew, *Sorex hoyi winnemana* (Insectivora: Soricidae), from the Coastal Plain of North Carolina. Brimleyana 21:87-90.

Page, L. K. 2013. Parasites and the conservation of small populations: the case of *Baylisascaris procyonis*. International Journal for Parasitology: Parasites and Wildlife 2:203-210.

Pagels, J. F. 1979. Virginia mammals: the changing scene. Pages 603-609 *in* D. W. Linzey (ed.), Proceedings of Endangered and Threatened Plants and Animals of Virginia. Center for Environmental Studies, Virginia Polytechnic Institute and State University, Blacksburg, VA. 665 pp.

Pagels, J. F. 1987. The pygmy shrew, rock shrew and water shrew: Virginia's rarest shrews (Mammalia: Soricidae). Virginia Journal of Science 38:364-368.

Pagels, J. F. 1990. First record of the rock vole, *Microtus chrotorrhinus* (Miller) (Rodentia: Cricetidae), in Virginia. Brimleyana 16:1-3.

Pagels, J. F. and R. G. Adleman. 1971. A note on the cotton rat in central Virginia. Virginia Journal of Science 22:195.

Pagels, J. F. and T. W. French. 1987. Discarded bottles as a source of small mammal distribution data. American Midland Naturalist 118:217-219.

Pagels, J. F. and C. M. Tate. 1976. Shrews (Insectivora: Soricidae) of the Paddy Knob-Little Back Creek area of western Virginia. Virginia Journal of Science 27:202-203.

Pagels, J. F., R. P. Eckerlin, J. R. Baker, and M. L. Fies. 1990. New records of the distribution and internal parasites of the endangered northern flying squirrel, *Glaucomys sabrinus*, in Virginia. Brimleyana 16:73-78.

Pagels, J. F., M. L. Fies, and R. Glasgow. 1991. Recovery plan: Appalachian water shrew, *Sorex palustris punctulatus* Hooper. Virginia Department of Game and Inland Fisheries. 32 pp.

Pagels, J. F., S. Y. Erdle, K. L. Uthus, and J.C. Mitchell. 1992. Small mammal diversity in forest and clearcut habitats in the Virginia Piedmont. Virginia Journal of Science 43:171-176.

Pagels, J. F., L. A. Smock, and S. H. Sklarew. 1998. The water shrew, *Sorex palustris* Richardson (Insectivora:Soricidae), and its habitat in Virginia. Brimleyana 25:120-134.

Paradiso, J. L. 1969. Mammals of Maryland. North American Fauna 66:1-193.

Patton, C. P. 1941. The eastern cotton rat in Virginia. Journal of Mammalogy 22:91.

Payne, J. L., D. R. Young, and J. F. Pagels. 1989. Plant community characteristics associated with the endangered northern flying squirrel, *Glaucomys sabrinus*, in the southern Appalachians. American Midland Naturalist 121:285-292.

Peacock, D. and R. Peacock. 1962. *Peromyscus maniculatus bairdii* in Virginia. Journal of Mammalogy 43:98.

Petersen, K. E. and T. L. Yates. 1980. Condylura cristata. Mammalian Species 129:1-4.

Pisula, N. L. and S. J. Meiners. 2010. Relative allelopathic potential of invasive plant species in a young disturbed woodland. The Journal of the Torrey Botanical Society 137:81-87.

Pitra, C., J. Fickel, E. Meijaard, and C. Groves. 2004. Evolution and phylogeny of old world deer. Molecular Phylogenetics and Evolution 33:880-895.

Pitts, R. M. and G. L. Kirkland, Jr. 1987. A record of the prairie deer mouse (*Peromyscus maniculatus bairdii*) from Rockbridge County, Virginia. Proceedings of the Pennsylvania Academy of Science 61:205.

Pocock, R. I. 1917. The classification of the existing Felidae. Annals and Magazine of Natural History 20:329-350.

Powell, R. A. 1981. Martes pennanti. Mammalian Species 156:1-6.

Powers, K.E., R.J. Reynolds, W. Orndorff, W.M. Ford, and C.S. Hobson. 2015. Post-white-nose syndrome trends in Virginias cave bats, 2008-2013. Journal of Ecology and The Natural Environment 7:113-123.

Rageot, R. H. 1955. A new northernmost record of the yellow bat, *Dasypterus floridanus*. Journal of Mammalogy 36:456.

Reich, L. M. 1981. Microtus pennsylvanicus. Mammalian Species 159:1-8.

Reynolds, R. J. and R. T. Fernald. 2015. A Guide to the Bats of Virginia. Bureau of Wildlife Resources Special Publication Number 5, Virginia Department of Game & Inland Fisheries. Richmond, Va. 40 pp.

Reynolds, R. J., J. F. Pagels, and M. L. Fies. 1999. Demography of northern flying squirrels in Virginia. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 53:340-349.

Romin, L. A. and J. A. Bissonette. 1996. Deer-vehicle collisions: status of state monitoring activities and mitigation efforts. Wildlife Society Bulletin 24:276-283.

Rose, R. K. 1986. Late prehistoric and protohistoric large mammal zoogeography of Virginia. Pages 79-88 *in* J. N. McDonald and S. O. Bird (eds.). The Quaternary of Virginia---A Symposium Volume. Virginia Division of Mineral Resources, Special Publication 75. 137 pp.

Rose, R. K. 1999. The small mammals of the Dismal Swamp: an update. Pages 214-219 *in* R.K. Rose (ed.), The Natural History of the Great Dismal Swamp. Old Dominion University Publications, Norfolk, VA. 300 pp.

Rose, R. K. 2006. Distribution and status of the southern bog lemming, *Synaptomys cooperi*, in southeastern Virginia. Virginia Journal of Science 57:153-165.

Rose, R. K. 2013. The history of mammal studies in Virginia. Banisteria 41:17-26.

Samuels, J. X. and J. Cavin. 2013. The earliest known fisher (Mustelidae), a new species from the Rattlesnake Formation of Oregon. Journal of Vertebrate Paleontology 33:448-454.

Serpell, J. (ed.). 1995. The Domestic Dog: Its Evolution, Behaviour, and Interactions with People. Cambridge University Press. 284 pp.

Sheffield, S. R. and C. M. King. 1994. Mustela nivalis. Mammalian Species, 454:1-10.

Sheffield, S. R. and H. H. Thomas. 1997. Mustela frenata. Mammalian Species 570:1-9.

Shump, K. A., Jr. and A. U. Shump. 1982a. Lasiurus borealis. Mammalian Species 183:1-6.

Shump, K. A., Jr. and A. U. Shump. 1982b. Lasiurus cinereus. Mammalian Species 185:1-5.

Skog, A., F. E. Zachos, E. K. Rueness, P. G. D. Feulner, A. Mysterud, R. Langvatn, ... and K. S. Jakobsen. 2009. Phylogeography of red deer (*Cervus elaphus*) in Europe. Journal of Biogeography 36:66-77.

Sleeman, J. 2006. Wildlife zoonoses for the veterinary practitioner. Journal of Exotic Pet Medicine 15:25-32.

Smith, J. S., J. W. Sumner, L. F. Roumillat, G. M. Baer, and W. G. Winkler. 1984. Antigenic characteristics of isolates associated with a new epizootic of raccoon rabies in the United States. Journal of Infectious Diseases 149:769-774.

Smith, W. P. 1991. Odocoileus virginianus. Mammalian Species 388:1-13.

Smolen, M. J. 1981. Microtus pinetorum. Mammalian Species 147:1-7.

Snyder, D. P. 1982. Tamias striatus. Mammalian Species 168:1-8.

Sorvillo, F., L.R. Ash, O.G.W. Berlin, J. Yatabe, C. Degiorgio, and S.A. Morse. 2002. *Baylisascaris procyonis*: an emerging helminthic zoonosis. Emerging Infectious Diseases 8:355-359.

Sparks J. L., Jr. 2005. Genetic variability, pathogen susceptibility, subspecies identity, and conservation of the endangered northern flying squirrel (*Glaucomys sabrinus*) in Virginia. MS Thesis, Virginia Commonwealth University, Richmond, VA. 73 pp.

Sparks, J. L., Jr. and J. E. Gates. 2012. An investigation into the use of road drainage structures by wildlife in Maryland, USA. Human-Wildlife Interactions 6:311-326.

Stalling, D.T. 1997. Reithrodontomys humulis. Mammalian Species 565:1-6.

Statham, M. J., B. N. Sacks, K. B. Aubry, J. D. Perrine, and S. M. Wisely. 2012. The origin of recently established red fox populations in the United States: translocations or natural range expansions? Journal of Mammalogy 93:52-65.

Steele, M. A. 1998. Tamiasciurus hudsonicus. Mammalian Species 586:1-9.

Stephenson, S. L., H. S. Adams, and M. L. Lipford. 1992. The impact of human activities on the upland forests of western Virginia. Virginia Journal of Science 43:121-132.

Stewart, D. T., A. J. Baker, and S. P. Hindocha. 1993. Genetic differentiation and population structure in *Sorex haydeni* and *S. cinereus*. Journal of Mammalogy 74:21-32.

Tate, C. M., J. F. Pagels, and C. O. Handley, Jr. 1980. Distribution and systematic relationship of two kinds of short-tailed shrews (Soricidae: *Blarina*) in south-central Virginia. Proceedings of the Biological Society of Washington 93:50-60.

Tenter, A. M., A. R. Heckeroth, and L. M. Weiss. 2000. *Toxoplasma gondii*: from animals to humans. International Journal for Parasitology 30:1217-1258.

Thogmartin, W. E., C. A. Sanders-Reed, J. A. Szymanski, P. C. McKann, L. Pruitt, R. A. King, ... and R. E. Russell. 2013. White-nose syndrome is likely to extirpate the endangered Indiana bat over large parts of its range. Biological Conservation 160:162-172.

Thompson, J. and K. Francl-Powers. 2013. A brief history of terrestrial game species management in Virginia: 1900-present. Banisteria 41:59-66.

Thomson, C. E. 1982. Myotis sodalis. Mammalian Species 163:1-5.

Torrey, E. F. and R. H. Yolken. 2013. *Toxoplasma* oocysts as a public health problem. Trends in Parasitology 29:380-384.

Tumlison, R. and M. E. Douglas. 1992. Parsimony analysis and the phylogeny of plecotine bats (Chiroptera: Vespertilionidae). Journal of Mammalogy 73:276-285.

Turner, D. C. and P. Bateson. (eds.). 2013. The Domestic Cat: the Biology of Its Behaviour. Cambridge University Press. 288 pp.

[USDA] U. S. Department of Agriculture Forest Service [Internet]. 2015. George Washington & Jefferson National Forests. About the Forest. [accessed 28 Aug. 2015]. Available from www.fs.usda.gov/detail/gwj/home/?cid=stelprdb5313325

[USFWS] U. S. Fish and Wildlife Service, Department of Interior. 2008. Endangered and threatened wildlife and plants; final rule removing the Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*) from the Federal List of Endangered and Threatened Wildlife. Federal Register 73:50226-50247.

[USFWS] U. S. Fish & Wildlife Service [Internet]. 2013a. Chesapeake Bay Nutria Eradication Project. [updated 7 Mar. 2013; accessed 28 Aug. 2015]. Available from www.fws.gov/chesapeakenutriaproject.

[USFWS] U. S. Fish and Wildlife Service, Department of Interior. 2013b. Endangered and threatened wildlife and plants; reinstatement of removal of the Virginia Northern Flying Squirrel from the Federal list of Endangered and Threatened Wildlife. Federal Register 78:14022-14023.

[USFWS] U. S. Fish & Wildlife Service [Internet]. 2013c. 2013 Interim Chincoteague Pony Management Plan. [edited and submitted 2 Feb. 2013; accessed 13 Oct. 2015]. Available from www.fws.gov/uploadedFiles/Appendix%20D_CHN%20Draft%20CCPEIS(1).pdf

[USFWS] U. S. Fish and Wildlife Service, Department of Interior. 2015a. Endangered and threatened wildlife and plants; final rule removing the Delmarva Peninsula Fox Squirrel from the Federal List of Endangered and Threatened Wildlife. Federal Register 80:70700- 70717.

[USFWS] U. S. Fish& Wildlife Service [Internet]. 2015b. Refuge List by State. [accessed 28 Aug. 2015]. Available from www.fws.gov/refuges/profiles/ByState.cfm?state=VA

[USFWS] U. S. Fish & Wildlife Service [Internet]. 2016. Endangered and threatened wildlife and plants. [accessed 13 Apr. 2016]. Available from www.federalregister.gov/endangered-threatened-species

Van Zyll de Jong, C. G. 1972. A systematic review of the Nearctic and Neotropical river otters (genus *Lutra*, Mustelidae, Carnivora). Royal Ontario Museum, Life Sciences, Contribution, 80:1-104.

Van Zyll de Jong, C. G. 1979. Distribution and systematic relationships of long eared *Myotis* in Western Canada. Canadian Journal of Zoology 57:987-994.

Van Zyll de Jong, C. G. 1991. Speciation in the *Sorex cinereus* group. Pages 65-73 *in* J. S. Findley and T. L. Yates (eds.), The Biology of the Soricidae. Museum of Southwestern Biology, Albuquerque, NM. 91 pp.

Vilà, M., J. L. Espinar, M. Hejda, P. E. Hulme, V. Jarošík, J. L. Maron, J. Pergl, U. Schaffner, Y. Sun, and P. Pyšek. 2011. Ecological impacts of invasive alien plants: a meta analysis of their effects on species, communities and ecosystems. Ecology Letters 14:702-708.

[VDACS] Virginia Department of Agriculture and Consumer Services [Internet]. 2015. Virginia Agriculture - Facts and Figures. [accessed 28 Aug. 2015]. Available from www.vdacs.virginia.gov/agfacts/.

[VDCR] Virginia Department of Conservation and Recreation [Internet]. 2015a. Invasive Plant Species of Virginia. [accessed 28 Aug. 2015]. Available from www.dcr.virginia.gov/natural_heritage/invspinfo.shtml.

[VDCR] Virginia Department of Conservation and Recreation [Internet]. 2015b. I Love Virginia Parks Fun Facts. [updated 6 Feb. 2015; accessed 28 Aug. 2015]. Available from www.dcr.virginia.gov/state-parks/fun-facts.shtml.

[VDCR] Virginia Department of Conservation and Recreation [Internet]. 2015c. Natural Heritage. Virginia Conservation Lands Database. [updated Feb. 2015; accessed 28 Aug. 2015]. Available from www.dcr.virginia.gov/natural_heritage/clinfo.shtml#stats.

[VDGIF] Virginia Department of Game and Inland Fisheries [Internet]. 2015a. Chronic Wasting Disease. [accessed 28 Aug. 2015]. Available from www.dgif.virginia.gov/wildlife/diseases/cwd/.

[VDGIF] Virginia Department of Game and Inland Fisheries [Internet]. 2015b. Feral Hogs. [accessed 3 Nov. 2015]. Available from www.dgif.virginia.gov/wildlife/feral-hogs/

[VDGIF] Virginia Department of Game and Inland Fisheries [Internet]. 2015c. Hemorrhagic Disease. [accessed 28 Aug. 2015]. Available from www.dgif.virginia.gov/wildlife/diseases/hd.asp.

[VDGIF] Virginia Department of Game and Inland Fisheries [Internet]. 2015d. Wildlife Management Areas. [accessed 28 Aug. 2015]. Available from www.dgif.virginia.gov/wmas/.

[VDGIF] Virginia Department of Game and Inland Fisheries [Internet]. 2016. Virginia Department of Game and Inland Fisheries Special Legal Status Faunal Species in Virginia [updated 1 Apr. 2016; accessed 13 Apr. 2016]. Available from www.dgif.virginia.gov/wildlife/virginiatescspecies.pdf

[VDGIF] Virginia Department of Game and Inland Fisheries, National Wildlife Federation, and Virginia Conservation Network. 2009. Virginia's strategy for safeguarding species of greatest conservation need from the effects of climate change. Virginia Department of Game and Inland Fisheries, Richmond, Va. 24 pp.

[VDOF] Virginia Department of Forestry [Internet]. 2015a. Forested Acreage of Virginia (Historical). [accessed 28 Aug. 2015]. Available from www.dof.virginia.gov/stateforest/facts/historical-acres.htm.

[VDOF] Virginia Department of Forestry [Internet]. 2015b. Virginia Forest Facts. [accessed 28 Aug. 2015]. Available from www.dof.virginia.gov/stateforest/facts/forest-facts.htm.

[VDOF] Virginia Department of Forestry [Internet]. 2015c. Virginia's Forests. [updated 30 Apr. 2015; accessed 28 Aug. 2015]. Available from www.dof.virginia.gov/stateforest/index.htm.

[VDOT] Virginia Department of Transportation [Internet]. 2015. Virginia's Highway System. [accessed 28 Aug. 2015]. Available from www.virginiadot.org/about/vdot_hgwy_sys.asp.

[VOF] Virginia Outdoors Foundation [Internet]. 2015. Land Stewardship. [accessed 28 Aug. 2015]. Available from www.virginiaoutdoorsfoundation.org/stewardship/.

Wade-Smith, J. and B. J. Verts. 1982. Mephitis mephitis. Mammalian Species 173:1-7.

Watkins, L. C. 1972. Nycticeius humeralis. Mammalian Species 23:1-4.

Watling, J. I., A. J. Nowakowski, M. A. Donnelly, and J. L. Orrock. 2011. Meta analysis reveals the importance of matrix composition for animals in fragmented habitat. Global Ecology and Biogeography 20:209-217.

Webster, W. D., J. K. Jones, Jr., and R. J. Baker. 1980. Lasiurus intermedius. Mammalian Species 132:1-3.

Webster, W. D., N. D. Moncrief, B. E. Gurshaw, J. L. Loxterman, R. K. Rose, J. F. Pagels, and S. Y. Erdle. 2009. Morphometric and allozymic variation in the southeastern shrew (*Sorex longirostris*). Jeffersoniana 21:1-13.

Webster, W. D., N. D. Moncrief, J. R. Choate, and H. H. Genoways. 2011. Systematic revision of the northern short-tailed shrew, *Blarina brevicauda* (Say). Virginia Museum of Natural History Memoir 10:1-77.

Weigl, P. D. and T. W. Knowles. 2014. Temperate mountain grasslands: a climate herbivore hypothesis for origins and persistence. Biological Reviews 89:466-476.

Wells-Gosling, N. and L. R. Heaney. 1984. Glaucomys sabrinus. Mammalian Species 229:1-8.

Whitaker, J. O., Jr. 1972. Zapus hudsonius. Mammalian Species 11:1-7.

Whitaker, J. O., Jr. 1974. Cryptotis parva. Mammalian Species 43:1-8.

Whitaker, J. O., Jr. 2004. Sorex cinereus. Mammalian Species 743:1-9.

Whitaker, J. O., Jr. and R. E. Wrigley. 1972. Napaeozapus insignis. Mammalian Species 14:1-6.

Wilkins, K. T. 1987. Lasiurus seminolus. Mammalian Species 280:1-5.

Wilkins, K. T. 1989. Tadarida brasiliensis. Mammalian Species 331:1-10.

Willner, G. R., G. A. Feldhamer, E. E. Zucker, and J. A. Chapman. 1980. Ondatra zibethicus. Mammalian Species 141:1-8.

Wilson, D. E. and D. M. Reeder (eds.). 2005. Mammal species of the world: a taxonomic and geographic reference. Third edition. Johns Hopkins University Press, Baltimore MD. 2142 pp.

Wolfe, J. L. 1982. Oryzomys palustris. Mammalian Species 176:1-5.

Wolfe, J. L. and A. V. Linzey. 1977. Peromyscus gossypinus. Mammalian Species 70:1-5.

Woods, C. A. 1973. Erethizon dorsatum. Mammalian Species 29:1-6.

Woods, C. A., L. C. Contreras, G. W. Chapman, and H. P. Whidden. 1992. Myocastor coypus. Mammalian Species 398:1-8.

Woodward, S. L. and R. L. Hoffman. 1991. The nature of Virginia. Pages 23-48 *in* K. Terwilliger (coordinator), Virginia's Endangered Species. McDonald and Woodward Publishing Company, Blacksburg, VA. 672 pp.

Yates, T. L. and D. J. Schmidly. 1978. Scalopus aquaticus. Mammalian Species 105:1-4.

Yu, J. and F. S. Dobson. 2000. Seven forms of rarity in mammals. Journal of Biogeography 27:131-139.

Zukal, J., H. Bandouchova, T. Bartonicka, H. Berkova, V. Brack, J. Brichta,... and J. Pikula. 2014. White-nose syndrome fungus: a generalist pathogen of hibernating bats. PloS One 9:e97224.