1-1-2005

Home Range and Behavior of the Timber Rattlesnake (Crotalus horridus)

Jennifer P. Adams
jennifer_p_adams@hotmail.com

HOME RANGE AND BEHAVIOR OF THE TIMBER RATTLESNAKE (*CROTALUS HORRIDUS*)

THESIS SUBMITTED TO
THE GRADUATE COLLEGE OF
MARSHALL UNIVERSITY

IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE
BIOLOGICAL SCIENCES

BY
JENNIFER P. ADAMS

COMMITTEE CHAIR: DR. THOMAS K. PAULEY
COMMITTEE MEMBER: DR. DAN K. EVANS
COMMITTEE MEMBER: DR. PATRICK D. KEYSER

MARSHALL UNIVERSITY

OCTOBER 2005

ABSTRACT

Seventeen timber rattlesnakes were surgically implanted with radio transmitters and subsequently radio-tracked to determine the home range and behavior, as well as cause-specific mortality, of timber rattlesnakes on production forests in Randolph County, West Virginia. Mean home range sizes were 94.3 ha, males; 31.2 ha, nongravid females; 8.5 ha, gravid females; and 44.7 ha, among sex classes. Among sex classes, the mean daily movement rate was 20.2 m per day; the mean maximum known distances from den sites was 1110.2 m; the mean distance from den sites was 514.2 m; and the mean total distance moved was 2852.9 m. Mean active season for was 165.5 days, males; 171.0 days, females; and 167.3 days, among sex classes. Vehicles and mammalian predators each caused 17.6 % of total mortalities and avian predators caused 5.9% of total mortality. No rattlesnakes that died of vehicle-induced injuries were found on the road.

ACKNOWLEDGEMENTS

I wish to thank all persons and organizations who facilitated the completion of this project. I extend my sincerest thanks to Dr. Thomas K. Pauley, my major professor, thesis advisor, and research advisor on independent study projects. Dr. Dan K. Evans served as a committee member and thus advised me as well. Drs. Pauley, Evans and Somerville provided quality course work. Marshall University staff members, Mary Jo Smith, Vickie Crager, and the library personnel, were very helpful to me as I was a working student who lived 4 hours from campus. Dr. Patrick D. Keyser, MeadWestvaco Regional Biologist and committee member, provided the study area and partial funding. Other MeadWestvaco associates, Eldon Plaugher, Gene Wentz, and Rhonda Cornwell, were provided keys, maps, and contact information. The West Virginia Division of Natural Resources Wildlife Resources Section provided project support and funding: Game Research provided equipment and the Wildlife Diversity Program provided major research funding. Joel Harrison provided technical support, Barbara Sargent provided permits, Craig Stihler and Kathy Leo provided administrative support, and Dr. James M. Crum coordinated necropsies. Tom Allen's assistance was instrumental during project initiation, and Tom Allen and Bill Igo provided monetary support via books and tuition loans. Jennifer Wykle provided database support, lots of laughter, and became a good friend through this project. Dr. Ron Thompson and his staff at Audubon Animal Clinic, particularly Dr. Cynthia Linner, provided veterinary services. Dr. Mike R. Caudill, Hocking College, identified rock samples and lended geological expertise. Randy Stechert, David Garst, and especially Marty Martin contributed knowledge on numerous occasions and became respected colleagues. Jayme Waldron assisted with fieldwork, provided conversational support, and became a good friend as well as a respected colleague. Mike Reynolds and Dave Swanson, Ohio Division of Wildlife, offered analytical advice on several occasions. Jim Crum supported the completion of the project in many roundabout but very important ways.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

BACKGROUND

Taxonomy

The timber rattlesnake is a member of the nearly worldwide family Viperidae. The viperids include both Old World and New World species of venomous snakes (Green and Pauley 1987) and have existed since the Miocene (Campbell and Brodie 1992). The subfamily Crotalinae, commonly called pitvipers, includes 16 genera and 144 species (Campbell and Brodie 1992) among a few Old World species and many New World species (Green and Pauley 1987, Campbell and Brodie 1992). The presence of 2 heat-sensitive pits between the eyes and nares (Green and Pauley 1987, Campbell and Brodie 1992), hollow, retractable fangs, a single row of subcaudal scales, and vertical pupils (Green and Pauley 1987) characterize Crotalinae members. The genus Crotalus includes 33 New World species and subspecies, 25 of which occur in North America. The rattle and the conspicuously wide head that narrows at the neck into a broad, heavy body (Green and Pauley 1987) distinguish the genus Crotalus.

Natural History

Conant and Collins (1998) recognize 4 color morphs, discerning western from southern variations while including the typical yellow and black variations represented in eastern portions of the range (Brown 1993). The 2 eastern color morphs or phases, determined by dorsal-lateral head color, are yellow (also called light) and black (also called dark). A yellow or tan head with a light yellow chin (often with brown flecks), neck, and ventrum identify the yellow morph; a black or gray head with a white chin (often with black flecks), neck, and ventrum (Brown 1993, Martin 1992b) identify the black morph. The head of both morphs are unmarked, body color varies greatly from yellow, brown, gray, to black, and the tail color is black (Green and Pauley 1987). *Crotalus horridus* is acclaimed by 18-25 chevron-shaped dorsal crossbands bordered by lighter colors, creating color contrast between crossband and body colors (Green and Pauley 1987). Size and shape of the crossbands vary across the range (Brown 1993). Scales are highly keeled and occur in 23-25 rows (Green and Pauley 1987).

Crotalus horridus may attain a maximum lifespan of more than 36 years in captivity (Cavanaugh 1994) and 25 years in the wild (Brown 1993). Average specimens commonly approach 1.5 m and may occasionally reach 1.8 m in length (Green and Pauley 1987). Conant and Collins (1998) report the record specimen at 1.9 m length, but the specific locality is not reported. The species is sexually dimorphic with respect to size; males are larger than females (Brown 1993, 1991; Galligan and Dunson 1979).

Crotalus horridus is a “model sit and wait predator” that sits in “ambush posture,” where an individual coils alongside and positions its head on a fallen log, and waits for prey (Reinert et al. 1984). This position allows individuals to detect prey from vibrations and to recognize prey thermally, visually, and chemically (Reinert et al. 1984), after which they strike and subsequently trail prey (Chiszar et al. 1977). Adults classically prey on small mammals, particularly sciurids, murids, dipodids, leporids, and soricids, although prey from other taxa have been reported (Clark 2002). Although authors suggest that neonatal rattlesnakes may not prey on rodents in their first year (Scudder et al. 1992), Scudder et al. (1992) determined that neonatal rattlesnakes are capable of searching and trailing prey in manners paralleling those of adults. Henceforth, it is more likely that size of prey items limits foraging success of neonates (Galligan and Dunson 1979).

Timber rattlesnakes mature at 3 to 4 years of age (Green and Pauley 1987), but age of sexual maturity varies. Females attain sexual maturity from 4 to 14 years of age (Brown 1993; Martin 1995, 2002) and 79.0-96.5 cm in length (Martin 2000). Males attain sexual maturity between 4 and 6 years of age (Aldridge and Brown 1995) and 85.0 cm in length (Martin 2000).

The mating system of *C. horridus* is polygynous, specifically “prolonged mate-searching polygny” (Aldridge and Brown 1995, Brown 1995). Matings occur in spring (Aldridge and Brown1995, Green and Pauley 1987, Martin 1992*a*) and into early summer (L. Cartmill, Personal Communication), but most occur from late summer to early fall (Aldridge and Brown 1995; Brown 1995; Martin 1992a, 1992b; Rudolph and Burgdorf 1997). Reproductive intervals for females vary from 2 (Green and Pauley 1987, Martin 1993) to 5 year intervals (Brown 1993, Martin 1995). Gravid females may hibernate before giving birth (Martin 1996). This viviparous species (Brown 1991) is thought to exhibit delayed fertilization (Aldridge and Brown 1995), where spring ovulation (Martin 1993) follows matings of the previous active season. Gestation lasts 2.5 to 4.0 months (Martin 2000, 1993). Young are born in late summer (Galligan and Dunson 1979; Green and Pauley 1987; Martin 1996, Martin 1992*a*, 1992*b*) and early fall (Martin 1996, 1995, 1992*a*, 1992*b*). Average litters consist of 8-10 neonates (Green and Pauley 1987) but litter sizes from 2 (Martin 2000) to 18 young have been reported (Green and Pauley 1987, Martin 2000). Neonates measure 25.4-33.0 cm at birth (Green and Pauley 1987). The first molt occurs 8 to 16 days post-birth (Martin 1996), and thereafter, as adults, molting occurs one to 2 times per year (Martin 1993). Females stay with their young up to 2 weeks (Martin 2002, 1996), after which neonates follow scent trails of adults to dens (Brown and MacLean 1983, Reinert and Zappalorti 1988).

Survivorship is higher among adults than among neonates. Neonatal mortality is relatively high due to lack of suitable-sized prey items, lack of suitable hibernacula, and relatively high predation, particularly due to increased search time for prey items. Known predators include hawks, owls, coyotes, foxes, and skunks (Galligan and Dunson 1979), in addition to black racers, wild turkeys, white-tailed deer (i.e., stomping), and humans (Brown 2000).

Timber rattlesnakes inhabit specific microhabitats within deciduous hardwood forests including overwinter dens, rookeries, and summer ranges (Brown 1993, Martin et al. 2000). Overwinter den habitat includes fissures and crevices associated with ledges, talus associated with outcrops, and scree, all which provide hibernacula for overwinter survival (Brown 1993, Green and Pauley 1987, Martin 1992). Hibernacula lie below the frost line (Brown et al. 1982, Green and Pauley 1987) where above-freezing temperatures allow overwinter survival (Brown 1982). Birthing rookeries are typically found in areas of open forest canopy often associated with road edges (Reinert et al. 1984, Reinert and Zappalorti 1988) or rock slabs (Brown 1993, Keenlyne 1972) and are often described as bask sites (Reinert 1984*a*). Summer ranges of males and nongravid females include closed, partially closed, and open canopies of forested areas in which timber rattlesnakes utilize rock, woody debris, and vegetation for thermoregulating and foraging (Brown 1993, 1982; Green and Pauley 1987, Martin et al. 2000, Reinert and Zappalorti 1988).

Timber rattlesnakes have adapted to temperate climates by hibernating during colder months (Gregory 1984; Martin 1992*a*, 1992*b*) and becoming seasonally active during warmer months (Brown 1982, Martin 1992*a*). Active seasons vary throughout the distributional range (Brown 1993) as well as among West Virginia physiographic provinces (Martin 1995). Active seasons in West Virginia vary from 4.3 months to possibly over 6 months (Martin et al. 2000). The active season begins with egress during April and May and extends through ingress during September and October (Brown 1992, 1991; Green and Pauley 1987; Martin 1995, 1992*a*; Martin et al. 2000).

Distribution

Crotalus horridus occurs in 30 states (Brown 1993) (Fig. 1). The eastern periphery of the range extends from southern New Hampshire southward to northern South Carolina; the western periphery of the range extends from southeastern Minnesota southward to northern Texas (Green and Pauley 1987); southern Ohio and Indiana establish the northern periphery and the Gulf States establish the southern periphery of the range (Conant and Collins 1998). Martin states (Brown 1993) that *C. horridus* populations are densest in southern and southeastern coastal plains, but northern populations are densest in the central to southern Appalachian Mountains from Pennsylvania to Alabama (Brown 1993).

West Virginia populations are most numerous in mountainous and forested areas (Green and Pauley 1987; Martin et al. 2002) where forest fragmentation is less and anthropogenic threats are fewer. *Crotalus horridus* populations in West Virginia are distributed primarily in the east-central and southern counties as well as in the eastern panhandle (Fig. 2). Populations are nonexistent in the 4 northern panhandle counties and scarce in western counties, excepting recent documentations of *C. horridus* in Putnam County and summer range reports in Calhoun and Wirt Counties (J. Adams, Unpublished Data).

Status

The U.S. Forest Services lists *C. horridus* as a sensitive species in some national forests and places the species in "risk" in terms of criteria for risk evaluation. In the Monongahela National Forest (MNF), West Virginia, the species is designated as "Regional Forester Sensitive," where designations are based on the global (i.e., G rank) and the national (i.e., N rank) rank. The ranks of *C. horridus* in the MNF are G4 and N4, indicating "The species (or trinomial) is either nationally widespread, abundant, or apparently secure, but with cause for long term concern" (USFS 2000).

The West Virginia Wildlife Diversity Program (WV WDP) lists species by the state (i.e., S) rank while recognizing global ranks. Henceforth, the WV WDP assigns the rank S3 to *C. horridus*, which demands statewide monitoring of the species. The WDP defines both the state rank and the global rank by population numbers, "...21 to 100 documented occurrences…" and both ranks describe the species with potential for extirpation in West Virginia (WV WDP 2005)."

CHAPTER II

INTRODUCTION

Crotalus horridus is the most expansive crotalid of North America (Brown 1991), and the only rattlesnake in the northeastern United States (Conant and Collins 1998). The species occupies upland and lowland (Conant and Collins 1998) eastern deciduous forests (Brown 1991), where it exists as a secondary consumer (Martin 1993). Because secondary consumers are both predators and prey, *C. horridus* fulfills an important niche in eastern forests, given its broad geographical distribution.

Herpetologists, state agencies, and federal agencies are concerned about the status of *C. horridus* due to rangewide and statewide declines resulting in disjunct populations and local to statewide extirpations throughout the range (Green and Pauley 1987; Martin 2002, 1982; Martin et al. 2000; Reinert 1990). Biological and anthropogenic factors contribute to population declines of *C. horridus*. Biological reasons for declines are documented including the long life span, late age of maturity, and low reproductive capability (Brown 1993). Many anthropogenic factors are known to reduce populations of timber rattlesnakes including hunting, collecting, and wanton killings (Brown 1993, Galligan and Dunson 1979, Reinert 1990); the presence and development of roads (Galligan and Dunson 1979, Green and Pauley 1987, Rudolph and Burgdorf 1997, Rudolph et al. 1998); habitat alteration and destruction (Brown 1993, Green and Pauley 1987); development (Brown 1993, Green and Pauley 1987); and disturbance (Brown 1993).

Writers of status reports, assessments, and conservation and management plans (Brown 1993, Brown et al. 2000, Galligan and Dunson 1979, Tyning 1991, Reinert 1990) have reviewed and discussed the biology and ecology of the species and established guidelines and needs for conservation and management in northeastern states. Authors have examined literature and researched *C. horridus* in northeastern states including New Jersey, New York, Pennsylvania, Virginia, and West Virginia. Such studies include, but are not limited to, various aspects of reproduction (Aldridge and Brown 1995; Brown 1991; Martin 2002, 1996, 1995, 1993); genetics (Bushar et al. 1998, Villarreal et al. 1996); habitat use (Brown et al. 1982; Reinert 1984*a*, 1984*b*; Reinert and Zappalorti 1988); behavior (Brown and MacLean 1983, Reinert et al. 1984); translocations (Galligan and Dunson 1979, Reinert and Rupert 1999); movement (Brown et al. 1982, Reinert and Zappalorti 1988); phenology (Brown 1992, Martin 1992*a*); temperature relationships (Brown et al. 1982, Galligan and Dunson 1979); and foraging (Reinert et al. 1984).

Additionally, food habit studies have been conducted in Virginia (Smyth 1949, Uhler et al. 1939) and Tennessee (Savage 1967) as well as Clark's (2002) rangewide studies of food habits.

In West Virginia, Martin (1986) completed a survey to establish baseline data for locations of dens and rookeries, and similar studies (Adams 2005; Adams and Pauley 2002, 2003; Martin et al. 2000) further documented the range of *C. horridus* in West Virginia. Martin (2002, 1996, 1995, 1993, 1992*a*), who focused studies on phenology and reproduction, conducted the only extensive studies of timber rattlesnakes in West Virginia. No studies of home range and behavior have been conducted in West Virginia, and no studies of home range and behavior have been conducted on production forests in the Appalachian Mountains.

CHAPTER III

STUDY AREAS

The study was conducted on 2 MeadWestvaco tracts of land: the Wildlife and Ecosystem Research Forest (WERF) located on the Adolph, West Virginia quadrangle, 7.5 minute series topographic map (USGS 1977); and the Roaring Creek Hunting Club Lease (RCHC) located on the Junior, West Virginia quadrangle, 7.5 minute series topographic map (USGS 1969). Both study areas are located in Randolph County, West Virginia (Fig. 3) on western slopes of Rich Mountain.

Both study areas were production forests managed specifically for timber production, although management regimes differed between the 2 areas. The management regime of the WERF includes variable and flexible harvest plans on 20-25 and 80-100 year rotations, as well as a no-harvest plan for 850 acres of higher elevation red spruce forest, where all harvest plans facilitate wildlife and ecosystems research. The management regime of the RCHC includes site- and objective-specific harvest plans on 55-60 year rotations, where objectives are met through individual tree selection, deferment harvests, along with clearcuts with crop-tree release treatments after 12-15 years (E. Plaugher, Personal Communication).

The WERF encompasses 3,411.5 ha (MeadWestvaco Corp. 2005) and spans in elevation from 717 m to 1095 m (USGS 1977). Percent slope varies from 0-3 % at valley streams to 3-80 percent on slopes (Pyle et al. 1982). RCHC encompasses 763.2 ha (E. Plaugher, Personal Communication) and spans in elevation from 656 to 1034 meters (USGS 1969). Percent slope varies from 0-3 % at valley streams to 3-70 % on slopes (Pyle et al. 1982).

Randolph County lies in the Allegheny Mountains physiographic province in east-central West Virginia (Green and Pauley 1987, Stephenson 1993) (Fig. 4). The Allegheny Mountains physiographic province lies in the Allegheny Mountains (Fig. 5), a portion of the central Appalachian Mountains commonly known as the High Alleghenies (Green and Pauley 1987, Pyle et al. 1982, Stephenson 1993, Strausbaugh and Core 1978).

Elevations over 1200 m and relief over 600 m are ordinary in the region (Green and Pauley 1987, Pyle et al. 1982, Stephenson 1993, Strausbaugh and Core 1978), and vegetation consists primarily of northern hardwoods forests from 760 to 912 m and red spruce forests above 912 m (Strausbaugh and Core 1978). The Allegheny Plateau is characterized by Paleozoic sandstones and conglomerates composing ridges and rocky cliffs and outcrops, and shales and limestones composing subsurface rock in the deep valleys (Core 1966, Stephenson 1993). Soils are relatively young and include, but are not limited to, the orders Ultisols, Spodosols, and

Inceptisols (Stephenson 1993). Surface rocks consisting of sandstone, shale, and coal are from The Allegheny Formation and the Conemaugh and Pottsville Groups. Gilpin, Dekalb and Lily soils occur in the Conemaugh Group and the Allegheny Formation, and Gilpin, Dekalb, and Buchanan soils occur in the Pottsville Group (Pyle et al. 1982).

The Allegheny Mountain physiographic province is characterized by mixed mesophytic and cove hardwoods below 850 m and in moist coves of north slopes, respectively (Strausbaugh and Core 1978, WVGES 1969). Young Pennsylvanian and Permian rocks occurring as sandstones and conglomerates form outcrops, rocky cliffs and ledges, particularly on ridges, and Mississippian shales and limestones occur in valleys (Core 1966, WVGES 1969). Geologic faults and forms give rise to strong topographic relief, high elevations, and dendritic drainage patterns (Core 1966) with high-gradient streams (Pyle et al. 1982, Stephenson 1993, Strausbaugh and Core 1978). Soils are Ultisols, Spodosols, and Inceptisols (Core 1966, Pyle et al. 1982) that are broadly infertile, acid soils formed under forests with relatively high amounts of organic matter (Pyle et al. 1982, Stephenson 1993).

Soils of study areas were Inceptisols and Ultisols. Soils of the WERF were Gilpin-Dekalb-Buchanan associations occurring as stony complexes defined by moisture and percent slope. Portions of RCHC included soils of Gilpin-Dekalb-Lily associations although most of the area includes soils of Gilpin-Dekalb-Buchanan associations occurring as stony complexes, defined by moisture and percent slope (Pyle et al. 1982, SSSA 1996).

The southwest-northeast trend of the Appalachian Mountains combined with the wayward position of the Allegheny Mountains physiographic region causes orographic climatic effects, resulting in high precipitation and cold temperatures (Core 1966). The average annual temperature for Elkins, Randolph County, West Virginia is 9.9 ^{o}C, and the average annual precipitation is 117.1 cm (C. Leonardi, Personal Communication). Randolph County is one of 3 West Virginia counties with lowest temperatures and highest precipitation, where up to 16 percent of annual precipitation occurs as snow (Core 1966, Pyle et al. 1982, Strausbaugh and Core 1978). Table 1 (NRCC 2004) lists climatic data for Elkins, Randolph County, West Virginia.

Forests of the WERF included American beech (*Fagus grandifolia*), yellow birch (*Betula alleghaniensis*), black cherry (*Prunus serotina*), Fraser magnolia (*Magnolia fraseri*), red maple (*Acer rubrum*), and sugar maple *(Acer saccharum)* above 850 m. Cove hardwoods and mixed mesophytic communities occurred below 850 m including tulip tree (*Liriodendron tulipifera*), northern red oak (*Quercus rubra*), American basswood (*Tilia americana*), cucumber tree (*Magnolia acuminata*), sweet birch (*Betula lenta*), and white ash (*Fraxinus americana*). Stands of red spruce (*Picea rubens*) and hemlock (*Tsuga canadensis*) occurred above 1000 m. Stands of chestnut oak (*Quercus prinus*), black oak (*Quercus veluntina*), scarlet oak (*Quercus coccinea*), and hickory species (*Carya* species) occurred in xeric locations, typically on southwestern slopes of lower elevations. Rhododendron (*Rhododendron maximum*) thickets were common on the WERF, and other shrub stands were dominated by striped maple (*Acer pennsylvanicum*). The common groundcover was hay-scented fern (*Dennstaedtia punctilobula*) (MWWERF 2005). Forests of the RCHC lacked red spruce (*P. rubens*) and hemlock (*Tsuga candensis*) stands, rhododendron (*R. maximum*) thickets, and striped maple (*A. pennsylvanicum*) shrub layers. Stands of black oak (*Quercus velutina*), scarlet oak (*Q. coccinea*) and chestnut oak (*Q. prinus*) were more common due to the relatively lower elevation and western aspect of the tract of land. At higher elevations and in coves, forest stands and composition of the RCHC were similar to that of the WERF.

CHAPTER IV

METHODS

Dates and Objectives

The study was initiated during ingress (i.e., movement of rattlesnakes from summer range toward overwinter hibernacula) 2000, and the study continued from egress (i.e., movement of rattlesnakes from overwinter hibernacula toward summer range) 2001 through ingress 2002. The primary objectives were to determine the home range and behavior of timber rattlesnakes, locate den, rookery, and bask sites on a production forest, and identify habitat types used on a production forest to provide practical applications for forest management. Secondary objectives were to determine cause-specific mortality and to gain insight into predator-prey relationships involving *C. horridus*.

Timber rattlesnakes were radio-tracked on the WERF from ingress 2000 through ingress 2002; timber rattlesnakes were tracked on the RCHC during 2002. Telemetry was conducted to locate den sites, locate particular hibernacula at den sites, and to obtain locations for home range estimates, movements, and habitat use. Telemetered rattlesnakes with only external transmitters were tracked from their capture point during ingress to den sites and to particular hibernacula entrances at den sites. Rattlesnake movements among hibernacula entrances were monitored. Implanted rattlesnakes were located with a Wildlife Materials (TRX-2000S) radio telemetry receiver at least once each week when possible. Location coordinates were recorded with a Trimble GPS unit, and the coordinates were differentially corrected.

Den Sites

Locations

Overwinter den sites were located by radio-tracking timber rattlesnakes from summer or transient ranges to overwinter den sites. Specific locations were determined by collecting location data via a global positioning system. All telemetered timber rattlesnakes were monitored at overwinter den sites to locate specific hibernacula, monitor movements of rattlesnakes among hibernacula, and to determine the potential repeated use of hibernacula by individuals.

Descriptions

A 0.04-ha plot was centered within one meter of a known hibernaculum entrance at each of 6 den sites. Stem density and percent cover of deciduous and coniferous/evergreen canopy, ground cover and woody debris were measured (Noon 1981). Tree stands were described by forest cover type (SAF 1980), where stand data was collected by measuring and identifying trees within the 0.04-ha plot. Substrate type and woody forest floor species were measured by sampling 4 one-meter plots located 4 meters from the plot center in each cardinal direction. Dominant overstory, subcanopy, and woody understory species were noted at each den site. Thus, lists of commonly occurring species at den sites might have included species not in the sampled plots but noted as dominant species in the general area outside the plot. Aspect and slope were measured from the plot center at each den site.

Geologic strata were sampled and site-specific lithology was described. Hibernacula formation in terms of geology was described as well, and hibernacula entrances were recorded as horizontal, vertical or irregular. Den sites with multiple hibernacula diffusely located across an area were considered complexes (W. Martin, Personal Communication). Distances to forest roads were measured in ArcView (ESRI 1996) and resulting distances were rounded to the nearest one-tenth m.

Rookery and Bask Sites

Rookery sites were located by radio-tracking telemetered rattlesnakes and by searching potential habitat. Rookery locations were monitored for use by timber rattlesnakes other than telemetered gravid females. Distances to forest roads were measured, and distances to den sites were calculated by measuring distances to hibernacula locations of rattlesnakes using the rookery sites. Distance measures were calculated using ArcView (ESRI 1996) and measurements were rounded to the nearest one-tenth m.

Bask sites were located by searching potential habitat and by radio-tracking telemetered rattlesnakes. Bask sites on the WERF were monitored following initial site location. Distances of bask sites to den sites were calculated by measuring the distance from bask sites to hibernacula locations of rattlesnakes using the bask sites. Distances from the bask sites to forest roads were also measured. Distance measures were calculated using ArcView (ESRI 1996) and measurements were rounded to the nearest one-tenth m. For the purpose of this study, bask sites were defined as sites repeatedly used by snakes during the active season.

Timber rattlesnakes on the RCHC were radio-tracked to locate den sites and to determine common use of bask sites by rattlesnakes from different den sites. Thus, rattlesnakes on the RCHC were captured at one bask/shed site and subsequently tracked to overwinter den sites.

Transmitters

Both implants and external temporary transmitters were used. Implants were used on snakes radio-tracked for extended periods and external transmitters were affixed to snakes to radio-track rattlesnakes while enroute to the den site and specific hibernacula. Implants were temperature-sensitive transmitters (Advanced Telemetry Systems, RPT, 15 g; Holohil, AI-2T, 17 g) and non-temperature sensitive transmitters (Holohil, SI-2, 15 g). External transmitters were non-temperature sensitive transmitters (Advanced Telemetry Systems, A3900, 10 g) modified for affixing to timber rattlesnakes with surgical glue and tape. External transmitters were affixed dorsal-laterally on the tail.

Rattlesnakes were marked with passive integrated transponder (PIT) tags (Biomark; TX1400L, 11.5 mm; TX1405L, 14 mm) and read with a portable scanner (Destron-Fearing Corporation, Pocket Reader). Color marks on rattles consisted of paint on juveniles (Brown et al. 1984) and rattle tags on adults. Methods for affixing color marks to rattles were modified instructional methods provided conversationally by Reinert (H. Reinert via T. Allen, Personal Communication). Rattle tags (Fig. 6) were created by placing pieces of plastic cut into shapes (e.g., squares, triangles, circles) on either side of the rattle and affixing the tag to the rattle by piercing the rattle with coated fishing wire. Tags were secured with clamped fishing weights.

Surgery

All surgeries were conducted by a veterinarian with experience implanting transmitters in multiple wildlife species. Transmitters were implanted according to methods described in

Reinert and Cundall (1982) and further explained in Reinert (1992). Suture methods of Hardy and Greene (1999) were followed, although surgical adhesive was used in lieu of sutures (Reinert and Cundall 1982) on 2 rattlesnakes. Guidelines from Hardy and Greene (2000) and Hardy et al. (2001) regarding anesthetic techniques, fluid replacement, recovery monitoring, and post-surgical release were considered as well.

At the beginning of the study, initial anesthesia was delivered while rattlesnakes were restrained in tubes. Later in the study, an anesthesia box (Fig. 7) was designed and used for this study, and the anesthesia box was a modified method of the box described in Hackenbrock and Finster (1963). The improved design allowed regulated delivery of controlled concentrations of anesthesia from the gas anesthesia machine to the anesthesia box via a hose. The anesthesia box eliminated or drastically reduced stress of rattlesnakes while guiding them into restraining tubes, and the anesthesia box improved safety precautions for personnel. Following initial delivery of anesthesia in the anesthesia box, rattlesnakes were transferred to restraining tubes for controlled delivery of concentrated anesthesia. The concentrated anesthesia was delivered from the anesthesia machine to the restraining tube via a hose (Fig. 8). Each rattlesnake was prepared for surgery while in the restraining tube.

Sevoflurane (SevoFlo, Abbott Laboratories) inhalation anesthesia was used because of its advantages during induction, maintenance, and recovery of specimens: during induction sevoflurane causes minimal irritation in airways and eyes; during maintenance sevoflurane is easily controlled; and recovery is fast (Abbott Laboratories 2004). The inhalation anesthesia was delivered to rattlesnakes at 7 percent concentrations prior to surgery, 5 percent concentrations during surgery, and straight oxygen was delivered upon surgery completion. Antibiotics or fluids were administered as needed.

Rattlesnakes were removed from restraining tubes following surgery, checked for general health, and placed in containers over mild heat sources where they were monitored for recovery from anesthesia. Most rattlesnakes were color marked; PIT tagged, probed to determine sex, and measured immediately following surgical procedures.

Cause-Specific Mortality

Cause of mortality was determined through visual and physical examination of remains and field evidence. Necropsies were conducted to determine cause of mortality for snakes for which field evidence was inconclusive. Causes of mortality were categorized broadly as mammalian predation, avian predation, vehicular-induced predation, unknown cause of mortality, and implant-induced mortality. Machinery and all-terrain vehicles were considered vehicles, and delayed mortality from vehicles was considered vehicular-induced mortality. The mortality date for each snake was documented as the date that the rattlesnake was confirmed dead. Percent mortality was calculated for each study area and for both study areas combined.

Home Range and Movements

Home range sizes were calculated with ArcView 3.2 (ESRI 1996) Home Range Extension (HRE) (Rodgers and Carr 1998) and rounded to the nearest one-tenth ha. Home range sizes were calculated by using all locations to construct minimum convex polygons (Jenrich and Turner 1969), where "minimum" indicates the smallest polygon fitting the outside locations (Rodgers and Carr 1998) and "convex" indicates minimum angles of 90 degrees (Reinert 1992). The use of the convex polygon method to calculate home range sizes (Jenrich and Turner 1969) has been common and effective in calculating maximum areas traversed (Reinert 1992) in studies of reptiles (Durner and Gates 1993, Gregory et al. 1987, Rose 1982).

Home range estimates were calculated only for timber rattlesnakes on the WERF. Home range estimates of rattlesnakes radio-tracked for more than one active season were calculated between years to consider annual differences in home range sizes and among years for a more representative estimation of home range size (Reinert and Zappalorti 1988). Mean home range sizes among sex classes were calculated by averaging total home range estimates.

Distance measures were calculated for timber rattlesnakes on the WERF using the animal movements extension in ArcView 3.2 (ESRI 1996) HRE (Rodgers and Carr 1998), and measurements were rounded to the nearest one-tenth meter. Maximum known migratory distances from den sites (Brown 1993) were calculated for each rattlesnake and dates of maximum known distances were recorded. Distances between locations were calculated and summed to determine total distances moved by each rattlesnake (Reinert and Zappalorti 1988). For gravid females captured later in the active season rather than during egress, the distance from the den to the rookery was assumed a straight-line distance in order to estimate total distances moved. Thus, total distances moved were calculated for gravid females regardless of when their monitoring periods began, and total distances moved for gravid females were probably under represented. Daily movement rates (Reinert and Zapplaorti 1988) were calculated for rattlesnakes tracked for a full active season. Mean distances from den sites (Brown et al. 1982) were calculated for rattlesnakes tracked for at least half active seasons. The hibernaculum entrance of each rattlesnake was considered the den site location for determining maximum and mean distances from den sites.

Habitat Use by Stand Type

Rattlesnakes were located in 4 broad stand types: cove hardwoods, mountain hardwoods, upland hardwoods, and nonforest stands (i.e., edges including log landings, roads, and road edges). Locations in terms of stand types were determined by GIS data provided by MeadWestvaco. Regenerating clearcuts were considered any forest stand less than 20 years of age. Locations of rattlesnakes at den sites were included in these data.

Phenology

Active season

Lengths of active seasons were determined for rattlesnakes radio-tracked for full active seasons on the WERF. Lengths of active seasons were determined by noting the date of the first and last known active days for each rattlesnake. The first known active date was the first date that the rattlesnake was either observed on the surface or observed at different hibernacula, and the last known active date was the last date the rattlesnake was observed moving among hibernacula at the den site. First or last known active dates were noted for rattlesnakes that were radio-tracked for partial active seasons.

Temperatures

Daily and monthly normal temperatures (NWSFO 2005) were described by month for egress (April and May) and ingress (September and October). Monthly climate summaries, frost statistics and season lengths (NWSFO 2005) were described for egress and ingress of each year during the study. Season lengths were not reported for egress 2000 because no rattlesnakes were studied prior to egress 2000. NWSFO (2005) data is preliminary and thus has not been quality checked. Data was converted to ^{o}C degrees and rounded to the nearest one-tenth ^{o}C.

CHAPTER V

RESULTS

Den Sites

Location

Six den sites were located on the 2 study areas; 3 den sites were on each of the 2 study areas. Two den sites were located on the WERF during ingress 2001, and another was located during ingress 2002. All 3 den sites on the RCHC were located during ingress 2002.

On the WERF, 30 hibernacula were located at 3 den sites. During 2000, 20 hibernacula were located between 2 den sites. Nineteen hibernacula were located at LH Den and one hibernaculum was located at the RR den site. During ingress 2001, 9 hibernacula were located among 3 den sites. Five hibernacula were located at the LH den site, 2 hibernacula were located at the KC den site, and 2 hibernacula were located at the RR den site. During 2002, one hibernaculum was located during spring. On the RCHC one hibernaculum was located at each of the 3 dens during 2002.

Most hibernacula entrances were horizontal, although vertical and irregular hibernacula entrances existed. Known hibernacula entrances at LB and RDG dens were horizontal and potential hibernacula appeared to be horizontal as well. The exact hibernacula entrance at the RKS den was difficult to identify because the entrance was in a pile of rock fall below an outcrop, potential hibernacula entrances were irregular and vertical. Hibernacula entrances at the LH den were vertical, horizontal and irregular. KC den hibernacula entrances were horizontal and irregular, and entrances were difficult to locate due to the density of common greenbrier (*Smilax rotundifolia*). Known hibernacula entrances of the RR den were horizontal and irregular, where irregular was used to describe holes in the road bank.

Three rattlesnakes were monitored through 2 overwinter seasons. Two of the rattlesnakes used the same hibernacula for each of the 2 overwinter seasons. One rattlesnake changed hibernacula from the first overwinter season to the second overwinter season. The hibernacula were 268.1 m apart. Rattlesnakes were observed using particular crevices for basking and particular crevices for hibernating.

Description

Geologic strata at RCHC den sites were composed of quartz arenite (M. Caudill, Personal Communication); rock composition at WERF den sites varied among den sites and included quartz arenite, lithic arenite, and lithic sandstone (M. Caudill, Personal Communication) (Table 2). Generally, all den sites aspected the south. More specifically, 5 of 6 den sites aspected the southwest and one aspected the southeast. Five of 6 den sites ranged between 947 and 1006 m in elevation and one den site, LB, occurred at 430 m. Slopes of WERF dens ranged from 34 to 46 %; slopes at RCHC den sites ranged from 14 to 56%. Table 3 lists aspect, elevation, and slopes for each den site.

The forest cover types at RCHC den sites were chestnut oak (SAF 1980), and forest cover types at WERF den sites were mixed northern hardwoods, black cherry-maple (SAF 1980) and red maple (SAF 1980). Stem densities were relatively lower at RCHC than at the WERF. Basal area ranged from 8.0 to 34.8 m^2 per ha. Average basal area was 24.7 m^2 per ha at the WERF den sites, and was lowest at the RR Den due to the rhododendron thicket at the site. Average basal area at the RCHC was 24.0 m^2 per ha. Table 4 lists forest cover type, basal area per hectare, and stem density per hectare for den sites on the RCHC and the WERF.

Leaf litter ranged from 48.74 to 93.75 %, and leaf litter at 4 of 6 dens covered more than 75% of square meters (Table 5). Woody debris occurred at all den sites and moss, rock, and lichens occurred at most den sites (Table 5). Deciduous cover ranged from 75 to 95 % at all dens except RR, where deciduous cover was 55% (Table 6).

LB den site was a complex consisting of medium- to course-grained, quartz arenite (M. Caudill, Personal Communication) glide blocks and outcrops near a wide ridge top. The den site was in an upland hardwoods stand, and the SAF (1980) forest cover type was chestnut oak. Common tree species such as chestnut oak (*Q. prinus*), red maple (*A. rubrum*), black gum (*Nyssa sylvatica*), sweet birch (*B. lenta*), and black oak (*Q. velutina*) comprised the stand. Subcanopy and woody understory species included mountain laurel (*Kalmia latifolia*) and blueberry species (*Vaccinium* spp.). The den was 391.3 m from a forest road and 14.2 m from a well-traveled jeep trail.

RKS den site consisted of rock fall below a medium-grained quartz arenite rock outcrop with glide blocks and talus down slope (M. Caudill, Personal Communication). The den site was located in a mountain hardwoods stand, and the SAF (1980) forest cover type was chestnut oak.

Common tree species such as sourwood (*Oxydendrum arboretum*), chestnut oak (*Q. prinus*), northern red oak (*Q. rubra*), sweet birch (*B. lenta*), and red maple (*A. rubrum*) comprised the stand. Commonly occurring subcanopy and woody understory species were mountain laurel (*K. latifolia*) and blueberry species (*Vaccinium* spp.). The den was 198.8 m from a forest road and 40.5 m from a well-traveled jeep trail.

RDG den site consisted of medium-grained quartz arenite (M. Caudill, Personal Communication) outcrops and ledges below a ridge top. The den site was located in an upland hardwoods stand, and the SAF (1980) forest cover type was chestnut oak. The stand consisted of common tree species such as chestnut oak (*Q. prinus*), red maple (*A. rubrum*), sweet birch (*B. lenta*), American beech (*F. grandifolia*), and black gum (*N. sylvatica*). Common subcanopy and woody understory species were mountain laurel (*K. latifolia*), common greenbrier (S. rotundifolia) and blueberry berry (*Vaccinium* spp.). A log road approaches the den from one side, and the distance from a known hibernaculum to a forest road was 627.5 m. The distance to a well-traveled jeep trail was 480.6 m.

LH den site was a large complex of outcrops and ledges with glide blocks composed of medium- and coarse-grained, slightly conglomeratic, quartz arenite (up to 99% sandstone) (M. Caudill, Personal Communication). The den site was located in cove hardwoods stand, and the SAF (1980) forest cover type was mixed northern hardwoods. The stand consisted of chestnut oak (*Q. prinus*), black oak (*Q. velutina*), black gum (*N. sylvatica*), hemlock (*T. canadensis*), Frasier magnolia (*M. fraseri*), red maple (*A. rubrum*), and sweet birch (*B. lenta*), American beech (*F. grandifolia*), tulip tree (*L. tulipifera*), sassafras (*Sassafras albidum*), and northern red oak (*Q. rubra*). Common subcanopy and woody understory species were mountain laurel (*K. latifolia*), common greenbrier (*S. rotundifolia*), and partridge berry (*Mitchella repens*). The site was bordered on 2 sides by log roads, and the closest distance from a hibernacula entrance to a forest road was 227.7 m.

KC den site consisted of few ledges and one glide block of fine- to medium-grained, weathered lithic sandstones, with horizontal laminations (M. Caudill, Personal Communication). The den site was located in a mountain hardwoods stand, and the SAF (1980) forest cover type was black cherry-maple. The stand consisted of red spruce (*P. rubens*), sugar maple (*A. saccharum*), black cherry (*P. serotina*), witch hazel (*Hammelis virginiana*), and sassafras (*S. albidum*). The common subcanopy and woody understory species was common greenbrier (*S.*

rotundifolia). Two log roads approach the den area. The distance of the hibernacula entrance closest to the road was about 284.0 m.

RR den site was formed from lithic arenite medium-grained (M. Caudill, Personal Communication) glide blocks below a rock face. Rock fall filled road cuts. The den site was located in a cove hardwoods stand**,** where a rhododendron (*R. maximum*) thicket occurred under a red maple stand (SAF 1980). Common species consisted of red maple (*A. rubrum*), sweet birch (*B. lenta*), black gum (*N. sylvatica*), and sugar maple (*A. saccharum*). Common subcanopy and woody understory species were common greenbrier (*S. rotundifolia*), mountain laurel (*K. latifolia*), and rhododendron (*R. maximum*). The den site was bordered by a forest road. The distance of the hibernacula entrance closest to a forest road was ca. 2 meters.

Transmitters

During ingress 2000, external transmitters were affixed to 9 rattlesnakes: 8 at or en route to the LH den site and one at the RR den site. During ingress 2001, external transmitters were affixed to 7 rattlesnakes: one rattlesnake at the RR den site; and 6 rattlesnakes at or en route to the LH den site.

Seventeen timber rattlesnakes were surgically implanted with transmitters in both study years combined. Eleven timber rattlesnakes were surgically implanted with transmitters during 2001 and 6 timber rattlesnakes were surgically implanted during 2002. Six females and 5 males from the WERF were implanted during 2001. During 2002, 2 males on the WERF and 4 males on the RCHC were implanted.

Three rattlesnakes received replacement transmitters in 2002, and reactions ranged from minimal to severe. One rattlesnake showed little to no evidence of reaction to the implant, and 2 rattlesnakes showed moderate evidence of reactions to implants. Two necropsies showed evidence of extreme reactions to implants. In one case of extreme reaction, the tissue around the implant in one rattlesnake was necrotic. In another case of extreme reaction, the area around the implant was septic, a pseudo membrane encased the implant, and the transmitter moved ca. one inch from its original location.

Surgery

Eleven surgeries were conducted in 2001 and 9 surgeries were conducted in 2002. No snakes died as a direct result of surgery or anesthesia. Most rattlesnakes showed signs of alertness, such as tongue-flicking and head and body movement, within 20 minutes following surgery.

Two males were administered antibiotics due to signs of infection at the time of surgery. Two females were administered saline due to appearing dehydrated. One post-gravid female was administered less inhalation anesthesia and local anesthesia.

Eleven rattlesnakes were surgically implanted in 2001. Six specimens were captured and surgically implanted in 2002: 2 males on the WERF and 4 males on the RCHC. Transmitters were replaced in 3 snakes that were captured and originally telemetered in 2001.

No snakes experienced problems from sutures during the study period, although one snake experienced problems after the study ended. No snakes on which surgical glue was used experienced post-surgical problems during the study.

Rookery Sites and Bask Sites

Two rookeries near the LH den were located during 2001. Both rookeries were at anthropogenic edges. One rookery was located by searching potential habitat areas. The first rookery was located by locating a telemetered female that was captured at a bask site 59.5 m from the rookery. The rookery was less than 5 m from the forest road, formed from the rotted remains of a root system and the soil of an upturned tree, 327.7 m from the hibernacula. Hay-scented ferns (*D. punctilobula*), fescue species (*Festuca* spp.), sedge species (*Cyperaceae* spp.), broomsedge (*Andropogon virginicus*), and a stump provided cover. The second rookery located was found by searching potential habitat. The rookery was located at a log landing, 29.6 m from the forest road, 832.1 m from the hibernacula. A post-gravid female accompanied by 6 neonates was observed. A rock slab and timber slash provided cover.

Three bask sites were located on the WERF. Two bask sites used by rattlesnakes of the LH den site were found by locating telemetered rattlesnakes. One bask site was located near the KC den site, also by locating a telemetered rattlesnake. No bask site was located for the RR den site. The bask site associated with the KC den site was an underground cavity, accessed by at least one vertical fissure in the ground, at a log landing, 10.4 m from a forest road. A felled tree and grasses provided cover above ground. The site was 495.0 m from the overwinter crevice of the telemetered rattlesnake that used the site. Hay-scented ferns (*D. punctilobula*), fescue species (*Festuca* spp.), sedges (*Cyperaceae* spp.), and logs provided cover.

One bask site associated with the LH den was located at the end of a log road. Talus, timber slash, and hay-scented ferns (*D. punctilobula*) provided cover. The 2 telemetered rattlesnakes that used the site were 232.5 and 263.8 m from their hibernacula. One rattlesnake was captured at the site during 2001 and 2 were captured at the site during 2002. Another bask site associated with the LH den was a decaying log at the edge of a road, where the log and adjacent grasses provided cover. Rattlesnakes used the inside of the log as well. The site was 223.4 and 325.6 m from hibernacula of 2 telemetered rattlesnakes that used the site. Three snakes in total were captured at the latter bask site and one rattlesnake was captured near the site. The site was 89.4 m from a jeep trail, and 294.1 m from a forest road.

On the RCHC, no other bask sites were located other than the site where all 4 telemetered rattlesnakes were captured. The one bask site was located at the edge of a log landing, near the forest edge. Rock slabs and timber slash provided cover. Rattlesnakes other than telemetered rattlesnakes used this site. The site was 972.2, 242.3, and 932.0 m from overwinter den sites. The site was 32.1 m from a forest road and 59.4 m from a well-traveled jeep trail.

Cause-Specific Mortality

Of the 17 rattlesnakes implanted on the 2 study areas, 13 (76.5%) resulted in mortalities. Three (17.6%) mortalities were caused by mammalian predation; avian predation was the cause of one (5.9%) mortality; 3 (17.6%) mortalities were caused from vehicle-induced injuries; 4 (23.5%) mortalities were caused from complications associated with surgically implanted transmitters; one rattlesnake (5.9%) died as a result of post-partum condition; one (5.9%) rattlesnake died from an unknown cause. One (5.9%) timber rattlesnake was lost and thus the fate was unknown, and 3 timber rattlesnakes survived through the study period. Table 7 lists cause-specific mortality of telemetered rattlesnakes.

Specific to the WERF, 12 (92.3%) of 13 rattlesnakes resulted in mortalities. Three (23.1%) mortalities were caused by mammalian predation; one (7.7%) mortality was caused by avian predation; 2 (15.4%) mortalities from vehicular injuries; 4 (30.8%) mortalities were caused from implants; one (7.7%) was post-partum; and the specific cause of one (7.7%) mortality unknown. One (7.7%) rattlesnake survived the study.

Specific to the RCHC, one (25.0%) of 4 rattlesnakes resulted in mortalities. The specific cause of mortality for one (25.0%) timber rattlesnake was vehicle-induced injuries. One rattlesnake (25.0%) was lost and thus the fate was unknown. Two (50.0%) rattlesnakes survived until the end of the study.

Home Range and Movements

Home range estimates and distance measures were calculated for 7 rattlesnakes on the WERF. Home range sizes of males were largest, and home ranges of gravid females were smallest. Home range size for males ranged from 226.2 to 95.6 ha and the mean home range size for males was 94.3 ha. The home range of a male tracked for 2 seasons was larger in 2002 than in 2001. The home range sizes for gravid females were 6.3 and 10.7 ha, and the mean home range size for gravid females was 8.5 ha. The home ranges of non-gravid females were 21.6 and 9.9 ha and the mean home range size for nongravid females was 31.2 ha. Table 8 lists sizes of home ranges, numbers of locations, and extents of the active seasons monitored, by year and for combined years.

Home ranges of 3 females overlapped with home ranges of other females only at the den site**.** Home ranges of males overlapped at the den site and some home ranges of males overlapped in summer range. Home ranges of 2 males from the KC den site overlapped. The home ranges of 3 males from the LH den site overlapped at the den site, and the home ranges of 2 males overlapped in summer range.

The maximum known distances from overwinter den sites were 3632.7 m for males, 1127.1 m for nongravid females, and 837.0 for gravid females. The average maximum distances were 1515.8 m for males, 583.8 m for gravid females, and 871.5 nongravid females. Two males studied for a second season showed higher maximum distances from overwinter den sites in

2002 than in 2001. The nongravid female tracked for a second season, however, showed a higher maximum distance from the overwinter den site in 2001. Total distances moved were highest for males and lowest for gravid females. Total distances moved for males ranged from 6802.6 to 345.0 m (Table 9). One male tracked for 2 seasons showed a higher total distance moved in 2002 than in 2001. Total distances moved for the 2 gravid females were 1792.6 and 1349.1 m. Total distances moved for nongravid females ranged from 1128.4 to 3017.5 m. One female tracked for 2 seasons showed a higher total distance moved in 2001 than in 2002. Table 9 lists daily movement rates, maximum known distances from den sites and dates of maximum known distances from den sites, mean distances from den sites, and total distances moved for rattlesnakes radio-tracked for at least one-half of one active season on the WERF.

Daily movement rates were higher for males than for nongravid females. Daily movement rates for one male rattlesnake studied during both 2001 and 2002 were 32.1 m and 37.9 m, respectively. The daily movement rate of a second male rattlesnake tracked for a full 2002 season was 38.2 m. Mean distances from den sites were highest for males and lowest for gravid females. Mean distances from den sites of males ranged from 1813.4 to 230.5 m; mean distances from den sites of nongravid females ranged from 380.4 to 498.1 m; and mean distances from den sites of gravid females were 276.6 and 203.8 m. One male tracked for 2 seasons showed a higher mean distance from the den site in 2002 than in 2001, but one nongravid female showed a higher mean distance from the den site in 2001 than in 2002. Mean distance from the den site was not determined for one rattlesnake on the RCHC because it was lost or the transmitter failed. Table 10 lists daily movement rates, average maximum distances from dens, average total distances moved, and average home range estimates by sex class.

Habitat Use by Stand Type

On both study areas, locations of telemetered rattlesnakes while in summer range were more numerous in relatively mature hardwood stands than in clearcut hardwood stands and nonforest stands (i.e., roads/edges). However, nearly all telemetered rattlesnakes were located in a clearcut hardwood stand at least one time while in summer range. On the WERF, rattlesnakes tracked for at least one full season were located in a clearcut hardwood stand at least one time.

Four snakes tracked for less than a full season were located in a regenerating clearcut hardwood stand. With the exception of 3 snakes (one injured and 2 predated), 10 snakes were located at least one time in nonforest stands. Regeneration ages of clearcut hardwood stands occupied by timber rattlesnakes were cove hardwoods, 7-8 years; mountain hardwoods, 1-3 years; and upland hardwoods, zero years. Relatively mature hardwood stands and stand ages occupied by timber rattlesnakes were cove hardwoods, 79-89 years; mountain hardwoods, 68-85 years; and upland hardwoods, 77-81 years. On the RCHC, all telemetered rattlesnakes were located in a nonforest stand at least one time while in summer range. Two of 4 rattlesnakes were located in a 4-year-old clearcut hardwood stand one time each while in summer range. Relatively mature hardwood stands and stand ages occupied by timber rattlesnakes were mountain hardwoods, 63-69 years old; and upland hardwoods, 69 years old. Table 11 lists numbers of locations at road/edge locations and in clearcut (CC) and mature forests (MF) of cove, mountain, and upland hardwoods stands.

Phenology

Active season

Lengths of active seasons ranged from 149 to 178 days for all telemetered rattlesnakes, and the mean active season length was 167.3 days or 5.4 months (based on a 31-day month). Lengths of active seasons for males ranged from 166 to 168 days and the mean active season length for males was 165.5 days or 5.3 months. Lengths of active seasons for females ranged and from 159 to 178 days and the mean active season length for females was 171.0 days or 5.5 months (based on a 31-day month). The first known active dates for males were 28-29 April, and the first known active dates for females were 6-15 May. The last known active date of a telemetered female rattlesnake was 10 November, and the last known active date of a telemetered male rattlesnake was 23 November. Table 12 lists first and last known active dates and total known active days for each rattlesnake monitored on the WERF.

Egress

During 2001, egress occurred from 29 April to 11 May, based on captures at overwinter den sites. During 2001, the one large adult male was captured earlier, on 29 April, than adult females and juveniles. Adult females were captured at overwinter den sites during spring 2001 on 1 May (one capture), 6 May (2 captures), 11 May (2 captures). Rattlesnakes born the previous season were captured on 1 May (2 captures), 4 May (one capture), and 8 May (one capture). During 2002, egress occurred from 28 April to 16 May, based on activity of telemetered rattlesnakes. Two large, adult males were located in transient ranges, away from overwinter den sites, on 28 April, and 2 adult females were located within the area of the overwinter den site.

Ingress

During 2000, ingress occurred from 28 September to 4 October, based on captures at overwinter den sites. During 2001, ingress occurred from 12 September to 22 October, based on captures at overwinter den sites as well as known active days of telemetered rattlesnakes. During 2002, 26 September to 13 October, based on active dates of telemetered rattlesnakes.

Temperatures

The first fall frost in 2000 occurred on 8 October. September temperatures ranged from 2.2 ^{o}C to 28.3 ^{o}C, and averaged 16.3 ^{o}C. Maximum and minimum temperatures averaged 22.3 ^{o}C and 10.3 ^{o}C, respectively. Minimum temperatures did not fall below freezing during September. October maximum and minimum temperatures averaged 19.3 ^{o}C and 2.7 ^{o}C, respectively. Monthly temperatures averaged 10.9 ^{o}C and temperatures ranged from -6.7 ^{o}C to 26.7 ^{o}C. Minimum temperatures were below freezing on 10 days of the month.

The 2001 season length was 145 days, from the last spring frost reported for Elkins on 14 May to the first fall frost on 7 October. April maximum and minimum temperatures averaged 19.3 ^{o}C and 2.9 ^{o}C. Monthly temperatures averaged 11.1 ^{o}C and ranged from -3.9 ^{o}C to 31.1 ^{o}C. Below freezing temperatures occurred on 14 days of the month. Record high temperatures were 26.7 ^{o}C and 27.2 ^{o}C on 7 and 9 April 2001, respectively. May maximum and minimum temperatures averaged 21.7 ^{o}C and 7.7 ^{o}C . Monthly temperatures averaged 14.7 ^{o}C and ranged from -1.1 ^{o}C to 28.9 ^{o}C. Minimum temperatures were below freezing on one day in May.

September maximum and minimum temperatures averaged 22.1 ^{o}C and 8.8 ^{o}C, and the monthly average was 15.4 ^{o}C. Temperatures ranged from 2.8 ^{o}C to 28.3 ^{o}C, and no minimum temperatures were below freezing. October maximum and minimum temperatures averaged 18.3 ^{o}C and 0.9 ^{o}C. Temperatures ranged from -7.8 ^{o}C to 26.1 ^{o}C and the monthly average temperature was 9.7 ^{o}C. Minimum temperatures were below freezing 14 days of the month. Record lows were set at -5.6 ^{o}C and -5.0 ^{o}C on 8 and 9 October 2001, respectively.

During 2002, the season length was 152 days, from the last frost on 23 May to the first fall frost on 23 October. Maximum and minimum temperatures in April averaged 18.4 ^{o}C and 3.7 ^{o}C, and the monthly average was 11.1 ^{o}C. Minimum temperatures were below freezing 11 days of the month. A record high temperature was set on 16 April 2002 at 29.4 ^{o}C. Maximum and minimum temperatures in May averaged 21.0 ^{o}C and 6.2 ^{o}C. Temperatures ranged from -3.3 ^{o}C to 28.3 ^{o}C and monthly temperatures averaged 13.6 ^{o}C. Minimum temperatures were below freezing on 6 days of the month. Record low temperatures were set on 19, 20, 21, 22 May 2002 at 0.6 ^{o}C, -1.1 ^{o}C, -1.7 ^{o}C, -3.3 ^{o}C, respectively. Maximum and minimum temperatures in September averaged 26.1 ^{o}C and 10.6 ^{o}C. September temperatures ranged from 2.8 ^{o}C to 32.2 ^{o}C and averaged 18.3 ^{o}C. No minimum temperatures were below freezing and on one day maximum temperatures were at or above 32.2 ^{o}C. October maximum and minimum temperatures averaged 16.1 ^{o}C and 5.6 ^{o}C, and the monthly average temperature was 10.8 ^{o}C. The minimum temperature was below freezing one day of the month.

Average monthly normals for Elkins, West Virginia (NWSFO 2005) for April were 9.4 ^{o}C, average; 17.3 ^{o}C, maximum; 1.4 ^{o}C, minimum. May normals (NWSFO 2005) were 14.4 ^{o}C, average; 22.1 ^{o}C, maximum; 6.7 ^{o}C, minimum. September normals were 16.7 ^{o}C, average; 23.4 ^{o}C, maximum; 10.1 ^{o}C, minimum. October normals were 10.3 ^{o}C, average, 17.8 ^{o}C, maximum; 2.8 ^{o}C, minimum.

Reproduction

Matings most likely occurred in August, although matings may have occurred in June as well. Two males were captured by finding them with a telemetered female. The males were found with the telemetered female on 6 and 31 August 2001. Presumably, the female was vitellogenic although no copulations were observed.

On 2 occasions a telemetered male rattlesnake was found at a bask site with a female. One occurrence was on 2 August 2001. Copulation was not observed. The female moved to a rookery shortly thereafter. The second occurrence was from 12 -14 June at a bask site. The male and female were under a rock and thus copulation was not confirmed. The female did not move to a rookery, but rather moved throughout summer range.

Post-gravid females left rookery areas in September and returned to areas of overwinter den sites. One post-gravid female left the rookery by 10 September and returned to the area of the den site by 18 September, where she was active at least until 26 September. Another post-gravid female left the rookery by 22 September and moved toward the area of the den site, where she remained active at least until 28 September.

Parturition of one gravid female occurred by 5 September on the WERF, where one litter of 6 young was located during the study. Parturition was not verified for the other gravid female.

CHAPTER VI

DISCUSSION

Den Sites

<u>Location</u>

The location of den sites with respect to roads was probably disadvantageous to *C. horridus* populations on the study areas. Reinert and Zappalorti (1988) suggested that rattlesnake dens within close proximity to roads were at high risk of collecting, hunting, and accidental and wanton killings. This scenario was realized at one den site on my study areas when a female from the RR den site experienced vehicle-induced mortality upon emergence. I found only 4 rattlesnakes at the RR den site throughout the study. Rudolph and Burgdorf (1997) hypothesized that roads adversely affected timber rattlesnake populations in eastern Texas. Rudolph et al. (1998) later showed that roads and associated traffic detrimentally affected *C. horridus* distribution in eastern Texas, where distribution of C. *horridus* is currently limited to areas of low road density. Overall, due to the placement of roads on the study areas, all rattlesnakes were exposed to roads while either traversing their home ranges, basking, or migrating to and from den sites. Furthermore, the location of the den site respect to the road shows that road construction destroyed a large portion of the den site, thereby limiting available hibernacula at the den site.

Brown et al. (1982) showed that an individual timber rattlesnake would repeatedly use the same hibernaculum. Similarly, 2 timber rattlesnakes in this study repeatedly used the same hibernaculum for 2 consecutive overwinter seasons. One specimen changed hibernaculum from the first overwinter season to the second overwinter season. It is very likely that the rattlesnake changed its hibernaculum because of my disturbance at the den site, especially given Brown's statement (1992) that disturbance of timber rattlesnakes at den sites can make rattlesnakes difficult to find. Nonetheless, I am not able to base a conclusion on the result of one individual.

I observed timber rattlesnakes basking in front of horizontal crevices (i.e., spaces under rocks) that were distinctly in different locations than their hibernacula. However, I also observed timber rattlesnakes basking in front of known hibernacula entrances. The use of crevices for basking at den sites, as opposed to basking in front of hibernacula entrances, may allow for faster and easier retreat from predators. The crevices probably provide advantages in terms of temperature, shade, and wind. I did not measure vegetation at hibernacula entrances and basking crevices, but I did notice that some of the timber rattlesnakes using basking crevices, as opposed to rattlesnakes basking at hibernacula entrances, did not have cover from vegetation. One timber rattlesnake basking at a hibernacula entrance without vegetative cover basked with only the tail at or out of the hibernacula entrance. At den sites where common greenbrier (*S. rotundifolia*) was widespread, I repeatedly observed timber rattlesnakes basking under tangles of common greenbrier common greenbrier *(S. rotundifolia)* covering crevices, leaf litter, or bare ground. Upon approach, the rattlesnakes attempted to retreat either into the hibernacula or under leaf litter.

<u>Description</u>

The differing forest cover types between study areas could be explained by difference in elevations. The RCHC occurs at relatively lower elevations than does the WERF. The lower elevations in combination with aspect of den sites are suitable sites for chestnut oak (*Q. prinus*) stands. The differences in forest cover types among den sites at the WERF are slight in reality, because all forest cover types ultimately represent a broader category recognized as Allegheny hardwoods. The forest cover type at RR den site was based on few trees in the plot, and one could easily argue that the forest cover type was mixed northern hardwoods, given the recent classification of the red maple cover type (SAF 1980) and the few trees in the plot. Stem densities were relatively lower at the RCHC den sites than at the WERF den sites. Lower stem densities on the RCHC were probably due to less commonly occurring common greenbrier (*S. rotundifolia*) at the den sites. *Vaccinum* spp. occurred more commonly at the RCHC dens, resulting in lower stem densities. Deciduous cover ranged from 75 to 95 % at all dens except RR, where deciduous cover was 55% (Table 6). The relatively low deciduous cover at the RR den site was due to the rhododendron (*R. maximum*) thicket at the site.

Surgical Procedures

Problems with surgical implants have been attributed to the implant rather than surgical procedures (Hardy and Greene 1999). It is possible that the 2 rattlesnakes that were surgically implanted in August suffered a reaction to malfunctioning transmitters. The ATS transmitters were not covered in paraffin as were the Holohil transmitters. Perhaps the lack of paraffin coating allowed the transmitter to transmit heat to the rattlesnakes and thus induce reactions. Alternatively, in high elevations, August surgeries may have adverse affects on timber rattlesnakes. Rudolph et al. (1998) concluded that rattlesnakes should not be surgically implanted during or after September unless locating dens and hibernacula were important to studies. Rudolph et al. (1998) also showed that snakes with late implants emerged earlier in spring, were on the surface more, and basked more. My findings support results of Rudolph et al. (1998) for late implants, and my results indicate that timber rattlesnakes surgically implanted in August suffered transmitter-induced mortality as well. Whether or not the mortalities were from lack of appropriate healing time following surgeries, or from adverse reactions to transmitters, is unclear. Nonetheless, High Allegheny rattlesnakes implanted in August apparently are prone to infection and improper healing. Similarly, High Allegheny rattlesnakes implanted in May might be placed at increased risk. Increased risk resulting from basking in marginal temperatures in order to heal from surgical procedures is consistent with results of Rudolph et al. (1998). Below freezing temperatures are common during May in the High Alleghenies, and rattlesnakes basking in cool temperatures might be more subject to predation.

Brown et al. (1982) reported post-surgical inactivity of rattlesnakes up to 21 days. Rattlesnakes in my study also remained inactive following surgeries. The maximum time of inactivity was 30 days including several days of very moderate activity immediately following release. The rattlesnake basked at road edges following release until it moved to an underground refuge where it remained until it molted. The subsequent survival of the rattlesnake might suggest that rattlesnakes remaining sedentary and inactive following the surgery heal better with less potential for infection.

Rookery and Bask Sites

Reinert and Zappalorti (1988) concluded that rookeries were associated with road edges and “frequent fallen logs” on their study area in the Pine Barrens, New Jersey. Rookeries in my study were also associated with road edges. I did not quantify habitat components at rookery sites in my study and therefore cannot conclude that woody debris was either an important or a frequent component of rookery sites on my study area as Reinert and Zappalorti (1988) concluded. However, at one rookery formed from the root ball of an upturned tree, one entrance was through the rotting log, and no rock was located in the immediate vicinity of the rookery site. This qualitative evidence indicates that woody debris is important for rookery locations and that woody debris may be used in lieu of rock.

Similarly, bask site locations were associated with road edges and woody debris was seemingly common, although I did not quantify habitat components at bask sites. Also similar to the rookery sites, one bask site was a large rotting log, and the area immediately around it, where the rattlesnakes retreated inside the log for cover, and no rock was in the immediate vicinity.

Two of 3 bask sites served as "transient habitat," a term formally introduced by Brown (1992). Brown (1992) defined transient habitat as "stop-over" points used by migrating rattlesnakes and gravid females, and he concluded that rattlesnakes repeatedly use the stop-over points. One site near an overwinter den site also served as bask site for juvenile rattlesnakes whose home ranges were presumably small enough to limit their travels to bask sites farther from overwinter den sites. Furthermore, I did not observe juvenile rattlesnakes at bask sites located relatively father from overwinter den sites.

Four male rattlesnakes on the RCHC used a common bask site. I determined that 3 of the rattlesnakes were from 3 different den sites. I could not locate the den site of the fourth male because the rattlesnake was lost or the transmitter failed. Home ranges of male timber rattlesnakes radio-tracked on the WERF overlapped, but home ranges of female timber rattlesnakes in this study did not overlap. The larger home range sizes of males might be conducive to common use of bask sites by males. In contrast, smaller home range sizes of females might preclude common use of bask sites by females from different den sites. Home ranges of females in this study only overlapped at and near den sites, which may contribute to the lack of multiple females at one bask site.

One nongravid female only used a bask site (a stop-over point previously discussed) near the den site following healing after surgical implant procedures. The female did not use an area specifically recognized as a bask site during ingress of the same active season and during egress of the following active season. Furthermore, following the location at the one bask site, this female, was not located at any site where other snakes were present. I did not locate this female rattlesnake daily, although I did observe the female basking on and under slash piles on numerous occasions while migrating from the overwinter den site to summer range. Bushar et al. (1998) concluded that the availability of bask site locations determined the directions in which timber rattlesnakes traveled, which did not seem to be consistent with the behavior of this particular female. Another nongravid female did not use sites recognized specifically as bask sites, although I located her too few times (due to transmitter failure) for inclusion in this discussion. I would like to note that the female was located in a clearcut which I believe was used as a bask site.

Brown et al. (1982) included the use of rock slabs and outcrops in the discussion of transient habitat. Known bask sites on my study area were neither rock slabs nor outcrops. I am sure that such bask sites existed, and I did locate one rattlesnake basking on rock ledges in summer range. Brown et al. (1982) found rattlesnakes stopping over at bask sites in transient range for 1-2 weeks and found rattlesnakes at the sites in preshed condition. In my study, one male rattlesnake stayed at a bask site for 2 weeks, during which time the rattlesnake moved to and from a slash pile located in the mountain hardwoods forest stand behind the bask site. Another male exhibited the same behavior at a bask site, staying at the bask site for the nearly 2 weeks, although the latter rattlesnake was in preshed condition as a response to surgery. In both cases, the males suddenly left the site after ecdysis. The behavior that I observed in my study was consistent with behaviors of rattlesnakes reported by landowners when rattlesnakes are observed in yards and on farms, repeatedly foraging and basking in an area during summer and then suddenly leaving the area (J. Adams, Unpublished Data). The observed behavior is also consistent with conclusions of Brown et al. (1982) that rattlesnakes make sudden and extensive movements after ecdysis.

Gregory (1984) established the difficulty of aggregating snakes remaining inconspicuous against predators at den sites. Timber rattlesnakes are probably conspicuous to predators at bask sites and rookery sites. My data showed that predation is likely at or near bask sites because all 3 incidences of mammalian predation occurred at bask sites. One rattlesnake was predated while in a rotten log at a bask site; 2 rattlesnakes were either predated or scavenged while at or near a bask area.

Female timber rattlesnakes may select rookery sites that differ from bask sites. I did not measure habitat components and rookery and bask sites and did not test for site selection of rookery and bask sites by timber rattlesnakes. However, I observed one female at a bask site that later moved to a rookery site. Considering Brown's (1992) discussion of the negative affects of human disturbance on timber rattlesnakes, it is very likely that the female moved to another site simply due to disturbance.

All rookery and bask sites on my study areas were associated with results of anthropogenic activities. Road construction and timber harvesting caused felled trees, stumps, slash piles (i.e., woody debris), log landings (i.e., clearings), which were suitable timber rattlesnake habitat for bask and rookery sites. Historically, natural activities such as wildfire, wind and ice storms, and forest diseases caused felled trees, stumps, woody debris, and clearings. Whether natural or anthropogenic, timber rattlesnakes utilize edges for bask and rookery sites. Anthropogenic activities substitute for natural activities that historically caused edges. Only one rookery site and one bask site was associated with rock. Concern has been expressed about den sites becoming shaded over (Brown 1993). It is possible that rock ledges and outcrops used as rookery and bask sites become shaded over causing timber rattlesnakes to select rookery and bask sites associated with woody debris. Sites with woody debris were probably more available on my study areas than sites associated with rock.

Reinert and Zappalorti (1988) discussed the increased potential for mortality of timber rattlesnakes by humans when rattlesnakes utilize areas of increased human activity. Brown (1992) discussed the propensity of humans to repeatedly visit (e.g., to hunt, collect, and kill) rattlesnakes at sites where rattlesnakes are known to aggregate. Although my study areas were gated and locked, traffic from hunting, logging, and research activities was common on the production forest. My personal observations and interviews with loggers confirm the likelihood of timber rattlesnakes to be collected, hunted, and wantonly killed on production forests. Additionally, I found that timber rattlesnakes at bask sites near the road may bask close to road edges and thus increase their risk of vehicle-induced mortality.

Cause-Specific Mortality

Rudolph et al. (1998) reported the risk of infection and problematic healing from surgical procedures conducted after 1 September, and recommended caution due to potential mortality from “late season” surgical implants. New Jersey researchers therefore implanted timber rattlesnakes in September and October only for locating overwinter den sites, retaining study specimens, and studying body temperatures (Rudolph et al. 1998). I found very similar results with my study. Three rattlesnakes were surgically implanted after 1 September in order to locate overwinter den sites, and all 3 rattlesnakes with late season implants consequently died. One large male, however, was unhealthy and basking at initial capture, probably for healing purposes. It exhibited puncture wounds, possibly from escaping a raptor, and was administered antibiotics during surgical procedures due to apparent infection. The 20-25 year old specimen (W. Martin and R. Stechert, Personal Communication) was confirmed dead on 2 April after snow melted from the site. I am uncertain of the actual mortality date of this specimen, but I believe the rattlesnake died during late fall because only skeletal remains were recovered. A second rattlesnake with a late season implant returned to the den relatively late in the season (on November 23) and emerged and died by 1 April of the following season. The rattlesnake was found coiled below leaf litter near its hibernaculum. Necropsy revealed that the rattlesnake completely rejected the transmitter, evidenced by a bacterial membrane that encapsulated the transmitter. It appeared that the rattlesnake tried to "wallow" the transmitter as the transmitter moved about an inch from its original position in the body cavity. The third rattlesnake with a late implant was confirmed dead on 2 April of the following year. I was unable to recover remains of the rattlesnake.

Two rattlesnakes surgically implanted on 3 and 8 August died. One was a large, seemingly very healthy male without apparent problems from the implant until I confirmed him dead 1 April the following spring. Another was a female captured while with a telemetered male at a bask site. Following surgical procedures, the rattlesnake moved to a nearby rookery site where she stayed until 22 September when she began moving toward the overwinter den site. I confirmed the rattlesnake dead on 1 April but was unable to recover remains. I identified the cause of mortality as post partum condition because the rattlesnake behaved as a gravid female during the previous active season and because post partum females sometimes die in the spring (W. Martin, Personal Communication). However, I cannot eliminate complications or reactions from the surgical implant as a potential cause of mortality.

Three rattlesnakes were predated while healing from surgeries. Two rattlesnakes underwent surgery on 10 and 15 May 2001. The last spring frost occurred in Elkins on 14 May (NWSFO 2005), but the minimum temperature in Elkins decreased to 0.6 ^{o}C on 31 May, and minimum temperatures were less than normal on 7 out of the first 10 days of June. Additionally, my study areas occurred at higher and cooler locations than Elkins. Given the conclusion of Rudolph et al. (1998) that implanted snakes bask more, I believe that the 2 rattlesnakes were basking either at the bask site adjacent to the overwinter den site when they were predated. A third rattlesnake was predated by a mammal while recovering from surgical procedures, and the predation occurred at a bask site.

The one instance of avian predation occurred on 10 November when a female was migrating from summer range to the den site. I found the remains along with the PIT tag and transmitter at the base of a tree near a slash pile at which she stopped over a week prior. Minimum temperatures were below freezing on 7 of the first 10 days of November, and the highest maximum temperature was 10 ^{o}C from 1 November through 7 November, until maximum temperatures warmed to 17.8 ^{o}C, 19.4 ^{o}C, 22.2 ^{o}C on the 8, 9, 10 November, respectively. I assumed the rattlesnake stopped over at the slash pile during cold weather, began to bask and resume migration as temperatures warmed, and was predated while leaving the site on 10 November. This rattlesnake emerged in the spring with an infection about the eye, and spent a lot of time basking throughout the active season. The rattlesnake showed a propensity for basking on sticks and slash up to several feet off the ground, in areas that would be conspicuous to raptors. The rattlesnake also received a replacement transmitter during summer, and the surgery probably further extended the need for the extended active season. The replaced transmitter showed moderate signs of reaction, evidenced by bacteria on the transmitter. This rattlesnake completed ecdysis later, moved fully into summer range later, and moved throughout a smaller area during 2002 compared to 2001. Brown (1995) noted that follicular yolking may cause females to stay in range longer, and that may be possible as she was not reproductively active during 2001 and 2002, despite a pairing (without confirmed copulation) with a male rattlesnake during spring 2001.

Two of 3 rattlesnakes that experienced immediate mortality because of vehicle-induced injuries were found off the road and under cover. Cover consisted of a small rotting log in one case and a tree root in another case. A scavenger pulled the anterior end (ca. 15 cm) from the cover, and post mortem chew marks were present on one rattlesnake. Both rattlesnakes moved far enough from the road to prevent visual observations of the mortalities from the road. The third rattlesnake that died of vehicle-induced injuries was run over by a vehicle on or before 21 September and survived until it reached the overwinter den site after 8 October. Therefore, all 3 rattlesnakes that died of vehicle-induced injuries moved from the road. My results support conclusions of Reinert and Zappalorti (1988) that rattlesnakes near roads are subject to mortality by human-induced means.

Home Range and Movements

My study showed average home ranges by sex and reproductive condition as follows: males, 94.3 ha; nongravid females, 31.2 ha; gravid females, 8.5 ha. My results were lower than results of studies in New Jersey (Brown 1993), but much higher than results of studies in Pennsylvania (Brown 1993). Average home range sizes of New Jersey timber rattlesnakes were 207 ha, males; 42 ha, nongravid females; 22 ha, gravid females. Average home range sizes of Pennsylvania timber rattlesnakes were 65 ha, males; 17 ha, nongravid females; 4 ha, gravid females. Reinert and Rupert (1999) determined that average home range sizes of rattlesnakes (non-translocated) in Pennsylvania were 59.9 ha, males; 41.9 ha, nongravid females; 5.0 ha, gravid females, which is consistent with other Pennsylvania studies reported above. Obviously, differences in methods may reflect differences in home range sizes. Reinert and Zapplorti (1988) listed home range estimates by method with tabulated data signifying sex class. Averaging home range estimates, determined by convex polygons, shows that results of Reinert and Zappalorti (1988) were very similar to my results for only gravid females. My home range estimates for gravid females was 8.5 and average of home range areas in Reinert and Zapplorti (1988) were 9.9 ha. Reinert and Zapplorti (1988) showed average home range areas of 17.2 ha for nongravid females, nearly half of my home range estimate for nongravid females. However, when my data is viewed by year for each nongravid female, the 2 estimates appear much more similar. One of the nongravid females on my study area ranged throughout 40.8 ha compared to 21.6 for the other nongravid female. Data from my study, and from other studies mentioned for comparison, were consistent with conclusions of Brown et al. (1982) regarding nongravid and gravid females; Brown et al. (1982) concluded that nongravid females moved farther than gravid females. Data reported by Reinert and Zapplaorti (1988) for males averaged 48.6 ha, while male rattlesnakes in my study occupied an average home range size of 94.3 ha. Differences in results among studies may be reflected in the size and ages of the study specimens. Reinert and

Zappalorti (1988) concluded that home range sizes for male rattlesnakes was correlated with the extent of the monitoring period, but the correlation was not shown for females. Henceforth, I omitted study specimens from home range analyses with less than 12 locations. Three male rattlesnakes were omitted from home range estimates and distance calculations because of early mortality and few locations.

Brown (1993) reported mean maximum distances of 4.07 km for males and 2.05 km for females from a study. Martin (1992) reported a maximum distance of 6 km traveled by a timber rattlesnake from a den site in Virginia, and Martin reported distances from dens between 1.0 and 1.3 km from den sites for all age and sex classes. The maximum known distance of a male rattlesnake from a den site was 3621.7 m the maximum known distance from a den site for a nongravid female rattlesnake was 1120.9 m. Mean maximum distances of timber rattlesnakes in my study averaged 1110.2 m among study specimens in all sex classes, 1881.0 m for males, 869.6 m for nongravid females, and 579.9 m for gravid females. Clearly, my results did not approach the maximum distances reported for some of the aforementioned studies. My results were probably limited by equipment failures (i.e., transmitter failures and broken antennas).

My results of mean distances from den sites were very similar to results of other studies. Brown et al. (1982) found mean dispersal distance of 504 m. The distance from the den in my results averaged 514.2 m among study specimens in all sex classes. Reinert and Rupert (1999) documented daily movement rates in Pennsylvania and the results were 36.9 m, males; 24.6 m, nongravid females; 9.6 m, gravid females. My results were 36.1 m for males, 13.8 m for nongravid females, and 10.8 m for gravid females, and the average daily movement rate among sex classes was 20.2 m. My results for nongravid females appear low due to one female with a daily movement rate of 6.3 m in 2002. The female was in summer range for an extended time (until 10 November). Excepting that female, the daily movement rate for nongravid females was 17.6 m, which is more representative when compared to results of other studies. Because I captured the gravid females while in summer range, my calculations for daily movement rates of gravid females assumes the emergence date (15 May) and a straight line distance traveled from the den site to the first location. Therefore, distances for gravid females represent minimum distances traveled. Reinert and Rupert (1999) documented total distances moved and the results showed 5575 m, males; 3611 m, nongravid females; 1574 m, gravid females. Total distances moved in my study were 4727.3 m, males; 2265.6 m, nongravid females; 1565.9 m, gravid females and the average among sex classes was 2582.9 m. Reinert and Rupert (1999) reported a higher total distance moved for males and nongravid females. My results of total distance moved for gravid females is consistent with all the aforementioned studies that have shown the propensity of gravid females to stay within close proximity to the den site and to remain sedentary.

Brown et al. 1982 reported the use of the same migratory routes during ingress and egress. I observed the same behavior in all of my study specimens. Brown et al. (1982) speculated that land forms at and near dens affected migration pathways. In contrast, at den sites with multiple study specimens, rattlesnakes in my study used unique migratory pathways. The rattlesnakes in my study showed the same behavior as rattlesnakes in the study of Reinert and Zappalorti (1988) in 2 respects. Reinert and Zappalorti (1988) established that rattlesnakes moved in a "looping pattern" from and to the den site, and second, that timber rattlesnakes sometimes returned to the same hibernaculum (previously discussed). Timber rattlesnakes in my study employed the same looping pattern and 2 rattlesnakes returned to the same hibernaculum. The looping pattern exhibited during seasonal migrations was unique to each rattlesnake and each rattlesnake monitored for more than one season showed consistent patterns.

Brown (1992) formally introduced the concept of "transient habitat" which I previously discussed relative to my study. I noted that not all timber rattlesnakes in my study stopped over at bask sites. I did, however, notice habitat that I considered transient, based on Brown's (1992) definition of transient habitat in which he included habitat close to the den site or otherwise within an arbitrarily close distance of the den. Given resemblances of migratory patterns to loops (Reinert and Zappalorti 1988), consider for a moment a teardrop-shaped loop. For the rattlesnakes in my study, the transient habitat was best described as the small end of the teardrop-shaped loop. One nongravid female in my study particularly exemplifies this arbitrary scenario. The female did not stop over at particular bask sites, but rather would stop over at slash piles and other areas suitable basking areas while migrating from the den site to summer range. The summer range used by that female was clearly the large, round part of the teardrop-shaped loop. Such behavior demonstrates the importance of recognizing particular habitat areas for timber rattlesnakes.

Habitat Use by Stand Type

Timber rattlesnakes probably use clearcuts within their home ranges without discretion, especially if suitable bask sites are limited within their established home ranges. The summer range of one rattlesnake in my study encompassed a regenerating cove hardwood stand, and the rattlesnake was located within the clearcut through 2 consecutive years of studying the snake while in summer range. The rattlesnake also moved into an adjacent area that was clearcut earlier in the concurrent season. I suspect that stand use is a function of pre-established home range, meaning that timber rattlesnakes do not change their home ranges following clearcuts.

Herpetofauna response to silvicultural prescriptions in an Appalachian hardwoods forest (Adams et al. 1996) showed a positive response of reptiles to timber harvesting. Adams et al. (1996) found decreases in canopy closure and increases in woody debris, which may have provided cover for reptiles and their prey items. Similarly, timber rattlesnakes might experience positive effects in terms of increased availability of prey items, along with suitable cover for thermoregulating in clearcuts.

Phenology

<u>Active Season</u>

Mean active season in my study was 5.4 months (based on a 31-day month) or 167.3 days. The active season documented in my study is longer than the active season documented in West Virginia by Martin (2002). Martin (2002) documented a median active season of 4.7 months for individuals and 5.0 for the population at a High Allegheny den site. Martin’s den sites occurred on Allegheny Front ridge tops at a higher elevation, which may contribute to the shorter active season. Brown (1992) documented 4.6-month active season, although he concluded a possible active season of 192 days, which surpasses the length of active season length that I documented. Although the active seasons that I reported could have been over represented in the late season, my methods probably under represented the active season length during the early season.

Egress

The reasons for my observations of ontogenetic differences during egress are uncertain. Perhaps the earlier emergence allows the large, adult males extended foraging periods prior to breeding season, given their needs of ample fat reserves for mate-searching and male-male combat. On 28 April 2002, 2 large males were located outside the den area 624.3 and 278.0 m from their specific hibernacula. The male that was located 6234.3 m from the hibernacula during 2002 was located at the hibernacula on 29 April 2001. Rudolph et al. (1998) noted that New Jersey implanted rattlesnakes emerged earlier and basked more than rattlesnakes without implants.

Rattlesnakes in my study were noted moving inside hibernacula, presumably basking during periods of advantageous weather. Underground movements of male implanted timber rattlesnakes were recorded as early as 5 April for males and 1 May for females. Although it is difficult to draw conclusions based on sounds and locations of telemetry signals underground, it is evidence that is consistent with Martin's conclusions (1992*a*) of sporadic basking from late March to mid-April. Additionally, I observed an injured rattlesnake basking during the first week of April.

Ingress

I observed ontogenetic differences during ingress. Post-gravid females returned to dens earlier than other rattlesnakes; post-gravid females returned to dens on 18 September and 22 September. Nongravid females and males returned to den sites by the end of September. I observed 2 exceptions: first, I previously discussed (in Cause-Specific Mortality) the extended active season of one female; and second, one male rattlesnake returned to the bask site adjacent to the den site area on 10 October, and moved into the den site area on 23 October. The rattlesnake was implanted late in the season, and thus I excluded the specimen from this discussion because the later ingress date was probably due to the late season implant. The female that was in summer range later than other rattlesnakes (until mortality on 10 November) may be explained by follicular yolking as discussed by Brown (1995). Without the two exceptions, activity continued until the third week of October. During the last weeks of activity, rattlesnakes moved among hibernacula, presumably taking advantage of periods of warm weather on the surface.

Temperatures

Temperatures in this publication were reported for Elkins, West Virginia. Temperatures for Elkins, West Virginia are warmer than temperatures on the study area because of elevation differences. Climatic data sets for Pickens, Randolph County, West Virginia might have been more representative of the study area due to similarities in elevation and position on Rich Mountain. However, climatic data sets for Pickens were incomplete.

Galligan and Dunson (1979) suggested that snake emergence was not cued entirely by temperature although they did recognized an effect of temperature on emergence. They found no relationships between air temperature and soil temperature, and no direct relationship between temperatures and emergence. Brown (1992) documented temperatures of ingress and egress and showed associations with maximums and minimums of 15 ^{o}C and 5 ^{o}C, respectively. Martin (1992*a*) suggests an association of egress with the 12 ^{o}C isotherm. Average monthly normals during egress in my study were 9.4 ^{o}C in April and 14.4 ^{o}C in May. Average monthly normals during ingress in my study were 16.7 ^{o}C in September and 10.3 ^{o}C in October. Temperatures on my study areas support Martin's (1992*a*) conclusion that ingress and egress occur with the passing of the 12 ^{o}C.

Reproduction

Authors report variations in times and places of matings (Aldridge and Brown1995; Brown 1995; Green and Pauley 1987; Martin 1992*a*, 1992b; Rudolph and Burgdorf 1997). I did not observe or confirm copulating pairs, but I did observe male-female pairings associated with 3 female rattlesnakes. I observed one female that attracted 2 males during the 2001 active season: one on 6 August and one on 31 August. I observed a telemetered male and telemetered female under a rock at a bask site adjacent to a den site are on 14 June where they remained for several days. I was unable to confirm copulation, but I concluded that no successful copulation occurred based on subsequent behaviors of the female. My third observation involved the same male discussed in the previous sentence, where the male was located with a female on 2 August at a bask site. The rattlesnakes were not copulating, and the female was captured and surgically implanted. Following her release, the 2 rattlesnakes remained at the same site and in the immediate presence of one another for about one and one-half weeks. The female thereafter moved to a rookery site nearby. The female remained very sedentary, was extremely secretive, and remained at the site until 22 September. I did not observe a litter with the rattlesnake.

CHAPTER VII

CONCLUSIONS

Den sites were associated with southern exposures and chestnut oak stands at lower elevations and mixed northern hardwood stands at higher elevations. Plants, such as common greenbrier *(S. rotundifolia)*, may provide protection to rattlesnakes from predators. More extensive studies of plant communities at den sites should be conducted. Timber rattlesnakes show an affinity for particular basking crevices and hibernacula at den sites, the latter of which supports conclusions of Reinert and Zappalorti (1988).

My results negate the practice of implanting rattlesnakes after 1 August, supporting conclusions of Rudolph et al. (1998) who advise against implanting timber rattlesnakes after 1 September. Caution should be applied in implanting rattlesnakes early in the season in the High Alleghenies. Timber rattlesnakes with extended active seasons may be at a higher risk of predation.

Rookery and bask sites were associated with forest and log road edges as well as log landings. Ultimately, rookery and bask sites were associated with areas of anthropogenic activity mimicking natural edges. Despite the presumed availability of anthropogenic edges, in areas where rookery and bask sites are lacking, it is probably feasible to create and manage for rookery and bask sites.

Female timber rattlesnakes may select for particular rookery sites that differ from bask sites. Studies should be conducted to quantify and determine potential differences in rookery and bask sites. The availability of bask site locations may be limited for females due to smaller home ranges. Male timber rattlesnakes from different overwinter dens used common bask sites.

Vehicles are an important source of mortality that should be considered and managed for on West Virginia forests. Studies (Rudolph et al. 1998) documenting the decline of timber rattlesnake populations with the development of "road networks and associated vehicular traffic" further illustrate the need to be consider and manage road access on West Virginia forests. Results of road kill surveys should be interpreted with caution because of the propensity of rattlesnakes to move off the road following vehicle-induced injuries and for the likelihood of mortalities to be delayed.

My results of home range sizes, distance measures, movements, and behaviors support conclusions of other studies in the northeast. Males moved through larger home ranges compared to nongravid females, which moved through larger home ranges compared to nongravid females. Similarly, males moved greater total distances, showed greater maximum known distances from den sites, and higher average distances from den sites than nongravid females; nongravid females moved more, migrated farther from den sites, and showed higher average distances from den sites than gravid females. Rattlesnakes monitored for more than one active season used the same migration pathway through transient range into summer range, and migration pathways were unique for each rattlesnake.

Timber rattlesnakes might use any age forest stands within the confines of established home ranges. Although this study did not test for the effects of silvicultural treatments on the home ranges of timber rattlesnakes, qualitative evidence shows that home ranges were not affected. Furthermore, timber rattlesnakes may benefit from clearcuts within their home ranges.

Egress spanned an average of 15 days from the end of April to mid-May. Large, adult males emerge earlier than females and moved into transient range upon emergence. Post-gravid females returned to den sites before nongravid females and males during ingress.

Overall, my results of home range and behavior of *C. horridus* on production forests were consistent with other studies in the northeast. My results indicate the need to limit traffic on forests with *C. horridus* populations. Studies should further examine mortality factors of *C. horridus* populations in the northeast and predator-prey relationships involving *C. horridus*.

CHAPTER VIII

CONSERVATION OF *CROTALUS HORRIDUS* IN WEST VIRGINIA

Introduction

In this chapter, I discuss distribution, conservation, and management of *C. horridus* in West Virginia. More specifically, this chapter briefly reviews historic and current distribution of *C. horridus* in West Virginia, discusses current conservation and management regimes, and establishes the need for more stringent conservation and management strategies of *C. horridus* in West Virginia. Information presented in this chapter is a result of my studies, interviews, and investigations of *C. horridus* in West Virginia. Additionally, other authors are cited as well, particularly in the case of conservation and management plans.

Human Component

Prior to addressing distribution, conservation, and management issues, it is important for biologists and managers to consider the human component associated with *C. horridus*. The human component must be addressed in order to understand the difficulties in managing *C. horridus* and to establish the necessity of implementing and enforcing more stringent conservation and management regimes.

People of West Virginia, as well as people of Appalachia, have many attitudes about *C. horridus.* People revere *C. horridus* for religious purposes; hunt and kill *C. horridus* for sport, hides, and trophies; value *C. horridus* economically for pet collecting and trading; and fear unexpected encounters with *C. horridus*. Some people simply have an ophidiophobic attitude. Perhaps the common denominator to all the aforementioned attitudes is awe: people awe at *C. horridus*. Whether the attitude is reverence, sporting, economic, or even fear, awe of this species has provoked human attitudes throughout history. Thus, *C. horridus* has become a part of Appalachian cultural heritage, including West Virginian cultural heritage, and *C. horridus* conservation and management includes an important human component.

Distribution in West Virginia

Although West Virginia forests are expansive and potential timber rattlesnake habitat is plentiful, reports continue to document population declines in West Virginia (Adams and Pauley 2002, Green and Pauley 1987, Martin et al. 2000). While it is reasonable to expect that *C. horridus* historically occurred in all West Virginia counties, historic distribution is difficult to prove. Proof sources, such as archived newspaper articles, include anecdotal stories without clear locations. Perhaps the best evidence of historic locations is from historic accounts of West Virginia, and it is difficult to search such a wide scope of information for anecdotal information relating to *C. horridus*. Nonetheless, studies concur that a range contraction has occurred due to anthropogenic activities, although the extent of the range contraction remains unclear due to ambiguous knowledge of historic range. The range contraction is represented by the change in status, as the species was formerly ranked S5 (i.e., demonstrably secure) in West Virginia, compared to the current S4 rank (i.e., with some risk for extirpation).

Sources of Wanton and Unnecessary Killings

<u>Loggers and Road Construction Workers</u>

Loggers and road construction workers are widely known for killing timber rattlesnakes, although such a statement should not include all persons in these professions. These killings are especially a problem for construction projects establishing new roads in forested areas, such as forest roads and new highways. Stories abound of loggers who have killed dozens of rattlesnakes in one day, and road construction workers who were fearful of stepping off their dozers due to the presence of so many rattlesnakes. Without doubt, one could understand the initial fearful responses of loggers and construction workers to timber rattlesnakes. Those workers are often in situations conducive to unexpected encounters resulting in potential snakebites.

It seems that one of 3 attitudes about timber rattlesnakes result. First, some loggers and construction workers do not worry about what they do not know and do not see. Second, for some, I believe that the initial fearful responses develop into ophidiophobic tendencies, resulting in wantonly and unnecessarily killing every rattlesnake they see. Third, some loggers and road construction workers are hunters and collectors of timber rattlesnakes, opportunistically capturing or killing every timber rattlesnake they see. Additionally, loggers occasionally serve as guides for out-of-state hunters and collectors.

Hunters and Collectors

Hunters and collectors from bordering states hunt and collect rattlesnakes in West Virginia. Advertisements in outdoor magazines (Outdoor Times 2000) solicit guides and display the willingness of collectors to pay for wild caught timber rattlesnakes. The article referenced in this document seeks a guide in West Virginia or Virginia and expresses a willingness to pay on a per snake basis. The phone number provided is an Ohio phone number. Regulations in Ohio, in combination with limited extant population of *C. horridus* in Ohio (Wynn 2000), probably force hunters to West Virginia. The same situation must apply to the numerous reports of snake hunters from Pennsylvania frequenting Cooper's Rock State Park. Without doubt, in-state hunters and collectors negatively affect populations and habitat as well, and are often the location source for out-of-state hunters and collectors. Numerous reports describe snake hunters leaving state-owned properties with bags of rattlesnakes, and reports further describe hunters and collectors who sell West Virginia rattlesnakes to out-of-state buyers. Hunting and collecting rattlesnakes without regulations can ultimately cause habitat degradation and extirpation. A Pendleton County logger and snake hunter shared den and basking site locations with out-of-state snake hunters from New York. Thereafter, the den and basking areas were heavily hunted by the out-of-state hunters. Consequently, populations were either extirpated or nearly extirpated and that habitat was degraded (D. Garst, Personal Communication). Unverified report of snake hunters and collectors spraying gasoline in hibernacula and other specific habitat types further exemplify this problem.

A practice commonly reported concerns people collecting and holding timber rattlesnakes as short-term pets. These amateurs rarely have an interest in timber rattlesnakes other than entertainment and undoubtedly have no biological understanding of the species. They frequently hold timber rattlesnakes in poorly constructed or dirty cages without food and water. They release timber rattlesnakes outside their home ranges, negatively affecting their abilities to find their respective hibernacula, especially in the case of neonates born in captivity. Thus, local populations could be drastically impacted by these activities.

Clearly, the lack of regulations in West Virginia as well as the lack of enforcement of existing regulations, especially on state and federal properties, allows snake hunters from other states to illegally hunt and collect timber rattlesnakes in West Virginia without negative consequences. Moreover, West Virginia's lackadaisical approach to hunting and collecting *C. horridus* on state and federal properties enables the violations of state and federal regulations.

<u>ATVs</u>

All terrain vehicles (ATVs) increase the available access that persons have to trails previously traveled only by foot and horses. Increased access to trails results in increased access to rookeries and bask sites at road edges, in turn resulting in increased human predation on timber rattlesnakes. In one report I documented an ATV driver killing 8-10 timber rattlesnakes basking on a rock. The persecuted rattlesnakes included several gravid females (J. Adams, Unpublished Data) and may have been the year's production for the population. Clearly, the timber rattlesnakes were opportunistically and unnecessarily killed because an ATV user had increased access to trails.

<u>Government Employees</u>

While many managers of Wildlife Management Areas (WMAs), state parks, and state forests promote species conservation and enforce laws and regulations on their management areas, some managers either hunt or wantonly kill the species themselves. During interviews, several managers expressed a lack of knowledge about regulations protecting *C. horridus* on state parks and forests. One manager allowed out-of-state hunters to collect *C. horridus* on his park.

<u>Citizens</u>

Who wants a timber rattlesnake living in their back yards or under their front porches? Nobody does. Nobody wants their children or pets threatened by venomous snakes. Henceforth, every day citizens kill rattlesnakes in order to protect themselves, their families, and their pets from snakebites.

Crotalus horridus management on private properties depends on attitudes of landowners about *C. horridus.* Interestingly, people seem to express more concern about *C. horridus* than *Agkistrodon contortrix mokasen*; people simply associate fears and myths to *C. horridus* that they do not associate with *A. c. mokasen.* Some people base their fears on previous encounters with timber rattlesnakes, but mostly concerns of landowners are not validated and have no scientific basis.

Conservation and Management

Shading over of Dens

Brown (1993) reported that overwinter den sites may become shaded over, but Martin (Brown 1993) discounted the importance of overshading of den sites. Martin's opinions were based on facts that trees are not fully leafed out during egress and leaf fall has begun during ingress. My studies showed that timber rattlesnakes spent such an insignificant amount of their active season on the surface at den sites, indicating that canopy closure may not be important at overwinter den sites. Any importance may be advantageous to timber rattlesnakes on the surface at den sites in terms of protection and cover from avian predators. Stechert (Brown 1993) discussed the possibility of leaf litter blocking hibernacula entrances. I, in contrast, believe that leaf litter may offer some protection to rattlesnakes basking at den sites. Wynn (2000) suggested that crevices at den sites in Ohio might become filled with sediment. I have not observed this problem at my den sites.

Doug Wynn (2000) reported problems due to amateur herpetologists in southeastern Ohio. Amateur herpetologists read reports of overshading of den sites and felled saplings at overwinter den sites. While their intention was to improve habitat, there was no scientific basis for the activities and the activities were conducted without permission. Furthermore, the amateur herpetologists made the sites more visible and thus more available to hunters and collectors. In West Virginia, amateur herpetologists are particularly a problem at rookeries and bask sites. Several amateur herpetologists frequent areas with snake hooks and bags. While their claims include photography and viewing, the snake hooks and bags indicate bothersome disturbance to the rattlesnakes. Actions of amateur herpetologists negatively affect populations because they lack an understanding of the biology of the species. I have documented numerous reports of herpetologists taking *C. horridus* to laboratories for parturition. Even when neonates are subsequently released, their abilities to find overwinter den sites are probably adversely affected. Such activities exemplify the disturbance and impact caused to West Virginia populations by amateur herpetologists. These activities lack scientific basis or expertise and pose disease threats to the wild populations after being exposed to pathogens and parasites in captivity.

Property Management

Managers of public and private parks and forests maintain wildlife clearings by mowing or otherwise maintaining an early stage of succession. Stumps, slash piles, and rock slabs in and at edges of wildlife clearings provide rookery and bask sites for rattlesnakes, and such habitat is not only plentiful but also used by timber rattlesnakes, particularly on WMAs (Adams, Unpublished Data). Because timber rattlesnakes use the rookery and bask sites during summer months, it is important to adjust management regimes to avoid adverse impacts to timber rattlesnakes using the rookery and bask sites. Wynn (2000) suggested mowing during fall months in Ohio to avoid disturbance to timber rattlesnakes using bask sites. The management practice of mowing during fall months is recommended for other species as well. Thus, mowing during fall months could easily be implemented on WMAs, parks, and forests to benefit multiple wildlife species.

Diseases

Wynn (2000) addressed the potential for the spread of diseases through equipment, with particular concern for potential spread of disease by amateur herpetologists. Whether participating in educational activities or catching and releasing snakes for personal entertainment, the potential for the spread of disease exists and is thus a valid point of concern raised by Wynn (2000). Many people often capture and keep timber rattlesnakes as temporary pets or trophies, then return them to the wild. Such temporary captures are potential portals for diseases and parasites to wild populations. For instance, mites are common parasites among captive snakes that are often overlooked by amateur herpetologists (D. Sagan, Personal Communication).

Species Management

Management in West Virginia

Crotalus horridus has been considered a predatory species and some still consider it a nuisance species. Historically, the Conservation Commission of West Virginia defined snakes as predatory reptiles. Predatory reptiles, among other predatory animals, were destroyed in order to maintain populations of game species, particularly game birds. These attempted eradications of predatory species were accomplished via game wardens and sportsmen's groups. Although reptiles were not always counted and listed, reports listed predatory reptiles during the early 1930s when sportsmen's groups sponsored contests for which prizes were awarded for destroying predatory species. Reports listed numbers of predator species killed, where rattlesnakes, water snakes, black snakes, and copperheads were listed collectively as one group. Reports showed that snakes accounted for more than half of the total number of species killed during 1938 and 1939. Obviously, people perceived snakes as nuisances and pests, and that attitude perpetuated eradication attempts and contributed to the ophidiophobic attitudes toward all snakes, especially timber rattlesnakes.

Currently, regulations regarding *C. horridus* possession limits and takings from state and federal properties are not enforced. State and federal properties should be occasionally patrolled for snake hunters. Current regulations allow collecting of timber rattlesnakes for purposes that are not scientific. Without regulations prohibiting collecting regardless of purpose, existing regulations, albeit lax, remain difficult to enforce.

State Properties and Federal Properties

Educational signs should be erected on all properties owned or managed by the state. The signs should inform the public of regulations regarding taking species (i.e., both plant and animal species) from state-owned and state-managed properties without permits. Such signs either should specifically recognize *C. horridus* or separate signs educating the public about *C. horridus* should be erected.

Crotalus horridus should be listed as a sensitive species on the George Washington National Forest. Increased development in the area, new highways, and purchases of weekend and summer properties by people from out-of-state landowners increasingly encroach upon habitat and place *C. horridus* at increased risk of human-induced mortality while in summer range.

Roads to known den sites, rookery sites, and bask sites should be closed to vehicles including ATVs during the active season.

State and federal employees, as well as county and city workers where applicable, should be educated about all aspects of ecology, conservation and management, and laws and regulations regarding *C. horridus*. Because state and federal conservation officers are often the first persons called about nuisance wildlife species, conservation officers should be among the first to be educated.

<u>Private Properties</u>

Managing *C. horridus* on private properties is difficult because managing *C. horridus* is dependent on private landowners. The most successful management regimes on private properties would involve private landowners with large tracts of land and landowners who have dens on their properties. Large tracts of land would be more likely to provide all habitat types utilized by timber rattlesnakes, and therefore would be most conducive to conservation because all habitat types could be managed and potentially protected. Landowners with specific habitat areas on their properties, such as den sites, could protect the habitat. However, in the case with landowners who own small tracts of land, protecting overwinter den sites might not always be an effective management plan. For example, one private landowner owns property in northeastern West Virginia with a large, extensive overwinter den on the site. The landowners do not persecute the rattlesnakes and rarely even kill a snake in their yard. However, when the rattlesnakes migrate into summer range, many experience mortality crossing the road and many are reportedly killed on a neighbor's property at a bask site (Adams, Unpublished Data). Therefore, management plans would be most effective with landowners who own large tracts of land with all specific types of habitat used by timber rattlesnakes.

County and City Properties

A gap exists among federal, state, and private properties, where potential for conservation and management failures occurs within this gap. County- and city-owned properties should be treated as state properties with educational signs and enforcement of regulations. While many county and city properties exclude forested habitat, many parks occur in areas that may be suitable basking habitat, or simply may lie within the home range of timber rattlesnakes. The greatest positive impact would be the increased number of people that would be reached by signs and educational information.

Public Education

Although public education is always important, it is difficult to change deeply entrenched feelings about species, and it is more difficult to change a thread of cultural heritage. State park and forest personnel should educate the public about timber rattlesnakes. Education should continue through lectures and question-answer sessions at state functions organized by the West Virginia Wildlife Diversity Program. Education would be very useful in terms of preventative measures, such as “what not to do when you see a snake” with grade school children, at county fairs, and through 4-H groups. Whether adults or children, all are citizens and citizens use public properties. Thus, it is most reasonable to focus education on public properties and at public functions.

Wildlife Agents and Animal Nuisance Control Personnel

With increased development of rural areas, the potential exists for increasing timber rattlesnake mortalities from nuisance purposes. Thus, licensed wildlife damage agents should be required to submit specific locations of timber rattlesnake removals/exterminations along with actual specimens. All specimens should be weighed, measured, and assessed for general health, and biological data should be collected.

Locating Den, Rookery, and Bask Sites

Efforts should be made to locate overwinter den sites, particularly on government properties and in counties where no confirmed sites exist. Rookery and bask sites should also be located near confirmed den sites. Den, rookery, and bask sites should be monitored, particularly on state and federal properties. However, only the strictest procedures should be employed in monitoring sites with minimal disturbance.

Secrecy of Locations

Maintaining secrecy of locations is of utmost importance, and is discussed by Brown (1993) in a conservation and management plans. There are inherent problems in maintaining secrecy. First, contracts and research projects completed for state and federal agencies require the submission of location information. The information then becomes available to the public. State and federal agencies do require requests for data, but the data is ultimately available. Knowledge of locations is not held sacred by all employees and locations travel by word of mouth. A website exists to provide specific locations of den sites and to provide directions for finding the den sites. Such websites illustrates the need for utmost secrecy of locations, as well as the need for strict regulations.

Permit System

In West Virginia, a permit system would regulate in-state hunters and eliminate out-of-state hunters. Permits could be purchased from the West Virginia Division of Natural Resources, Wildlife Resources Section, allowing West Virginia hunters to take a limited and enforced number of specimens within certain lengths, and taken within set seasons. Most importantly, a permit system would facilitate protection by enforcement of regulations.

Research

Research needs to establish unknown responses of *C. horridus* to mining activities and silvicultural prescriptions. Most studies have focused home range studies on adults, leaving home range sizes and behaviors of subadults and juveniles to be examined.

LITERATURE CITED

Abbott Laboratories. 2004. Online information. http://www.abbottanimalhealth.com/ane_sevoflo.html. Abbott Park, Illinois, USA. Accessed 18 July 2005.

Adams, J. P. 2005. *Crotalus horridus* on private properties in West Virginia. Unpublished data submitted to the West Virginia Division of Natural Resources, Wildlife Resources Division, Wildlife Diversity Program, Elkins, WV, USA.

Adams, J. P. and T. K. Pauley. 2003. Distribution of *Crotalus horridus* in West Virginia. Unpublished data submitted to the West Virginia Division of Natural Resources, Wildlife Resources Division, Wildlife Diversity Program, Elkins, WV, USA.

Adams, J. P. and T. K. Pauley. 2002. Range of *Crotalus horridus*. Unpublished report to the West Virginia Division of Natural Resources, Wildlife Resources Division, Wildlife Diversity Program, Elkins, WV, USA.

Adams, Jennifer P., Michael J. Lacki, and Michael D. Baker. 1996. Response of Herpetofauna to Silvicultural Prescriptions in the Daniel Boone National Forest, Kentucky. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 50:312-320.

Aldridge, R. D. and W. S. Brown. 1995. Male reproductive cycle, age at maturity, and cost of reproduction in the timber rattlesnake (*Crotalus horridus*). Journal of Herpetology 29(3):399-407.

Brown, W. S. 1995. Heterosexual groups and the mating season in a northern population of timber rattlesnakes, *Crotalus horridus*. Herpetological Natural History 3(2):128-133.

Brown, W. S. 1993. Biology, Status, and Management of the Timber Rattlesnake (*Crotalus horridus*): A guide for Conservation. Society for the Study of Amphibians and Reptiles. Herpetlogica Circular 22:1-78.

Brown, W. S. 1992. Emergence, ingress, and seasonal captures at dens of northern timber rattlesnakes, *Crotalus horridus*. *In*: Biology of the Pitvipers. J. A. Campbell, J. A. and E. D. Brodie, Jr. (editors). Selva, Tyler, TX, USA.

Brown, W. S. 1991. Female reproductive ecology in a northern population of the timber rattlesnake, *Crotalus horridus*. Herpetologica 47(1):101-115.

Brown, W. S. 1982. Overwintering body temperatures of timber rattlesnakes (*Crotalus horridus*) in northeastern New York. Journal of Herpetology 16:145-150.

Brown, W. S., V. P. J. Gannon, and D. M. Secoy. 1984. Paint-marking the rattle of rattlesnakes. Herpetological Review 15:75-76.

Brown, W. S, E. Possardt, W. H. Martin, J. Sealy, editors. 2000. Conservation action plan for upland populations of the timber rattlesnake (*Crotalus horridus*). Draft.

Brown, W. S. and F. M. MacLean. 1983. Conspecific scent-trailing by newborn timber rattlesnakes, *Crotalus horridus*. Herpetologica 39(4):430-436.

Brown, W. S. D. W. Pyle, K. R. Greene, and J. B. Friedlaender. 1982. Movements and Temperature Relationships of Timber Rattlesnakes (*Crotalus horridus*) in Northeastern New York. Journal of Herpetology 16(2):151-161.

Bushar, L. M., H. K. Reinert, and L. Gelbert. 1998. Genetic Variation and Gene Flow with and between Local populations of the timber rattlesnake, *Crotalus horridus*. Copeia (2):411-422.

Campbell, J. A. and E. D. Brodie (editors). 1992. Biology of the Pitvipers. Selva, Tyler, TX, USA.

Cavanaugh, C. J. 1994. Longevity. Herpetological Review 25(2):70.

Chiszar, D., D. W. Radcliffe, and K. M. Scudder. 1977. Analysis of the behavioral sequence emitted by rattlesnakes during feeding episodes. Behavioral Biology 1977(21):418-425.

Clark, W. C. 2002. Diet of the timber rattlesnake, *Crotalus horridus*. Journal of Herpetology 36(3):494-499.

Conant, R. and J. T. Collins. 1998. A Guide to Reptiles and Amphibians of Eastern and Central North America, 4th edition. Peterson, R. T. (editor). Houghton Mifflin Company, New York, NY, USA.

Core, E. L. 1966. Vegetation of West Virginia. McClain Printing Company, Parsons, WV, USA.

Durner, G. M. and J. E. Gates 1993. Spatial ecology of black rat snakes on Remington Farms, Maryland. Journal of Wildlife Management 57(4):812-826.

Environmental Systems Research Institute (ESRI). 1996. Using ArcView GIS. Environmental Systems Research Institute, Inc. Redlands, CA, USA.

Galligan, J. H. and W. A. Dunson. 1979. Biology and status of timber rattlesnake (*Crotalus horridus*) populations in Pennsylvania. Biological Conservation (15)13-58.

Green, N. B. and T. K. Pauley. 1987. Amphibians and Reptiles in West Virginia. University of Pittsburgh Press, Pittsburgh, PA, USA.

Gregory, P. T. 1984. Communal denning in snakes. *In*: Vertebrate Ecology and Systematics—At Tribute to Henry S. Fitch: 57-75. Seigel, R. A., L. E. Hunt, J. L. Knight, L. Malaret, and N. L. Zuschiag (editors). Museum of Natural History, The University of Kansas, Lawrence, KS, USA.

Gregory, P. T., J. M. MacArtney, and K. W. Larsen. 1987. Spatial patterns and movements. *In*: Snakes: Ecology and Evolutionary Biology. Seigel, R. A., J. T. Collins, and S. S. Nova (editors). MacMillan Publishing Company. New York, NY, USA.

Hackenbrock, C. R. and M. Finster. 1963. Fluothane: a rapid and safe inhalation anesthetic for poisonous snakes. Copeia 1963:440-441.

Hardy, Sr., D. L., and H. W. Greene. 2000. Inhalations anesthesia of rattlesnakes in the field for processing and transmitter implantation. Sonoran Herpetologist. 13:110-114.

Hardy, Sr., D. L., H. W. Greene, and C. S. Rau. 2001. Anesthesia and surgical techniques for radio-telemetry in rattlesnakes. SEASERG & SARC Productions. Portal, AZ, USA.

Hardy, Sr., D. L., and H. W. Greene. 1999. Surgery on rattlesnakes in the field for implantation of transmitters. Sonoran Herpetologist 12:26-28.

Jenrich, R. I. and F. B. Turner. 1969. Measurement of non-circular home range. Journal of Theoretical Biology 22:227-237.

Keenlyne, K. D. 1972. Sexual differences in feeding habits of *Crotalus horridus horridus*. Journal of Herpetology 6(3-4):234-237.

Martin, W. H. 2002. Life History constraints on the timber rattlesnake (*Crotalus horridus*) at its climatic limits. *In*: Biology of the Vipers. Schuett, G. W., M. Hoggren, M. E. Douglas and H. W. Greene (editors). Eagle Mountain Publishing, LC. Eagle Mountain, UT, USA.

Martin, W. H. 2000. Biology and Ecological Requirements. *In*: Conservation action plan for upland populations of the timber rattlesnake (*Crotalus horridus*) (Draft). Brown, W., E. Possardt, W. H. Martin, J. Sealy (editors).

Martin, W. H. 1996. Reproductive phenology. Herpetological Review 27(3):144-145.

Martin, W. H. 1995. Growth and reproduction in montane populations of the timber rattlesnake (*Crotalus horridus*). Proceedings from the North Carolina Herpetological Society (NCHS) Fall Conference and General Meeting. *In*: The North Carolina Herpetological Society Newsletter, January 1995.

Martin, W. H. 1993. Reproduction of the timber rattlesnake (*Crotalus horridus*) in the Appalachian Mountains. Journal of Herpetology 27(2):133-143.

Martin, W. H. 1992*a*. Phenology of the timber rattlesnake (*Crotalus horridus*) in an unglaciated section of the Appalachian Mountains. *In*: Biology of the Pitvipers. Campbell, J. A. and E. D. Brodie, Jr. (editors) Selva, Tyler, TX, USA.

Martin, W. H. 1992*b*. The timber rattlesnake: its distribution and natural history. *In*: Conservation of the timber rattlesnake in the northeast. Tyning, T. F. (editor). Massachusetts Audubon Society, Lincoln, MA, USA.

Martin, W. H. 1986. Unpublished report to West Virginia Division of Natural Resources, Wildlife Resources Section, Elkins, WV.

Martin, W. H., J. P. Adams, J. Wykle, C. Waggy, S. Blackburn, S. Butterworth. 2000**.** The timber rattlesnake in West Virginia. In: Conservation action plan for upland populations of the timber rattlesnake (*Crotalus horridus*) (draft). Brown, W., E. Possardt, W. H. Martin, J. Sealy (editors).

MeadWestvaco Corporation (MeadWestvaco Corp.). 2005. Online information. http://www.meadwestvaco.com/forestry.nsf/vDES/E2449D60E1DE26D385256DAB0071F8CA?OpenDocument. Accessed 17 June 2005.

MeadWestvaco Wildlife and Ecosystem Research Forest (MWWERF). 2005. Online Data, GIS Data. http://www.mwerf.org. Accessed 27 June 2005.

Noon, B. R. 1981. Techniques for sampling avian habitats. *In*: The use of multivariate statistics in studies of wildlife habitat. Editor: D. E. Capen. 42-52 USDA. Forest Service General Technical Report 87.

Northeast Regional Climate Center (NRCC). 2004. Online Data. Comparative Climatic Data for the United States. Cornell University, Ithaca, NY, USA.

National Weather Service Forecast Office (NWSFO). 2005. Online Data. http://www.erh.noaa.gov/rlx/. Accessed 5 August 2005.

Outdoor Times Magazine. 2000. Sportsmen's Bulletin Board Classified Advertisements. April Issue: 5(4). Altoona, PA, USA.

Pyle, R. E., W. W. Beverage, T. Yoakum, D. P. Amick, W. F. Hatfield, and D. E. McKinney. 1982. Soil Survey of Randolph County Area, Main Part, West Virginia. United States Department of Agriculture Soil Conservation Service and Forest Service.

Reinert, H. K. 1992. Radiotelemetric studies of Pitvipers. *In*: Biology of the Pitvipers. Campbell, J. A. and E. D. Brodie, Jr. (editors). Selva, Tyler, TX, USA.

Reinert, H. K. 1990. A profile and impact assessment of organized rattlesnake hunts in Pennsylvania. Journal of the Pennsylvania Academy of Science 64(3):136-144.

Reinert, H. K. 1984*a*. Habitat variation within sympatric snake populations. Ecology 65(5):1673-1682.

Reinert, H. K. 1984*b*. Habitat separation between sympatric snake populations. Ecology 65(2):478-486.

Reinert, H. K. and D. Cundall. 1982. An improved surgical implantation method for radio-tracking snakes. Copeia 1982(3):702-705.

Reinert, H. K. and R. R. Rupert. 1999. Impacts of translocation on behavior and survival of timber rattlesnakes, *Crotalus horridus*. Journal of Herpetology 33(1):45-61.

Reinert, H. K., D. Cundall, and L. M. Bushar. 1984. Foraging behavior of the timber rattlesnake, *Crotalus horridus*. Copeia (4)976-981.

Reinert, H. K. and R. T. Zappalorti. 1988. Timber rattlesnakes (*Crotalus horridus*) of the Pine Barrens: their movement patterns and habitat preferences. Copeia 1988:964-978.

Rodgers, A. R. and A. P. Carr. 1998. HRE: the home range extension for ArcView. Users Manual. Ontario Ministry of Natural Resources. Thunder Bay, ON, Canada.

Rose, B. 1982. Lizard home ranges: methodology and functions. Journal of Herpetology 16:253-269.

Rudolph, D. C. and S. J. Burgdorf. 1997. Timber Rattlesnakes and Louisiana Pine Snakes of the West Gulf Coastal Plain: Hypotheses of Decline. Texas Journal of Science 49(3) Supplement:111-122.

Rudolph, D. C., S. J. Burgdorf, R. N. Conner, and J. G. Dickson. 1998. The impact of roads on the timber rattlesnake, (*Crotalus horridus*), in eastern Texas. Proceedings of the International Conference on Wildlife Ecology and Transportation. 1998:236-240.

Rudolph, D. C., S. J. Burgdorf, R. D. Schaeffer, R. N. Conner, and R. T. Zappalorti. 1998. Snake mortality associated with late season radio-transmitter implantation. Herpetological Review 29(3):155-156.

Savage, T. 1967. Diet of rattlesnakes and copperheads in the Great Smoky Mountains National Park. Copeia 1967(1):226-227.

Scudder, K. M., D. Chiszar, H. M. Smith. 1992. Strike-induced chemosensory searching and trailing behaviour in neonatal rattlesnakes. Animal Behavior 1992(44):574-576.

Smyth, T. 1949. Notes on the timber rattlesnake at Mountain Lake, Virginia. Copeia 1949(1):78.

Society of American Foresters (SAF). 1980. Forest Cover Types of the United States and Canada. Erye, F. H. (editor). Washington, DC, USA.

Soil Science Society of America (SSSA). 1996. Glossary of Soil Science Terms. Madison, WI, USA.

Stephenson, S. L. 1993. Upland Forests of West Virginia. McClain Printing Co., Parsons, WV, USA.

Strausbaugh, P.D. and E.L. Core. 1978. Flora of West Virginia, 2nd edition. Seneca Books, Inc. Morgantown, WV, USA.

Tyning, T. F. (editor). 1991. Conservation of the Timber Rattlesnake in the northeast. Massachusetts Audubon Society. Lincoln, MA, USA.

Uhler, F. M. C. Cottam, and T. E. Clarke. 1939. Food of snakes of the George Washington National Forest, Virginia. Transactions of the Fourth North American Wildlife Conference:605-622.

United States Forest Service (USFS). 2000. Regional Forester Sensitive Animals. http://www.fs.fed.us/r9/wildlife/tes/tes_lists.htm. Accessed 17 June 2005.

United States Geological Survey (USGS). 1977. Adolph Quadrangle, West Virginia—Randolph County. 7.5-minute series (topographic) map. NE/4 Pickens 15' Quadrangle. N3837.5-W8000/7.5. AMS 4961 II NE—Series V854.

United States Geological Survey (USGS). 1969. Junior Quadrangle, West Virginia—Randolph County. 7.5 minutes series (topographic) map. NW/4 Elkins 15' Quadrangle. N3852.5-W7952.5/7.5. AMS 5061 IV NW—Series V854.

Villarreal, X., J. Bricker, H. K. Reinert, L. Gelbert, and L.M. Bushar. 1996. Isolation and characterization of microsatellite loci for use in population genetic analysis in the timber rattlesnake. The Journal of Heredity 87(2): 152-155

West Virginia Division of Natural Resources, Wildlife Diversity Program (WVWDP). 2005. http://www.wvdnr.gov/Wildlife/RareSpecList.shtm. Accessed 17 June 2005.

West Virginia Geologic and Economic Survey (WVGES). 1969. Geologic Map of West Virginia. MAP-25. Mont Chateau Research Center, Morgantown, WV, USA.

West Virginia GIS Technical Center (WVGISTC). 2005. http://wvgis.wvu.edu//data/data.php?mapinterface=1. Accessed 25 June 2005.

Wynn, D. 2000. Timber rattlesnake: Ohio conservation plan. Ohio Division of Wildlife, Wildlife Management and Research Group. Columbus, OH, USA.

APPENDIX I

FIGURES

Figure 1. Distribution of *Crotalus horridus* in the United States depicting eastern, western, and southern variations (Martin 1992*b*).

Figure 2. *Crotalus horridus* distribution in West Virginia represented by counties in yellow.

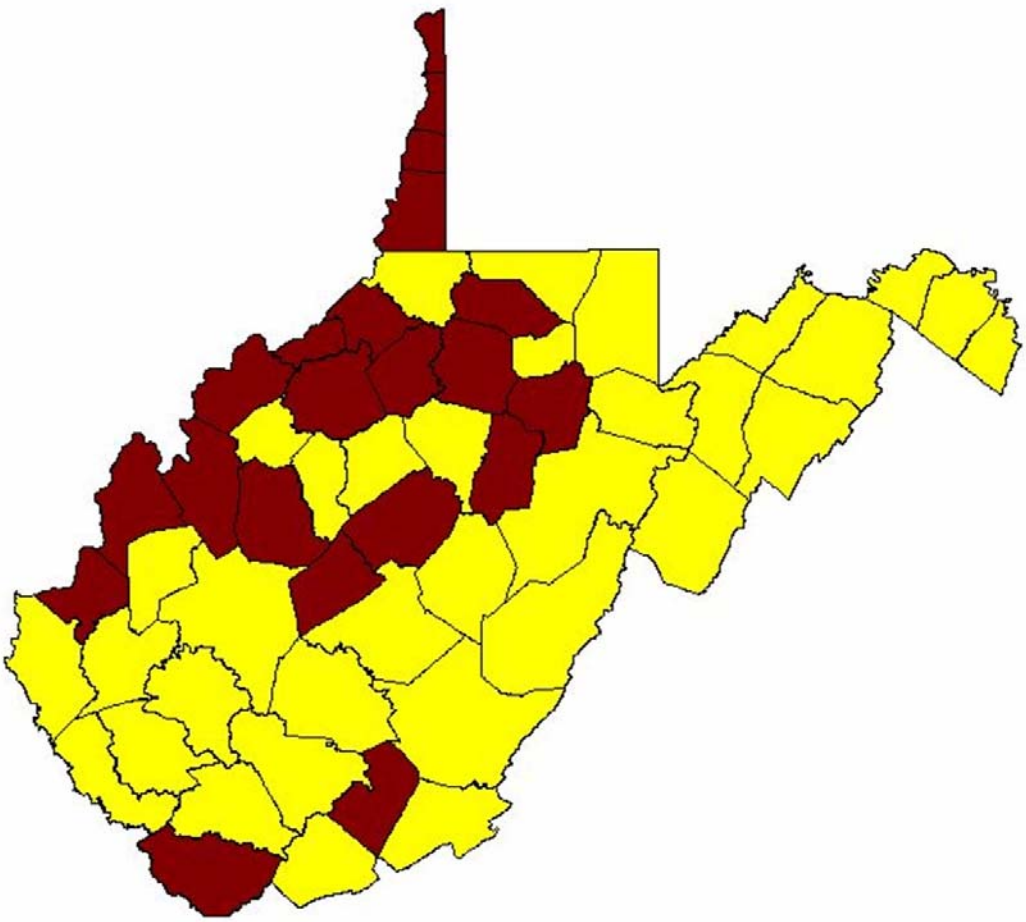

Figure 3. Map of West Virginia counties (WVGISTC 2005) illustrating locations of study areas in Randolph County, West Virginia.

Figure 4. Map of West Virginia illustrating 3 major physiographic provinces of West Virginia.

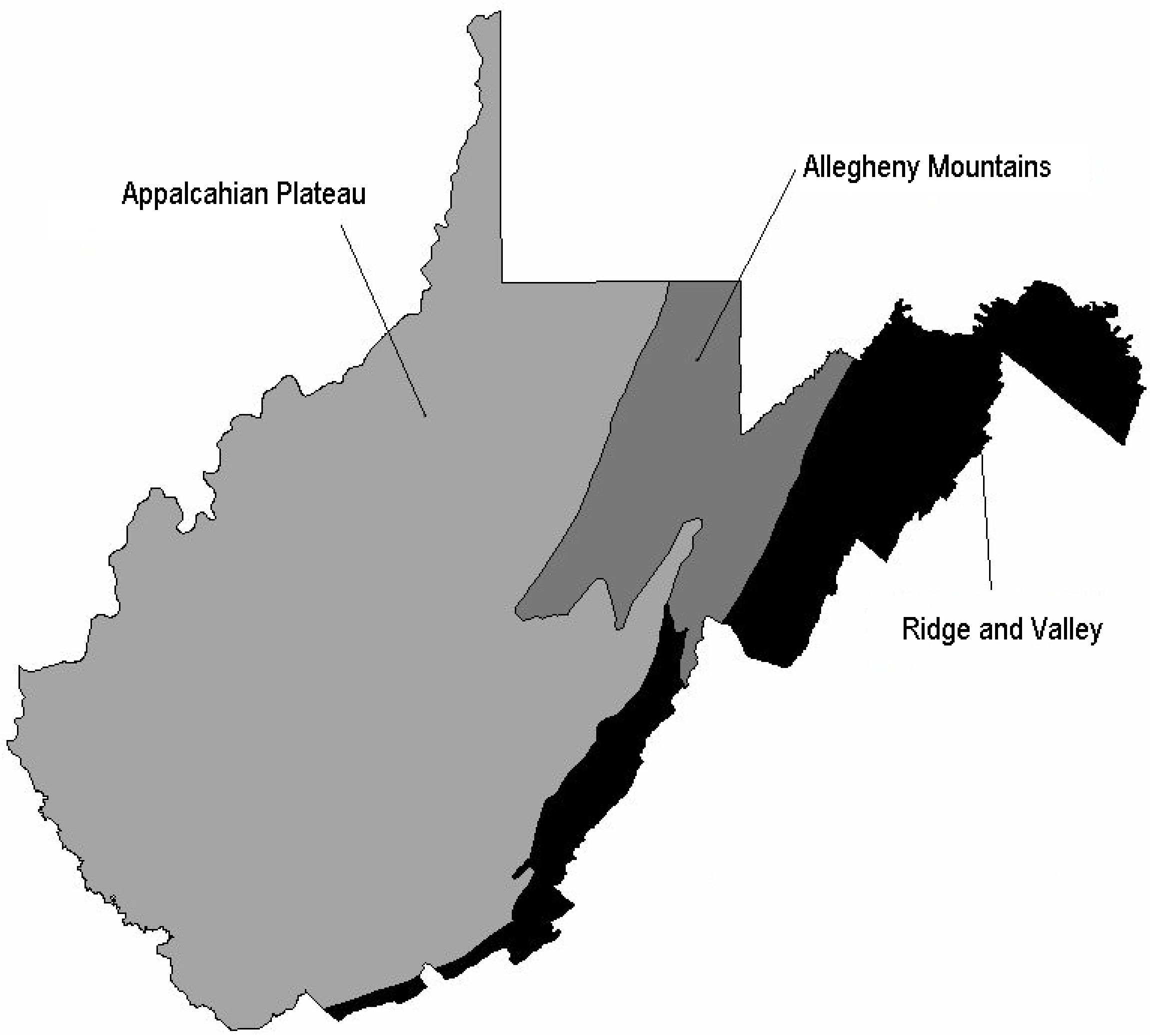

Figure 5. Physiographic map of West Virginia showing the position of the state relative to regional physiographic features.

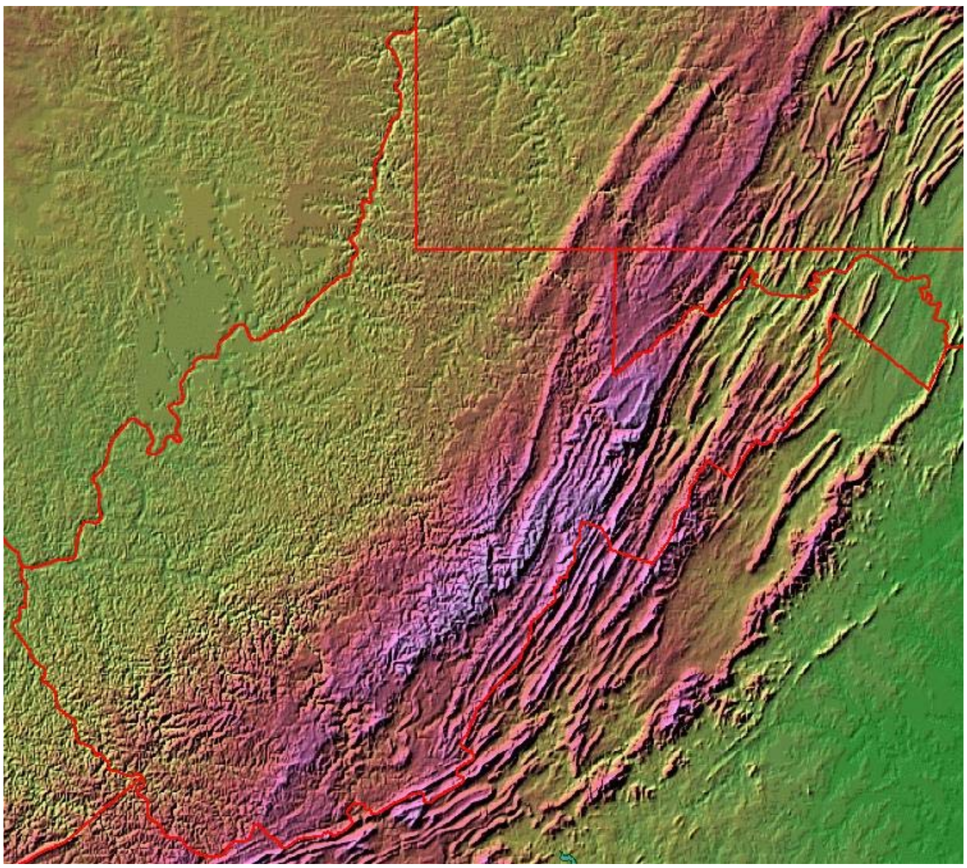

Figure 6. Rattle tags made with unique combinations of colors and shapes, pierced through the rattle with plastic-coated fishing wire, and affixed with clamped fishing weights.

Figure 7. Anesthesia box used for initial delivery of inhalation anesthesia via a hose from the anesthesia machine to the anesthesia box.

Figure 8. Restraining tubes used in combination with a connection hose from an anesthesia machine for delivery of concentrated inhalation anesthesia to rattlesnakes.

APPENDIX II

TABLES

Table 1. Climatic data sets for Elkins, Randolph County, West Virginia (NRCC 2004).

Climatic Data Set	Total Years	Data Years	Annual Average
Average Snowfall (cm)	34	through 1998	197.4
Average Relative Humidity (%)	35	through 1998	87 morning
			59 afternoon
Average Wind Speed (mph)	27	through 1998	6.0
Possible Sunshine (%)	11	through 1998	40
Highest Temperature (^{o}F)	54	through 1998	99
Lowest Temperature (^{o}F)	54	through 1998	-24
Days with Precipitation	54	through 1998	172
Normal Precipitation (cm)	30	1961-1990	113.9
Minimum Temperature <32 ^{o}F (mean number of days)	54	through 1998	144
Maximum Temperature >90 ^{o}F (mean number of days)	54	through 1998	2
Normal Daily Minimum Temperature (^{o}F)	30	1961-1990	37.0
Normal Daily Maximum Temperature (^{o}F)	30	1961-1990	61.2
Cloudiness (mean number of days)	49	unknown	48, clear
			103, partly cloudy
			212, cloudy
Maximum Wind Speed (mph)	15	through 1998	55, 250’

Table 2. Den name, study area, and site-specific lithology at overwinter den sites on the RCHC and WERF in Randolph County, West Virginia.

Name	Study Area	Lithology
LH	WERF	Quartz arenite, course grained, slightly conglomeratic
RR	WERF	Lithic arenite, medium grained
KC	WERF	Lithic sandstone with horizontal laminations, fine-medium grained
RKS	RCHC	Quartz arenite, medium grained
RDG	RCHC	Quartz arenite, medium grained
LB	RCHC	Quartz arenite, medium-coarse grained

Table 3. Den name, study area, slope, aspect, and elevation of overwinter den sites on the RCHC and the WERF in Randolph County, West Virginia.

Name	Study Area	Slope	Aspect	Elevation (m)
LH	WERF	46	192	950.4
RR	WERF	36	248	996.4
KC	WERF	42	166	1006.1
RKS	RCHC	20	215	961.6
RDG	RCHC	56	214	983.9
LB	RCHC	14	202	429.5

Table 4. Den name and study area, forest cover type, basal area per hectare, and stem density per hectare at overwinter den sites on the RCHC and the WERF in Randolph County, West Virginia.

Name	Study Area	Forest Cover Type	Basal Area (m^2)	Stem Density
LH	WERF	Mixed Northern hardwood	34.8	28,500
RR	WERF	Red Maple (SAF)	8.0	81,250
KC	WERF	Black Cherry-Maple (SAF)	31.2	34,250
RKS	RCHC	Chestnut Oak (SAF)	13.5	10,000
RDG	RCHC	Chestnut Oak (SAF)	26.7	6,750
LB	RCHC	Chestnut Oak (SAF)	31.9	7,250

Table 5. Den name and percentages of moss, rock, bare ground, leaf litter, woody debris, and lichens from square meter plots recorded at 6 den sites on the RCHC and the WERF in Randolph County, West Virginia.

Den	Moss	Rock	Bare Ground	Leaf Litter	Woody Debris	Lichen
LH	18.0	14.0	72.5	88.75	16.25	0
RR	0.5	0	99.25	48.74	5	0.25
KC	0	2.5	88.75	93.75	17.5	0
RKS	15.5	40	58.75	83.75	30	0.5
RDG	12.5	33.75	66.25	66.25	5.5	11.25
LB	5	15	83.25	78.75	11.5	10

Table 6. Den name and percentages (based on 400% possible cover) of deciduous cover, evergreen cover, ground cover, and woody debris recorded in 0.04 ha plots at 6 den sites on the RCHC and the WERF in Randolph County, West Virginia.

Den	Deciduous Cover	Evergreen Cover	Ground Cover	Woody Debris
RDG	360	40	20	80
RKS	380	0	100	60
LB	80	15	40	80
RR	55	300	120	40
KC	75	15	300	100
LH	340	20	80	140

Table 7. Rattlesnake identification numbers (#), sex (M, male; F, nongravid female; $F_{(g)}$, gravid female), and cause-specific mortality for timber rattlesnakes monitored on the RCHC and the WERF in Randolph County, West Virginia.

#	Sex	Study Area	Mortality Cause
A534-1	F	WERF	Avian Predation
A355-1	$F_{(g)}$	WERF	Post Partum Condition
A685-1	F	WERF	Vehicle-Induced
A263-2	F	WERF	Mammalian Predation
A402-1	F	WERF	Mammalian Predation
A263-2	M	WERF	Transmitter-Induced
A704-1	M	WERF	Transmitter-Induced
A613-1	M	WERF	Transmitter-Induced
A303-1	M	WERF	Unknown Cause
A876-1	M	WERF	Vehicular-Induced
A473-1	M	WERF	Mammalian Predation
A402-2	$F_{(g)}$	WERF	Transmitter-Induced
C704-2	M	RCHC	Vehicle-Induced

Table 8. Rattlesnake identification numbers (#), sex (M, male; F, nongravid female; $F_{(g)}$, gravid female), year(s) of monitoring, extent of active seasons that rattlesnakes were monitored, numbers of locations, and home range estimates for timber rattlesnakes on the WERF in Randolph County, West Virginia.

#	Sex	Year	Extent of Active Season Monitored	Number of Locations	Home Range (ha)
A534-1	F	2001	full	18	21.5
A534-1	F	2002	full	27	9.9
A534-1	F	2001, 2002	combined	44	21.6
A685-1	F	2001	full	15	40.8
A355-1	$F_{(g)}$	2001	partial	31	6.3
A402-2	$F_{(g)}$	2001	partial	12	10.7
A454-1	M	2001	partial	22	34.6
A454-1	M	2002	full	24	120.2
A454-1	M	2001, 2002	combined	45	157.1
A613-1	M	2001	partial	14	226.2
A303-1	M	2001	full	22	68.7
A303-1	M	2002	full	20	80.9
A303-1	M	2001, 2002	combined	41	95.6
A263-2	M	2001	partial	5	35.2
A704-1	M	2001	partial	11	3.4

Table 9. Rattlesnake identification numbers (#), sex, monitoring year, daily movement rate (DMR), maximum known distance from den (MXD), date of maximum known distance (MXD), mean distance from den (MND), and total distance moved (TD) for male (M), nongravid female (F), and gravid female ($F_{(g)}$) rattlesnakes on the WERF in Randolph County, West Virginia.

#	Sex	Year	DMR (m)	MXD (m)	Date of MXD	MND (m)	TD (m)
A263-2	M	2001	-	1845.0	31 Aug.	885.7	2016.7
A613-1	M	2001	-	3621.7	11 Sept.	1813.4	6802.6
A303-1	M	2001	32.1	1251.8	31 Aug.	499.4	5331.3
A303-1	M	2002	37.9	1709.1	27 June	701.4	5642.4
A454-1	M	2001	-	1054.5	22 July	411.3	2151.6
A454-1	M	2002	38.2	1803.8	1 July	822.8	6419.4
A685-1	F	2001	18.4	1120.9	6 Aug.	461.3	3017.5
A534-1	F	2001	16.7	869.6	5 Sept.	498.1	2651.0
A534-1	F	2002	6.3	618.2	22 Sept.	380.4	1128.4
A402-2	$F_{(g)}$	2001	12.1	832.1	5, 8 Sept.	203.8	1787.6
A355-1	$F_{(g)}$	2001	9.5	327.7	31 Aug. - 21 Sept.	276.6	1344.1

Table 10. Averages of daily movement rate (DMR), maximum distance from den (MXD), mean distance from den (MND), total distance moved (TD), and home range estimates for males (Males), nongravid females (Females), gravid females (Females $_{(g)}$), and averages among sex classes for rattlesnakes monitored on the WERF in Randolph County, West Virginia.

Sex	DMR (m)	MXD (m)	MND (m)	TD (m)	Home Range (ha)
Males	36.1	1881.0	855.7	4727.3	94.3
Females	13.8	869.6	446.6	2265.6	31.2
Females $_{(g)}$	10.8	579.9	240.2	1565.9	8.5
Average	20.2	1110.2	514.2	2852.9	44.7

Table 11. Rattlesnake identification numbers (#), sex (M, Male; F, nongravid female; $F_{(g)}$, gravid female) and numbers of locations at road/edge locations and in clearcut (CC) and mature forests (MF) of cove, mountain, and upland hardwoods for surgically implanted rattlesnakes on the RCHC and the WERF in Randolph County, West Virginia.

#	Sex	Road / Edge	COVE CC	COVE MF	MOUNTAIN CC	MOUNTAIN MF	UPLAND CC	UPLAND MF	Total
A534-1	F	0	15	18	1	3	0	8	44
A685-1	F	0	0	8	1	6	0	0	15
A355-1	$F_{(g)}$	23	0	0	0	1	0	6	30
A402-2	$F_{(g)}$	2	0	0	1	0	0	9	12
A454-1	M	10	0	4	1	30	0	0	45
A613-1	M	0	0	0	1	8	0	5	14
A263-2	M	0	0	1	1	0	0	3	5
A704-1	M	0	0	0	0	11	0	0	11
A303-1	M	6	0	2	0	13	1	19	41
C034-1	M	2	0	0	0	1	1	2	6
C685-1	M	1	0	0	0	2	1	3	7
C704-1	M	1	0	0	0	5	0	1	7
C755-1	M	3	0	0	0	2	0	0	5
A263-1	F	0	0	0	0	1	0	1	2*
A402-1	F	0	0	0	0	1	0	1	2*
A876-1	M	0	0	0	0	0	0	0	3*
A473-1	M	0	0	0	0	0	0	0	4*

*Represents timber rattlesnakes that experienced mortality while healing from surgical procedures.

Table 12. Rattlesnake identification numbers, sex (M, male; F, nongravid female; $F_{(g)}$, gravid female), year of monitoring, first known active dates, last known active dates, and total active days for surgically implanted rattlesnakes on the RCHC and the WERF in Randolph County, West Virginia.

#	Sex	Year	First Known Active Date	Last Known Active Date	Total Known Active Days
A303-1	M	2001	29 April		166
A303-1	M	2002	28 April		169
A454-1	M	2001	-	22 October	-
A454-1	M	2002	28 April	13 October	168
A685-1	F	2001	11 May	22 October	164
A685-1	F	2002	15 May	-	-
A534-1	F	2001	6 May	12 October	159
A534-1	F	2002	16 May	3 November	178
A402-1	F	2001	6 May	-	-
A263-1	F	2001	11 May	-	-
A355-1	$F_{(g)}$	2001	-	23 October	-
A613-1	M	2001	-	12 October	-
A263-2	M	2001	-	23 October	-
A704-1	M	2001	-	22 October	-
A402-2	$F_{(g)}$	2001	-	10 October	-

APPENDIX III

CURRICULUM VITAE

Education

Master of Science, Biology

August 2005
Marshall University
Department of Biological Science
Huntington, WV
Thesis topic: Home Range and Behavior of Timber Rattlesnakes

Bachelor of Science, Agriculture

May 2001
University of Kentucky
College of Agriculture
Lexington, KY
Minors: Plant & Soil Science; Biology

Instructional Experience

Wildlife Management Instructor
Sept. 2003 – present
Hocking College
School of Natural Resources
Nelsonville, OH
Accomplishments and Primary Duties:

- Develop courses and laboratory exercises for the Wildlife Management program
- Develop general courses for the School of Natural Resources
- Teach Wildlife Management courses and general courses for the School of Natural Resources
- Serve as an academic advisor
- Serve as a faculty advisor for the Student Chapter of the Wildlife Society

Associated Research Experience

Field Biologist
Environmental Solutions & Innovations, L.L.C.
Cincinnati, OH
May 1998 – present
Primary Duties:

- Conduct biological surveys for threatened and endangered bat species

Associated Research Experience (continued)

Research Associate
Dr. Thomas K. Pauley
Marshall University
Department of Biological Science
Huntington, WV
Oct. 2002 – June 2003
Primary Duties:

- Gathered, compiled, and analyzed data to complete a statewide range map of timber rattlesnake locations using ArcView GIS and described specific habitat types used by timber rattlesnakes
- Communicated with researchers, educators, government agencies, private landholders, and citizens to collect information from surveys, projects, locations, reported sightings, and documentations in databases regarding timber rattlesnakes in West Virginia

Specific Projects:

- Timber rattlesnake *(Crotalus horridus)* dens in West Virginia
- Timber rattlesnake *(Crotalus horridus)* range in West Virginia

Graduate Student / Field Assistant
May 2001-May 2003
Marshall University
Department of Biological Sciences
Huntington, WV
Primary Duties:

- Cooperated with private lands managers to secure research equipment, establish study areas, and develop research plans for the timber rattlesnake *(Crotalus horridus)*

Specific Project:

- Home Range and Behavior of Timber Rattlesnakes

Wildlife Research Technician
Oct. 1999-Oct. 2002
West Virginia Division of Natural Resources
Wildlife Resources Section
Elkins, WV
Accomplishments and Primary Duties:

- Completed research duties associated with the obligations of the West Virginia Division of Natural Resources Wildlife Resources Section to the Appalachian Cooperative Grouse Research Project including but not limited to trapping, banding, and affixing transmitters to ruffed grouse; radio-tracking; investigating mortalities
- Presented information to sportsmen's clubs and organizations and communicated with the public

Specific Project:

- Ruffed Grouse *(Bonasa umbellus*), Appalachian Cooperative Grouse Research Project

Associated Research Experience (continued)

Field Biologist
June 1999 - September 1999
James Kiser
Appalachian Technical Services, Inc.
Whitesburg, KY
Primary Duties:
- Conducted mist net surveys for threatened and endangered bat species

Specific Project:
- A Mist Net Survey for the federally endangered Indiana Bat in the Monongahela National Forest, WV

Student Research Assistant
January 1996 - April 1996
Dr. Paul Kalisz
University of Kentucky
Department of Forestry
Lexington, KY
Primary Duties:
- Sampled and identified soil invertebrates including native earthworms
- Sampled vegetation and identified plants

Specific project:
- Distribution of native earthworms in five states on the Cumberland Plateau

Student Research Assistant / Technician
August 1995-August 1997
Dr. Michael J. Lacki
University of Kentucky
Department of Forestry
Lexington, KY
Primary Duties:
- Conducted mist net surveys for bats
- Identified and preserved small mammal and herpetofauna specimens

Specific Projects:
- Home range of Rafinesque’s big-eared bats
- Home range and roost site selection of red bats
- Bat surveys of gorges in Elliott Co., KY
- The response of herpetofauna to silvicultural prescriptions in the Daniel Boone National Forest, KY
- The response of small mammals to silvicultural prescriptions in the Daniel Boone National Forest, KY

Independent Research Experience

Overwinter Dens Locations and Habitat Characteristics of the Timber Rattlesnake (*Crotalus horridus)* on Private Lands in West Virginia

- March 2004-January 2005
- Funded by the West Virginia Division of Natural Resources, Wildlife Diversity Program Grant for submission to the U.S. Fish & Wildlife Service

Locations of Overwinter Dens, Rookeries, and Summer Range of the Timber Rattlesnake (*Crotalus horridus)* in West Virginia

- March 2002-present

Grants and Contracts Received

West Virginia Division of Natural Resources, Wildlife Diversity Program Grant
Home Range and Behavior of the Timber Rattlesnake (*Crotalus horridus)*

- Awarded March 2001
- $4,040

West Virginia Division of Natural Resources, Wildlife Diversity Program Grant
Home Range and Behavior of the Timber Rattlesnake (*Crotalus horridus)*

- Awarded March 2002
- $8,400

West Virginia Division of Natural Resources, Wildlife Diversity Program Contract
Range of *Crotalus horridus* in West Virginia

- Contracted October 2002
- $4,000

West Virginia Division of Natural Resources, Wildlife Diversity Program Contract
Distribution of *Crotalus horridus* in West Virginia

- Contracted January 2003
- $4,000

West Virginia Division of Natural Resources, Wildlife Diversity Program Contract
Overwinter Dens Locations and Habitat Characteristics of the Timber Rattlesnake (*Crotalus horridus)* on Private Lands in West Virginia

- Awarded March 2004
- $7,500

Publications

Adams, Jennifer P. and Thomas K. Pauley. 2002. Historic and current range of *Crotalus horridus*. Unpublished report to the West Virginia Division of Natural Resources, Wildlife Resources Division, Wildlife Diversity Program.

Adams, Jennifer. 2001. Timber Rattlesnakes Misunderstood. In: The Ridgerunner: A newsletter for members and friends of hunt clubs leasing Westvaco land. Volume 2, Issue 1, Fall 2001. Westvaco Forestry Resources Division, Rupert, WV.

Adams, Jennifer P., Michael J. Lacki, and Michael D. Baker. 1996. Response of Herpetofauna to Silvicultural Prescriptions in the Daniel Boone National Forest, Kentucky. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 50:312-320.

Martin, W.H., Jennifer P. Adams, Chuck Waggy, Scott Blackburn, Scott Butterworth, and Jennifer Wykle. 2000. The Timber Rattlesnake in West Virginia. In: Conservation action plan for upland populations of the timber rattlesnake (*Crotalus horridus*). Draft. Editors: W. Brown, E. Possardt, W. H. Martin, J. Sealy.

Kiser, James D., Jennifer P. Adams, Robert R. Kiser, and Mark. W. Gumbert. 1999. A mist net survey for the Federally Endangered Indiana Bat (*Myotis sodalis*) in Six Focus Areas on the Monongahela National Forest, West Virginia. Prepared for the USDA-Forest Service Monongahela National Forest, Elkins, WV.

Professional Presentations

Timber Rattlesnakes. Annual Meeting of the WV Division of Natural Resources, Wildlife Resources Section. Canaan Valley, WV. September 2002.

Home Range and Behavior of Timber Rattlesnakes. MeadWestvaco Corporation Annual Research Meeting. Charleston, WV. January 2002.

Home Range and Behavior of Timber Rattlesnakes. Westvaco Corporation Annual Research Meeting. Morgantown, WV. March 2001.

The Response of Herpetofauna to Silvicultural Prescriptions in the Daniel Boone National Forest, KY. Southeast Association of Fish & Wildlife Agencies Annual Meeting. Hot Springs, AK. October 1996.