Volume 71, Number 2

WVAS
West Virginia
ACADEMY of SCIENCE
Founded 1924

Proceedings Of the West Virginia Academy of Science

1999

Submitted Papers of the Seventy-Fourth Annual Session

WVAS
West Virginia
ACADEMY of SCIENCE
Founded 1924

Member
American Association for the Advancement of Science

Proceedings of the West Virginia Academy of Science 1999

Vol. 71 No. 2
SUBMITTED PAPERS OF THE SEVENTY-FOURTH ANNUAL SESSION

National Conservation Training Center
Shepherdstown, WV
April 10, 1999

Printed by
Ralston Press
November 2006

West Virginia Academy of Science, Inc.

The West Virginia Academy of Science was founded at Morgantown, November 28, 1924. The Academy was incorporated under the Code of West Virginia on May 9, 1959 as a "nonstock corporation, which is not organized for profit but for the advancement of learning and scientific knowledge."

Officers 1999

Dues Structure

Student	$7.50
Regular	$15.00
Contributing	$30.00
Sustaining	$60.00
Life	$150.00
Corporation	$200.00 min.
Institutional	$200.00 min.
Patron	$1,000.00

Institutional Members

University of Charleston
Fairmont State College
West Virginia Institute of Technology
West Virginia University
Concord College
Marshall University
West Virginia State College
West Virginia Wesleyan College

Published as a peer reviewed journal at the West Virginia Academy of Science, Inc. Manuscripts for publication should be sent to the editor, Dr. John Warner, Box 129, West Virginia Wesleyan, Buckhannon, WV 26201. Manuscripts must be sent electronically (email or compact disk) in Microsoft WORD to **warner@wvwc.edu**. Three hardcopies should also be sent to the address above. Proofs, edited manuscripts, and all correspondence regarding papers for publication should be directed to the editor. For additional information call 304-472-1907.

Application for membership in the Academy and dues should be sent to Dr. Roger Seeber, Box 139, West Liberty State College, West Liberty, WV, 26074. Changes of address should be sent to Dr. Seeber. Correspondence concerning library exchanges should be directed to Director of Libraries, West Virginia University, Morgantown, WV 26506.

TABLE OF CONTENTS

A NEW LIZARD SPECIES, *CNEMIDOPHORUS SEXLINEATUS*, IN WEST VIRGINIA

W. JEFFREY HUMPHRIES[1] and ZACHARY I. FELIX[1], W. H. MARTIN[2], and THOMAS K. PAULEY[1*], [1]Department of Biological Sciences, Marshall University, Huntington, West Virginia 25755; [2]Rt. 3, Box 804, Harpers Ferry, West Virginia 25425. * Corresponding author, Office: (304) 696-2376, Fax: (304) 696-3243, Email: pauley@marshall.edu

ABSTRACT

We report a new lizard species, the eastern six-lined racerunner (*Cnemidophorus sexlineatus sexlineatus*), in West Virginia. During the summer of 1999, two specimens were collected in Morgan County along the CSX railroad bordering the Potomac River. Searches of other areas throughout the eastern panhandle of West Virginia failed to document additional populations of this species. Although racerunners may have always existed in West Virginia, we suggest that this lizard has recently invaded West Virginia by dispersing along railroad tracks. Further studies throughout the eastern panhandle and southeastern counties are necessary to determine the actual distribution of this species in West Virginia.

INTRODUCTION

The eastern six-lined racerunner, *Cnemidophorus sexlineatus sexlineatus*, is distributed from Maryland to the Florida Keys and west to Missouri and eastern Texas (Conant and Collins, 1998). Racerunners inhabit hot, open, xeric areas of fields, forests, rocky outcrops, dunes, road embankments, and railroad cuts. These are active lizards, maintaining very high body temperatures and sustaining activity only during the warmest months of the year (Mitchell, 1994; Ransom and Plummer,1999). Racerunners are known from neighboring Virginia and Maryland and were listed by Green and Pauley (1987) as a species likely to occur in West Virginia, but not officially reported as a member of West Virginia's herpetofauna. One of the authors, W.H. Martin, observed this species at the Randolph Tunnel in Morgan County on 26 May 1991 but did not collect a voucher or publish his observation. We validate the presence of this species in West Virginia and report the results of surveys in areas for this species.

MATERIALS AND METHODS

Surveys were concentrated along a section of the CSX railroad near Randolph Tunnel in Morgan County. Visual surveys were conducted along railroad embankments during the hottest part (1300 h DST) of the day. Lizards were collected by stunning them with rubber bands and catching them by hand. Two individuals were killed with the rubber bands and fixed in 10 % formalin and later stored in 70 % ethanol and deposited in the West Virginia Biological Survey collections at Marshall University (WV Scientific Collecting Permit 47-199). Stomachs were opened and prey contents examined under a dissecting microscope (20X). Subsequent searches were conducted along railroad tracks and shale barrens within 10 miles east and west of Randolph Tunnel. Other areas searched included the ridge of North Fork Mountain near Cabins in Pendleton County, and Tuckahoe Tunnel of the CSX railroad along the Virginia border in Greenbrier County. Air temperature (°C) at each site was measured with a Reotemp thermometer. Coordinates were obtained with a hand-held GPS unit and with USGS topographical maps. Additional characterization of the habitat included identification of the dominant plant species (Strausbaugh and Core, 1977).

RESULTS

Racerunners were observed at only one location in West Virginia. On 27 July 1999 at 1450 h, twelve adults were observed near the southwest entrance of the Randolph Tunnel along the CSX railroad, approximately 3.0 km southwest of Doe Gully, Morgan County (39°35'56" N, 78°23'89" W). Two individuals were collected and placed in the West Virginia Biological Survey collection at Marshall University (WVBS #12080-81). This population appears to be restricted to a shale outcrop and the surrounding shrubs less than 10 m from the railroad track. The outcrop has been blasted out on all sides and stands approximately 8.5 m high. Racerunners were only observed within an area 20 x 60 m in size. The lizards were extremely active, basking in direct sun and escaping capture by darting into the surrounding vegetation. Air temperatures ranged from 34° C in the shade to 38° C in the sun. The vegetation at this site was dominated by young black locust (*Robinia psuedoacacia*) trees, and included ash (*Fraxinus*), hawthorn (*Cretaegus*), and staghorn sumac (*Rhus typhina*). Ground cover included poison ivy (*Toxicodendron radicans*), various grasses, wild carrot (*Daucus carota*), spotted knapweed (*Centaurea maculosa*), ragweed (*Ambosia artemisifolia*), *Rubus,* and Virginia creeper (*Parthenocissus quinquefolia*).

Both individuals collected were non-gravid females. Measurements were as follows (refers to specimens #12080 and 12081 respectively): total length = 171 mm and 97 mm; snout to vent length = 65 mm and 63 mm; tail length = 106 mm (second specimen lost tail); tail length as percent of total length = 62.0%; ventral plates in midventral row = 34 and 30; dorsal granular scale count around midbody = 80 and 78; femoral pores = 29 and 25; number of lamellae on right fourth toe = 28 and 25. The stomach of one individual contained two adult spiders and the stomach of the other individual contained an adult wasp.

DISCUSSION

The six-lined racerunner may have always been a part of West Virginia's herpetofauna, remaining undiscovered until now because of the remoteness of the population. However, this species is known to benefit from human-induced changes to landscapes which create more open, drier, and hotter habitats (Mitchell, 1994), and may use landscape changes as a means of dispersal. Railroad tracks serve as dispersal corridors for *Podarcis muralis*, an exotic lizard which has been introduced into several urban areas in the United States (Hedeen and Hedeen, 1999). All known localities for the racerunner in the Shenandoah Valley in Virginia are along railroads (Mitchell, 1994), which suggests that the species has used the tracks as dispersal corridors from more eastern localities. It is possible that the population discovered in West Virginia has recently invaded the state from Maryland by crossing a railroad trustle across the Potomac River. Populations of this species are known to occur along the Maryland side of the Potomac River on shale barrens, from Old Town to Little Orleans (E. Thompson, Maryland DNR, pers. comm.; Harris, 1975). In this section of the Potomac River, there are eight locations where a railroad track crosses from Maryland to West Virginia.

The range expansion of introduced species usually occurs by either diffusion or by jump-dispersal (Pielou, 1979). The racerunner probably disperses by diffusion, gradually spreading its range along suitable habitat over a period of many generations. We suggest that other populations of this species will be discovered along the CSX railroad between the single known locality in West Virginia and the point of invasion from Maryland. Alternatively, the racerunner may be a "natural" resident of the drier, hotter mountains of the eastern panhandle. Other populations may have remained unnoticed because of remoteness or because of the tendency of racerunners to be active only during the hottest months of the year. Documentation of the distribution of the six-lined racerunner in other parts of West Virginia will help to answer questions about the biogeography of this species.

Surveys for this species should be done on very hot days during mid-summer. We noted that the individuals reported in this paper were active during midday in temperatures of 34 -38° C, but we were unable to locate any individuals at the same site in late afternoon when the temperature had decreased to below 30° C. The addition of this new species to the herpetofauna of West Virginia illustrates the need for continued surveys and natural history studies in the state.

ACKNOWLEDGMENTS

This project was supported by a grant from the West Virginia Department of Natural Resources as part of the Amphibian and Reptile Atlas Project. We thank Ed Thompson for providing information on Maryland racerunners.

LITERATURE CITED

Conant, R., and J. T. Collins. 1998. A field guide to reptiles and amphibians of Eastern and Central North America. Third edition, expanded. Houghton Mifflin Company, New York, NY. 615 pp.

Green and Pauley. 1987. Amphibians and reptiles in West Virginia. University of Pittsburgh Press, Pittsburgh, PA. 241 pp.

Harris, H. S. 1975. Distributional survey (Amphibia/Reptilia) of Maryland and the District of Columbia. Bull. Maryland Herpetological Society. 11:3.

Heeden, S. E., and D. L. Heeden. 1999. Railway-aided dispersal of an introduced *Pordarcis muralis* population. Herpetol. Rev. 30:57-58.

Mitchell, J. C. 1994. The reptiles of Virginia. Smithsonian Institution Press, Washington, D. C. 352 pp.

Pielou, E. C. 1979. Biogeography. John Wiley, New York, NY. 351 pp.

Ransom, R. E., and M. V. Plummer. 1999. *Cnemidophorus sexlineatus* (Six-lined racerunner) activity. Herpetol. Rev. 30:96-97.

Strausbaugh, P.D. and E.L. Core. 1977. Flora of West Virginia. Seneca Books, Inc. 1079 pp.

CASE-BUILDING EFFICIENCY OF *PYCNOPSYCHE GENTILIS* [McLACHLAN]: EARLY VERUSS LATE SUCCESSIONAL LEAVES

CHRISTOPHER T. RUHLAND, Department of Biology, S-242 Trafton Science Center, Minnesota State University, Mankato, MN 56001, Office (507) 389-2786, Fax: (507) 389-2788, Email: Christopher.ruhland@mnsu.edu and BENJAMIN M. STOUT, Department of Biology, Wheeling Jesuit University, Wheeling, West Virginia 26003 USA.

ABSTRACT

The effects of leaf rigidity on case-building behavior of the caddisfly larvae *Pycnopsyche gentilis* was examined. Leaves from early successional (sassafras, dogwood, redbud, sumac) and late successional deciduous trees (beech, pignut hickory, white oak, red oak) were softened in an aquatic environment fourteen days prior to the caddisfly case-building trials. Early-instar larvae of *P. gentilis* were collected from forested streams in mid-November, removed from their original leaf cases and placed in individual 0.5-l chambers at 10°C. Original case length and total length of new cases were measured using digital image analysis at regular intervals for 19 days. Case-building efficiency, expressed as new case length divided by original case length at each time period, was dependent upon leaf penetrance after 6 hours within the study. Penetrometry was used to compare rigidity of vascular and non-vascular areas of leaves and revealed that leaves of red and white oak exhibited the highest leaf penetrance. Early-instar *P. gentilis* were unable to complete case-building from some leaf materials characteristic of the late stages of forest succession. The inability to process high penetrance leaf detritus may play an important role in shredder production and survivorship in Appalachian forest streams.

INTRODUCTION

Larvae of the caddisfly genus *Pycnopsyche (*Limnephilidae) are abundant in freshwater streams in deciduous forests of North America. *Pycnopsyche* larvae are leaf shredders and subsequently play an important role in processing coarse organic detritus into fine particulate organic matter (Wiggins, 1977; Wiggins and Mackay, 1978). Eggs of *Pycnopsyche gentilis* (McLachlan) hatch in mid-October, coinciding with autumn leaf fall (Wiggins,1977). The larvae overwinter and adults emerge from slow moving areas of streams where leaf detritus has accumulated (Mackay, 1972).

Larvae quickly build cases soon after hatching (Hansell, 1968a; Merill, 1972), and appear to prefer case building material that is easily cut (Fankhauser and Reik, 1935) and highly palatable (Mackay and Kalff, 1973; Otto and Svensson, 1980). Early instar *P. gentilis* build flattened cases out of large leaf discs slightly curved around a central leaf cylinder. Prior to pupation, the case is modified to a round cylinder of bark chips and sand (Mackay, 1972). The larval case serves many purposes including respiration, feeding, buoyancy and camouflage (Cummins, 1964; Ross, 1964; Wiggins, 1977). Caddisfly larvae can select case-building material based upon particle size, weight and quality (Copeland and Crowell, 1937; Fankhauser and Reik, 1935; Hansell, 1968b, 1968c; Williams and Penak,1980). Because the larval case is important for survival, a case that is built rapidly and provides rigidity seems preferable and may deter predation of early instar larvae (Otto and Svennsen, 1980;) Otto1983; Nislow and Molles, 1993).

Because shredders process a large amount of detritus (Richardson and Mackay, 1984), survival of *Pycnopsyche* larvae may play an important role in energy flow of stream ecosystems. In a study comparing early versus late successional streams, Stout *et al.* (1993) found that production of leaf-shredding insects was significantly greater in early successional Appalachian forest streams. They attributed this increased production to the abundance of *Pycnopsyche gentilis* in early successional streams. Stout *et al.* (1993) speculated that decreased availability of suitable case material in mature forest streams could limit survival of caddisfly larvae.

The present study was undertaken to compare case-building rates and survivorship of *P. gentilis* larvae given detritus typical of early and late successional forests. We observed larvae over a 19-d period. We predicted that larval case-building efficiency would be higher for earlier successional leaf species and this would correspond to an increased larval survivorship.

METHODS AND MATERIALS

Leaves of typical early successional Appalachian forests (dogwood, C*ornus florida*; redbud, *Cercis canadensis*; sassafras, *Sassafras varifolium*; and sumac, *Rhus sp.*) and late successional Appalachian forests (American beech, *Fagus grandifolia*; pignut hickory, *Carya ovata*; red oak, *Quercus rubra* and white oak, *Quercus alba*), were collected in Wheeling, WV, USA (39°N, 80° 45'W) in late September 1991. Leaves were stored at room conditions for 7 d and placed in mesh bags (90 ìm screen size). Bags were weighted and then placed in a hardwater spring (10°C) to soften leaves for 14 d prior to case-building trials.

Second and third-instar *P. gentilis* larvae were collected in mid-November from second-order streams in the Fernow Experimental Forest near Parsons, WV, USA (39°3'N, 79°4'W; Griffith and Perry 1992) and held under laboratory conditions at 10°C for 5 d prior to the experiment. Individual larvae were gently removed from their cases and randomly assigned to 0.5-l chambers containing several leaves of a single leaf species. Each leaf species was replicated five times (5 chambers/larvae per leaf species). Chambers were rotated randomly at each sampling period to remove incubator position effects. Original case-lengths were measured using a video imaging system and new case lengths were measured at six-hour intervals for 48 hours, with daily measurements continuing for 19 days. Case-building efficiency (CBE) was calculated as the length of the new case built divided by the length of the original case (CBE = new/original case length).

Leaf rigidity measurements were made with a penetrometer (Cherrett, 1968). A softened leaf was placed between two sheets of plexiglass with a small hole in the center. A metal rod was placed through the hole onto the leaf surface and weight was added until the leaf was penetrated. Ten measurements were made on non-vascular and vascular areas of five leaves for each species.

The general linear model procedure was used with one-way analysis of variance (ANOVA) to examine leaf-species effects on CBE at early (6 h), middle (18 h) and late (19 d) sampling periods. Least square linear regressions were used to predict CBE and larvae survivorship from leaf penetrance and larvae survivorship from CBE.

RESULTS

There were significant differences in larval CBE between leaf species after 6 h of the study (ANOVA, $p<0.01$; Table 1). Larvae of *P. gentilis* given the sumac species began case construction within the first hour and had built completed cases within 12 h. Larvae given other early successional leaves (dogwood, redbud and sassafras) had completed approximately 85% of their cases within 120 h. At the other extreme, larvae given late successional leaves (American beech, red and white oak) completed less than 40% of their original case within 120 h. One exception to the trend was pignut hickory, which had exhibited low penetrance (Fig. 1) and all larvae completed 100% of their original case length within 5 d. With the exception of the late successional pignut hickory, early successional CBE was greater than late successional CBE. Within 24 h, *P. gentilis* larvae given early successional leaves had completed 74% of their original case length compared with late successional leaves that averaged approximately 19%.

There was a significant negative relationship ($p<0.05$) between CBE and leaf penetrance at three time intervals. Softer leaves were more conducive to case-building, and up to 77% of CBE could be explained by leaf penetrance (Fig. 2). Case-building rates were not significantly different among the three time periods (ANOVA, $p>0.10$), thus the 6-h test was as conclusive as the 192-h test. Again, sassafras and pignut hickory were exceptions to the CBE/penetrance relationship. Cases built from these and other leaf species with penetrance of non-vascular areas >390 g did not include full leaf discs, but rather chips cut from leaf extremities.

Survivorship tended to be higher in larvae given early successional leaves than late successional leaves ($p=0.09$). However, survivorship results should be interpreted cautiously given the small sample size (n=5 larvae) and considerable discrepancy between mean survivorship rates (Table 1). Survivorship at 19 d was related to both non-vascular and vascular penetrance ($r^2=0.79$ and 0.72, respectively; Fig. 3). CBE after 192 h was an excellent indicator of larval survivorship ($r^2=0.92$; Fig. 4).

Table 1. Mean Case-Building Efficiency (CBE)+ SE at 6h, 18h, 19d and percent survivorship at 19 d of larvae (n=5) given early and late successional species.

SPECIES	CBE at 6 hours	CBE at 18 hours	CBE at 19 days	Percent Survivorship at 19 days
Early Successional Species				
Dogwood	35 ± 15	66 ± 15	107 ± 3	80
Redbud	27 ± 10	36 ± 21	109 ± 4	100
Sassafras	14 ± 10	37 ± 15	86 ± 6	67
Sumac	68 ± 18	109 ± 5	126 ± 11	100
Late Successional Species				
Am. Beech	0	13 ± 11	35 ± 19	40
Pg. Hickory	31 ± 16	30 ± 15	114 ± 4	100
Red Oak	10 ± 8	16 ± 9	24 ± 13	20
White Oak	0	0	0	20

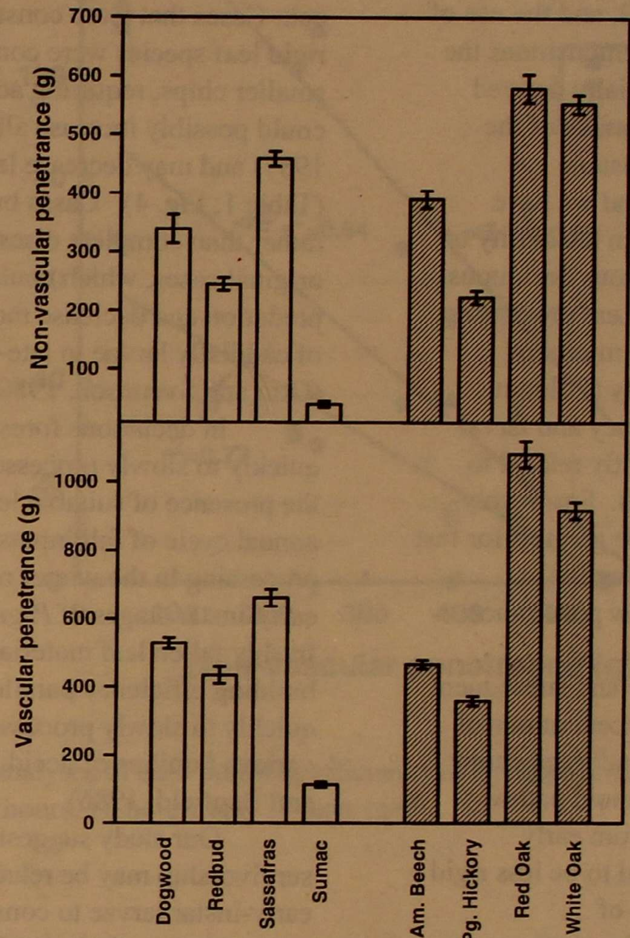

Figure 1. Mean penetrance in non-vascular and vascular areas of early (open shading) and late (shaded) successional leaf species prior to case building trials. Vertical lines indicate ± 1 SE (n = 50).

DISCUSSION

Timing of *P. gentilis* egg-hatching coincides with autumnal leaf fall, and the use of these leaves for case building demonstrates the dependence of larvae on terrestrially derived sources. Case material is often made of the same detritus that the larvae consume (Cummins, 1964; Otto, 1983) and we have found considerable differences in the ability of early-instar larvae to utilize various deciduous leaf species for case building. Leaf processing by shredders is dependent upon microbial softening and tissue penetrability (Polunin, 1984) and case-building efficiency and larval survivorship appears to be directly related to leaf penetrability (Figs. 2 and 3). For freshly-fallen leaves, CBE appears to be greatest for fast processing, mostly early-successional or understory, leaf species with low penetrance (Fig. 1).

Leaf toughness, rigidity and subsequent decomposition is related to concentrations of lignin polymers and other secondary phenolic compounds of the phenylpropanoid pathway (Kause et al., 1999). Leaves from early successional forest species tend to be less rigid and have lower concentrations of phenylpropanoid compounds than late successional species (Shure and Wilson, 1993; Dudt and Shure, 1994) which could reduce CBE. In addition, many of these secondary phenolic compounds, such as tannins, may act as anti-herbivory compounds (Koes et al., 1994; Matsuki, 1996) which could potentially reduce utilization by grazing insects (Faeth, 1992; Coley and Barone,1996; Ayres et al., 1997) in high penetrance species and may be unsuitable for case-building in *P. gentilis* larvae.

More slowly processed leaf species may require extensive in-stream incubation in order to provide suitable case material, but more slowly processed species such as American beech may eventually become preferred case material for *P. gentilis* (Mackay, 1972) later in winter months. In this study, *P. gentilis* was unable to cut complete leaf discs from leaves that were difficult to penetrate or that had close secondary vein patterns such as red and white oak. Cases that were constructed from these rigid leaf species were composed of many smaller chips, requiring additional silk which could possibly increase allocation costs (Otto, 1987) and may decrease larval survivorship (Table 1; Fig. 4). Cases built from leaf chips rather than complete discs were smaller than the original cases, which could potentially increase predation and decrease mobility and respiration of caddisfly larvae in late-successional streams (Otto and Svennson, 1980).

In deciduous forest streams, a mix of quickly to slowly processed leaf species ensures the presence of suitable leaf resources over the annual cycle of fall inputs and subsequent processing in the winter months. During the early-instar stages of *P. gentilis,* when only freshly fallen leaf material is available, case-building efficiency parallels the pattern of quickly to slowly processed leaves from the various families of deciduous leaves (Webster and Benfield, 1986).

Our study suggests that larval survivorship may be related to the ability of early-instar larvae to construct a suitable case in a short time period out of soft, penetrable leaf material typical of early successional forests. The increased mortality of larvae given high penetrance leaves in this study may be related to: (1) decreased larval respiration resulting from the inability to build complete cases or (2) the inability of larvae to feed upon this tough detrital material. In a comparison of early and late successional forest streams, Stout *et al.* (1993) found that significantly lower shredder production in mature forest streams was due mostly to reduced survivorship of early instar *P. gentilis*. This current study provides support to the speculation that lower *P. gentilis* survivorship may have been associated with the lack of suitable case-building material at a critical larval stage.

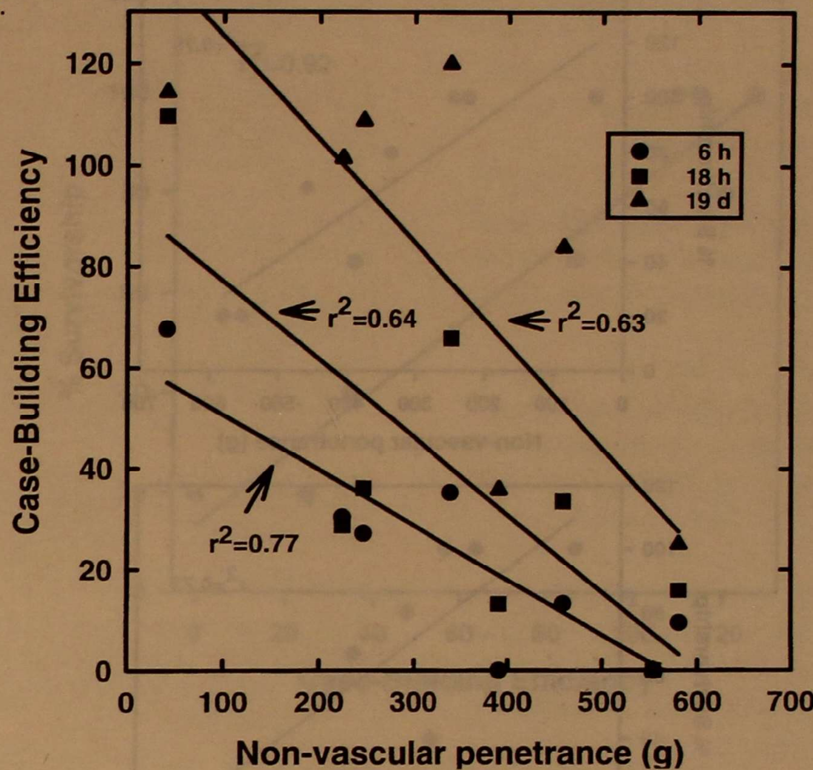

Figure 2. Regression analyses of case building efficiency of *Pycnopsyche gentilis* versus non-vascular leaf penetration for six hours, 18 hours, and 19 days (n=8).

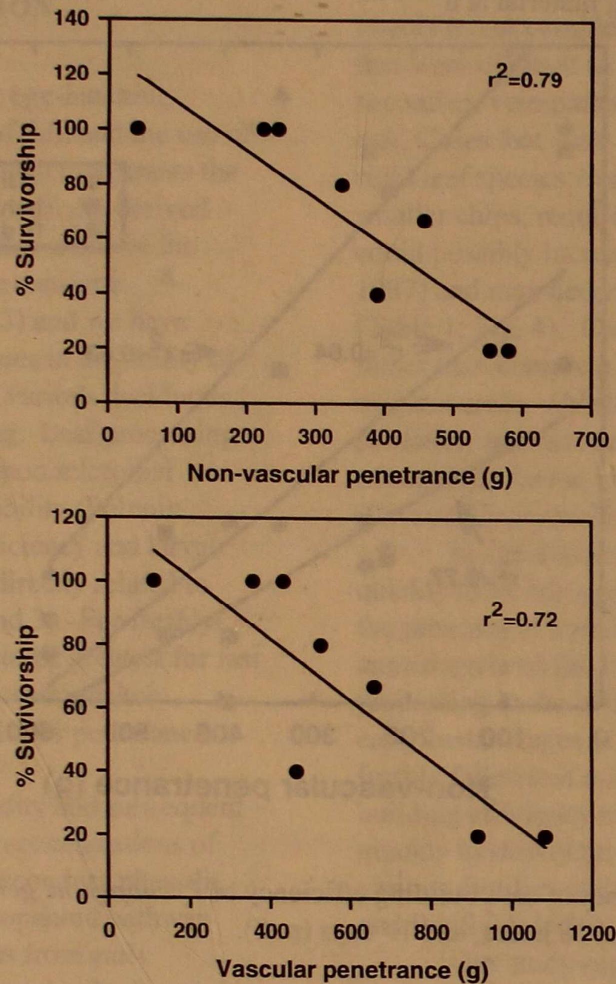

Figure 3. Regression of percent survivorship of *Pynopsyche gentilis* larvae after 19 days versus non-vascular and vascular penetrance (n = 8).

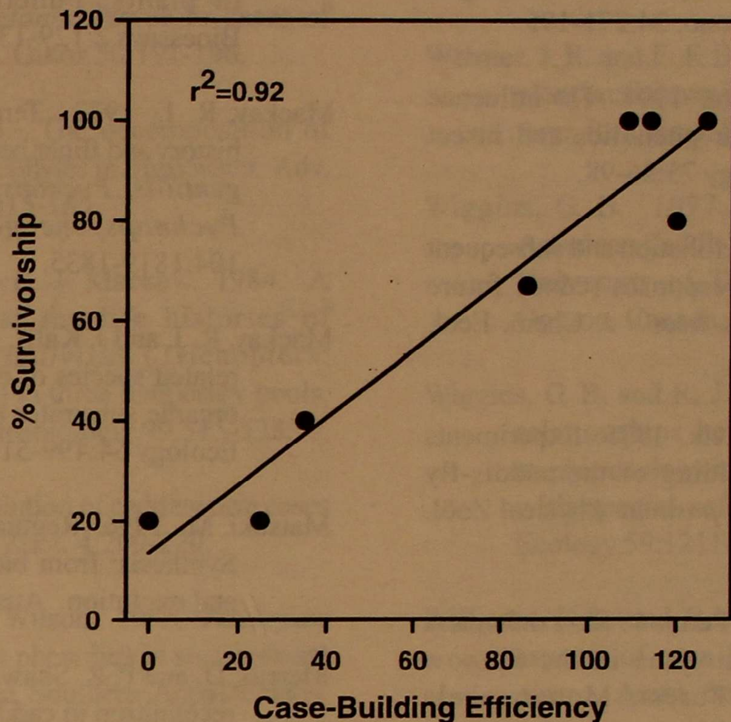

Figure 4. Regression of percent survivorship of *Pynopsyche gentilis* larvae after 19 days versus Case Building Efficiency at 19 days (n = 8).

ACKNOWLEDGMENTS

We would like to thank J.R. Webster and E.F. Benfield for use of the penetrometer. We also thank P. Benson, P. Talerico, S. Burchett and W. Cybulski for assistance in collection of larvae and C.C. Bennington for statistical advice.

LITERATURE CITED

Ayres, M. P., T. P. Clausen, S. F. MacLean, A. M. Redman and P. B. Reichardt. 1997. Diversity of structure and antiherbivory in condensed tanins. Ecology 78:1696-1712.

Cherrett, T. M. 1968. A simple penetrometer for measuring leaf toughness in insect feeding studies. Econ. Ent. 61:1736-1738.

Coley, P. D. and J. A. Barone. 1996. Herbivory and plant defenses in tropical forests. Ann. Rev. Ecol. Syst. 27:305-335.

Copeland, M. and S. Crowell. 1937. Observations and experiments on case-building instinct of two species of Trichoptera. Psyche 44:125-131.

Cummins, K. 1964. Factors limiting the microdistribution of larvae of the caddisflies *Pycnopsyche lepida* and

INTRODUCTION

Response of bird populations to clearcutting has been studied extensively (e.g. Conner and Adkisson, 1975; Thompson *et al.*, 1992), and it is clear that timber harvesting can result in fragmentation of forested habitats. Habitat fragmentation has been associated with factors which may depress or, in the case of forest interior species, displace local populations of passerine birds (Robinson, 1992; Faaborg *et al.*, 1995). In the northeastern United States, several songbird species have shown significant negative population trends (Rosenberg and Wells, 1995) in part due to forest fragmentation. In contrast, a few of these species, notably the Wood Thrush (*Hylocichla mustelina*), are increasing or remaining stable in West Virginia where forested landscapes are relatively intact and unfragmented (Rosenberg and Wells, 1995). However, over half the forest land in West Virginia is in private ownership and it is estimated that 35% of West Virginia's landowners plan to cut their forests in the next 10 years (Birch *et al.*, 1992). Thus it is important to identify less intensive alternative harvesting methods to clearcutting.

Response of bird populations to less intensive harvesting, such as harvesting for crop tree release, is not well documented. In 1989 the U.S. Forest Service (USFS) harvested an area using the crop tree release technique and monitored tree growth and vegetation changes (Arlen Perkey, person. commun.). Later, they expressed an interest in identifying use of this area by breeding birds. Therefore from 1995-97, we examined bird populations in USFS plots treated with different crop tree release strategies. Our objective in this study was to determine the relative density of breeding bird territories by species in four harvests of different intensities as well as in uncut adjacent areas.

STUDY AREA AND METHODS

This study was conducted on the Cooper's Rock Crop Tree Demonstration Area (CTDA) located northeast of Morgantown, West Virginia in Cooper's Rock State Forest. In 1989 the U.S. Forest Service established and harvested the CTDA to serve as a public demonstration area for the crop tree management technique. Crop tree management focuses on selecting and releasing individual trees to meet multiple landowner objectives including aesthetics, wildlife habitat enhancement, and timber management (Perkey *et al.*, 1993). When the crowns of neighboring trees interfere with the crown of the crop tree, neighboring trees are removed to provide growing space around the crop tree. Perkey *et al.* (1993) provide a detailed description of the crop tree harvesting method. The CTDA is composed of hardwood forest bisected by a paved road and a powerline corridor; no water sources occurred on the area.

The U.S. Forest Service established 4 harvest plots of 0.8 ha each on the CTDA. During March-April 1989, each plot was harvested at a different intensity. Harvesting intensities on each plot are summarized below and are based on descriptions by Arlen Perkey (person. commun.). Plots 1, 2 and 4 were harvested with the crop tree release method where canopy trees adjacent to crop trees were removed. Plot 2 had the highest harvesting intensity and was cut to release 13 crop trees per ha resulting in dense growth in the understory. Timber production was the only objective in plot 2. Plot 1 was cut to release 10 crop trees per ha which resulted in a relatively dense understory. The objective for this moderate intensity harvest was to benefit both timber and wildlife resources. In plot 4, only 8 trees were released per ha for a balance between timber, wildlife and aesthetic uses. Consequently, subsequent understory development was limited. Plot 3 was harvested using a traditional silvicultural thinning method with primarily small diameter understory trees removed. Few canopy trees were removed; thus, this plot was harvested at the lowest intensity.

To examine the impact of the cut areas on birds in the adjacent uncut forest, we established a 4 ha unharvested plot immediately adjacent to the 4 cut plots (hereafter termed the buffer plot). The Forest Service had also established an unharvested control plot (1.6 ha in size) near but not adjacent to the cut plots. We spot-mapped bird territories (Bibby et al., 1992) on the study area (8.8 ha) in May-July 1995-97 (4 harvested plots of 0.8 ha each, a 4 ha unharvested buffer plot, and a 1.6 ha unharvested control plot). Spot-mapping was completed once per week for 11 weeks in 1995 and 1996 and for 12 weeks in 1997. We walked transects through the study area in different directions on alternating visits to avoid approaching birds from the same spot, and so that no one plot would be consistently surveyed first. Locations of birds detected were estimated on plot maps by using plot boundary markers as reference points. Bird detections were marked so that individuals could be distinguished from one another. Behaviors such as vocalizations and interactions with other individuals were recorded to aid in delineating territories.

We delineated territories for each species detected in three non-consecutive weeks and for those detected in more than three consecutive weeks. Three weeks of observation in a row with no further observations could indicate a transient individual. More than three observations, especially if spread out over time, we felt represented a valid territory (Bibby et al., 1992). Territories were assigned to a plot based on the following criteria. If all or most of the detections were in one plot, a territory was counted for that plot. If approximately half of the detections were in a plot, it was counted as a half territory. We calculated territories per ha for each harvest plot, uncut buffer plot, and uncut control plot. We identified bird species as forest-interior or edge-tolerant after Freemark and Collins (1992). Because we were not able to replicate the study area, data on territory abundance were not statistically analyzed. Our intent was to identify avian use of our specific study area, not to extrapolate results to other areas.

Nest searching and monitoring (Martin *et al.*, 1997) were conducted in 1996 and 1997. Protocols of Martin and Geupel (1993) were followed to minimize disturbance to breeding birds. Plots were searched every 1-2 days with equal search effort in each plot. Nests were located by watching bird behavior (e.g. adults carrying nest material or food) that would indicate nesting. Each nest found was monitored every two to three days to determine its status until young fledged or the nest failed. A nest was considered successful if at least one young fledged.

We collected vegetation data on the 4 harvested treatment plots, the unharvested buffer, and the unharvested control treatments. We measured average canopy height and density of understory vegetation on 5 m radius vegetation plots using guidelines of Martin *et al.* (1997). Understory stem density was classified into two diameter at breast height (dbh) categories: <2.5 cm dbh or 2.5 - 8.0 cm dbh. Canopy cover (James and Shugart, 1970) and stem density of all trees >8 cm dbh were measured on 11.3 m radius plots. For analyses, data from unharvested buffer and control plots were combined into an unharvested treatment. Means of vegetation variables were compared between four harvested and one unharvested treatments using analysis of variance (ANOVA) with each vegetation variable as the dependent variable and treatment as the independent variable. If ANOVA indicated a significant difference ($P \leq 0.05$), we used Waller-Duncan multiple comparisons to determine which treatments differed.

RESULTS AND DISCUSSION

We detected 42 species of birds from 1995 - 1997 in and around the harvested plots. Ten species in 1995 and 1996 and 12 in 1997 had greater than three detections, therefore territories were drawn for these species (Table 1). Over the three years, the number of territories per ha was higher in the harvested plots than in the unharvested areas. When we examined results of forest-interior and edge-tolerant species separately, the average number of territories for each group again was greater in the harvested plots (Table 1). Thus, crop tree thinning apparently did not exclude forest-interior species from establishing territories on the CTDA. The remaining canopy trees provided suitable habitat with no difference in canopy cover between harvested and unharvested plots (Table 2). Of the harvested plots, the traditional thinning plot (3) tended to have the fewest territories, while plot 1 had the most. Plot 3 had considerably fewer understory stems 2.5-8 cm in size than plot 1 (Table 2) which would result in less mid-story vegetation in plot 3. For edge-tolerant species, none established more territories on the unharvested plots (Table 1). The only forest-interior species with more territories on the unharvested than harvested plots was the black-throated green warbler. This species is typically found in large stands of mature open mixed woodlands (DeGraaf and Rappole, 1995), and is sensitive to heavy harvesting (>50% volume) but not light logging (<25% volume) in northern hardwood forests (Webb *et al.*, 1977). In our woodlands, the black-throated green warbler appeared to be sensitive to the relatively light harvesting that occurred on the crop tree release plots since the species established territories almost exclusively in unharvested areas.

Forest-interior species established the most territories in plot 1; a large number (28%) were hooded warblers (Table 1). Hooded warbler territories were most common on plots 1 and 2. These two plots had the greatest harvesting intensity and had significantly greater densities of stems 2.5-8 cm in size. Hooded warblers generally nest and forage in mixed hardwood forests with dense undergrowth and tend to be associated with canopy gaps in mature forests (DeGraaf and Rappole, 1995). Three nests of forest-interior species were found in the harvested plots; 2 hooded warblers and 1 American redstart. Two of these nests successfully fledged young.

Territories of edge-tolerant species were most abundant on plots 1 and 2 (Table 1) where dense mid-story vegetation (stems 2.5-8 cm dbh) provided nesting habitat for these species (Table 2). Wood thrush were the most common species with the greatest number of territories delineated and the most nests monitored. Nine wood thrush nests were found on the harvested plots, with 6 of these in plot 1. Seven of the 9 successfully fledged young. No wood thrush nests were found in unharvested areas. Nests of other edge-tolerant species monitored on the harvest plots included eastern towhee (1 nest, 1 successful), eastern wood-pewee (1 nest, 1 successful), gray catbird (3 nests, 1 successful), and red-eyed vireo (2 nests, 1 successful). Thus of 16 nests monitored for edge-tolerant species, 11 successfully fledged young.

In summary, our data suggest that crop tree release harvesting can provide suitable habitat for both forest-interior and edge-tolerant species. Both groups established territories and nested within the harvested areas. Although replicate study sites were not available, our data provide information on relative abundance of territories on our study area and indicate levels of use of crop tree harvests by avian species. Harvesting opened the canopy which allowed understory and midstory structure to develop, while the remaining crop trees provided structure in the canopy. The increased structural diversity provided habitat for both groups of species, similar to findings in other studies (Wood *et al.*, 1998). The average number of territories in the crop tree harvests was similar for both groups. However, few nests of forest-interior species were found, probably because many of these species are canopy nesters and their nests are difficult to locate. Therefore, we could not determine the effects of this harvesting method on nesting success. Although forest-interior species established territories within the crop tree harvests, we cannot judge habitat quality for this group. Presence of a species does not necessarily indicate good quality habitat suitable for successful nesting (Vickery et al., 1992). For edge-tolerant species, crop tree release harvesting provided suitable habitat for territory establishment and for successful nesting.

Table 1. Mean Number of bird territories per ha at Cooper's Rock State Forest, Crop Tree Demonstration Area, West Virginia, May - July 1995 - 1997.

	Harvested[a]				Total	Unharvested[b]		Total
Species	Plot 2	Plot 1	Plot 4	Plot 3	Harvested	Buffer	Control	Unharvested
Forest-interior								
American Redstart	0.4	0.4	0.5	0.1	0.35	0.04	0.10	0.07
Black and White Warbler	0.2	0.2	0.2	0.2	0.20	0	0.10	0.05
Black-throated Green Warbler	0	0.2	0	0	0.05	0.08	0.35	0.22
Blue-headed Vireo	0	0	0	0	0	0.04	0	0.02
Cerulean Warbler	0	0	0	0.2	0.05	0	0	0
Hooded Warbler	1.0	0.9	0.3	0.3	0.63	0.10	0	0.05
Ovenbird	0	0.6	0.3	0.6	0.37	0.56	0.05	0.31
Scarlet Tanager	0.2	0.2	0.2	0.1	0.17	0.11	0	0.06
Total	1.8	2.5	1.5	1.5	1.82	0.95	0.60	0.78
Edge-tolerant								
Downy Woodpecker	0.2	0	0	0	0.05	0	0.05	0.03
Eastern Towhee	0.4	0.2	0.5	0	0.27	0.02	0	0.01
Eastern Wood-pewee	0	0.3	0.4	0.2	0.22	0.14	0.10	0.12
Gray Catbird	0.6	0.5	0.1	0	0.30	0	0	0
Red-eyed Vireo	0.4	0.6	0.7	0.6	0.57	0.51	0.45	0.48
Wood Thrush	1.3	1.3	0.3	0.1	0.75	0	0	0
Total	2.9	2.9	2.0	0.9	2.17	0.67	0.6	0.64

[a] Harvest plots are 0.8 ha in size and are ordered from highest to lowest harvesting intensity. Plots 1,2, and 4 were harvested with the crop tree release method; plot 3 was harvested with a traditional thinning method.

[b] The buffer included 4 ha of unharvested forest immediately adjacent to harvested plots. The control area was 1.6 ha of unharvested forest not adjacent to harvest plots.

Table 2. Vegetation characteristics of crop tree harvested (plots 1 - 4) and unharvested plots at Cooper's Rock State Forest, West Virginia. Within a row, means with the same letter are not significantly different (ANOVA and Waller-Duncan multiple comparisons; alpha = 0.05)

Variable	Plot 2	Plot 1	Plot 4	Plot 3	Unharvested	F, df, P
Canopy Height (m)	5.1 AB	3.9B	5.8A	6.2A	5.9A	3.69, 4, 0.01
Canopy cover (%)	64.0A	63.3A	72.0A	72.5A	82.4A	2.02, 4, 0.11
# stems < 2.5 cm dbh	108.2AB	58.5BC	144.0A	159.5A	43.6C	9.90, 4, 0.0001
# stems 2.5 - 8 cm dbh	8.0A	7.5A	1.8B	1.2B	2.9B	7.08, 4, 0.0001
# trees > 8 cm dbh	11.2B	11.7B	13.6AB	10.2B	17.9A	4.64, 4, 0.003

LITERATURE CITED

Bibby, C. J., N. D. Burgess, and D. A. Hill. 1992. Bird Census Techniques. Academic Press, New York, NY. 257pp.

Birch, T. W., D. A. Gasner, S. L. Arner, and R. H. Widmann. 1992. Cutting activity on West Virginia timberlands. North. J. Appl. For. 9:146-148.

Conner, R. N., and C. S. Adkisson. 1975. Effects of clearcutting on the diversity of breeding birds. J. For. 73:781-785.

DeGraaf, R. M., and J. H. Rappole. 1995. Neotropical migratory birds: natural history, distribution, and population change. Cornell Univ. Press, Ithaca, NY.

Faaborg, J., M. Brittingham, T. Donovan, and J. Blake. 1995. Habitat fragmentation in the temperate zone. Pp. 357-380 *in* Ecology and management of neotropical migratory birds: a synthesis and review of critical issues. T. E. Martin and D. M. Finch, eds. Oxford Univ. Press, New York and Oxford.

Freemark, K. and B. Collins. 1992. Landscape ecology of breeding birds in temperate forest fragments. Pp. 443-454 *in* Ecology and conservation of neotropical migrant landbirds. J.M. Hagan and D.W. Johnston, eds. Smithsonian Inst. Press, Washington.

James F. C., and H. H Shugart, Jr. 1970. A quantitative method of habitat evaluation. Aud. Field Notes 24:727-736.

Martin, T. E. and G. R. Geupel. 1993. Nest-monitoring plots: methods for locating nests and monitoring success. J. Field Ornithol. 64:507-519.

Martin, T. E., C. R. Paine, C. J. Conway, W. M. Hochachka, P. Allen, and W. Jenkins. 1997. BBIRD field protocols. Unpubl. Report. Montana Coop. Wildlife Research Unit, Univ. Montana, Missoula.

Perkey, A. W., B. L. Wilkins, and H. C. Smith. 1993. Crop tree management in eastern hardwoods. USDA Forest Service, Northeastern Area State and Private Forestry, Tech. Rept. NA-TP-19-93.

Robinson, S. K., 1992. Population dynamics of breeding Neotropical migrants in a fragmented Illinois landscape. Pp. 408-418 *in* Ecology and conservation of neotropical migrant landbirds. J.M. Hagan and D.W. Johnston, eds. Smithsonian Inst. Press, Washington.

Rosenberg, K. V., and J. V. Wells. 1995. Importance of geographic areas to neotropical migrant birds in the northeast. Unpub. Rept. submitted to USFWS Region 5, Hadley, MA.

Thompson, F. R., III, W. D. Dijak, T. G. Kulowiec, and D. A. Hamilton. 1992. Breeding bird populations in Missouri Ozark forests with and without clearcutting. J. Wildl. Manage. 56:23-30.

Vickery, P. D., M. L. Hunter, Jr., and J. V. Wells. 1992. Is density an indicator of breeding success? Auk 109:706-710.

Webb, W. L., D. F. Behrend, and B. Saisorn. 1977. Effect of logging on songbird populations in a northern hardwood forest. Wildl. Monogr. No. 55. 35 pp.

Wood, P. B., J. P. Duguay, and J. V. Nichols. 1998. Songbird abundance, nest success, and invertebrate biomass on two-age, clearcut, and unharvested forest stands in the Monongahela National Forest, West Virginia. Final Proj. Rept., WV. Coop. Fish and Wildlife Research Unit, Morgantown, WV.

BATS OF THE FERNOW EXPERIMENTAL FOREST, TUCKER COUNTY, WEST VIRGINIA.

CRAIG W. STIHLER, West Virginia Division of Natural Resources, Nongame Wildlife and Natural Heritage Program, Elkins, WV 26241

ABSTRACT

Five species of bats, including the federally endangered Indiana myotis (*Myotis sodalis*), have been documented hibernating in Big Springs Cave on the Fernow Experimental Forest, Tucker County, West Virginia. The present study examined bat activity at the cave entrance and within 2.0 km of the cave from April through November 1995. A total of 1,054 bats of 9 species were captured; 859 were trapped at the cave entrance, and 195 were captured in mist nets set at six locations. Species captured, in decreasing order of abundance, were: *Myotis lucifugus* (N=363), *M. septentrionalis* (N=307), *Pipistrellus subflavus* (N=237), *M. sodalis* (N=69), *Lasiurus borealis* (N=51), *Eptesicus fuscus* (N=18), *L. cinereus* (N=4), *Lasionycteris noctivagans* (N=4), and *Corynorhinus townsendii virginianus* (N=1). This study produced the first summer records of *M. sodalis* in West Virginia: 1 in June, 5 in July, and 10 in August. There was no indication that maternity colonies existed in the immediate vicinity. Over half of the captured bats (N=585) were banded. On 23 February 1996, a bat survey in Big Springs Cave located 990 hibernating bats of four species; 110 were individuals that had been banded on the Forest during the previous summer. Banded bats in the cave represented 11% of the *P. subflavus* banded during the study; 36% of the banded *M. lucifugus*, 86% of the banded *M. sodalis*, and 2% of the banded *M. septentrionalis*.

INTRODUCTION

Caves provide suitable microhabitats for hibernating bats of many species (Twente, 1955; Henshaw, 1972), and caves are abundant geologic features in the limestone strata of West Virginia (Davies, 1958). Because of the importance of caves to bat populations and the relative ease of observing bats during hibernation, most bat studies in West Virginia have focused on hibernating concentrations of these animals (Reese, 1934; Hall, 1972; Davis, 1959; Davis, 1966; Dotson, 1977; Hall and Stihler, 1992; Stihler and Brack, 1992; Delfino, unpub. data). Caves have also been the focus of bat studies during other times of the year (Kretzsch 1961). McKeever (1951) compiled data on the distribution of bats in West Virginia based on both cave and non-cave records, although no areas of the state were surveyed intensively.

The listing of the Indiana bat, *Myotis sodalis*, as a federally endangered species (Fed. Reg. 32:4001) and subsequent recovery efforts drew attention to the habitat needs of this species, including summer habitat away from the hibernacula. Research aided by technological advances, such as those in radio telemetry, have allowed biologists to identify the summer habitats of *M. sodalis* in some portions of the species' range (Brack, 1983; Clark *et al.* 1987; Gardner *et al.*, 1991). A habitat suitability index model for summer habitat needs of *M. sodalis* has been developed (Romme, 1995).

Although concentrations of hibernating *Myotis sodalis*, including one of range-wide significance, have been documented in West Virginia caves (Dotson 1977; Stihler and Brack, 1992; Hall and Stihler, 1992) and suitable summer habitat appears to be present, no summer records of this species have been reported for West Virginia. In Kentucky, Hall (1962) found that at least a few male *M. sodalis* remained in the vicinity of hibernation caves throughout the year and often returned to night-roost in the cave during the summer. The present study attempts to document the presence of *M. sodalis* in West Virginia during the summer by monitoring bats at and near the entrance of a known hibernaculum, Big Springs Cave (Hall, 1972; Stihler, 1995) on the Fernow Experimental Forest, Tucker County. The study also provides data on other bat species, including "tree bats" which are poorly documented because they rarely roost in caves or buildings.

STUDY SITE

The Fernow Experimental Forest, located in Parsons, WV, is an 11,609 ha research forest maintained by the USDA Forest Service, Northeastern Research Station. The area is characterized as having steep slopes covered with hardwood forests. Elevations range from 533 m to 1,112 m. Soils are well-drained medium textured loams and silt loams. Upland oaks are the most common tree species group, and northern red oak (*Quercus rubra*) is most abundant. A belt of Greenbrier Limestone outcrops near Big Springs Gap, and it is in this limestone formation that Big Springs Cave is formed. Mean annual temperature is approximately 8.9° C.

MATERIALS AND METHODS

A 0.91m x 0.91m harp trap was used to capture bats at the entrance of Big Springs Cave. Mist nets (2-ply, 50 denier) were set at six stations within 2.0 km of the cave entrance. Nets were set across potential travel corridors (roads and streams) and over standing water. Bat sampling site locations and descriptions are presented in Table 1. Nets of three lengths (6m, 9m, and 12m) were used. Nets were 2.6m high although two-tier net systems (5.2m high) were constructed (Gardner *et al.*, 1989). Both one-tier and two-tier nets were employed. Bats were sampled at least once each month from April to November 1995 (11 capture sessions); sampling effort varied between capture sessions (Table 2).

The following data were recorded for most bats captured: sex, body mass, length of right forearm, time of capture, and capture height (for bats captured in mist nets). Digital balances were used to measure body mass. Observations of parasites were also noted. Several bats were banded (males on the right forearm; females on the left forearm) to obtain information on recapture rates and bat movements between summer habitat and hibernacula. Most bats were banded using yellow plastic bands; numbered (embossed) aluminum bands were used on *Myotis sodalis* and a few *M. septentrionalis*. Bats were released at the point of capture. Hibernating bats in Big Springs Cave were censused on 23 February 1996. Bats were tallied by species, and the species and sex of banded bats were recorded. Statistical analyses were conducted using the JMP statistical package (SAS Institute, Inc., Cary, NC).

RESULTS AND DISCUSSION

Mist netting and harp trapping sessions.

During the study, 1,054 bats of nine species were captured (Table 3). *Myotis lucifugus* was the most commonly encountered species (N=363) comprising 34.4% of the captures; *M. septentrionalis* was the second most abundant species (N=307) (Table 3). Most (76.8%) of the bats captured were males (Table 3). Number of captures by species for each trapping session are presented in Table 4. Bats were captured during all capture sessions. Only one bat was captured in late November when there was approximately 0.4 m of snow on the ground outside the cave. This bat, a male *M. septentrionalis*, was captured going into the cave. Over 81% (N=859) of the captures occurred at the cave entrance, but only four species were caught there (Table 5).

Forearm length data for 1,005 bats of nine species and body mass data for 966 bats of nine species are summarized in Table 6. Significant differences in body mass were found between males and females of three species: *Pipistrellus subflavus* ($p<0.01$); *Eptesicus fuscus* ($p<0.05$); and *Lasiurus borealis* ($p<0.01$). Forearm lengths were found to be significantly different between the sexes in two species: *M. septentrionalis* ($p<0.05$) and *L. borealis* ($p<0.05$). Table 7 presents the body mass data for each species by capture session. Species that were captured throughout the study period showed an increase in body mass during the latter portion of the study (September and October), although the greatest mass was often noted prior to the end of the study (November 1995) (Table 7). This suggests that bats that have acquired sufficient fat reserves enter hibernation earlier than bats that require additional fat reserves.

Over half (N=585) of the bats captured during the study were banded (Table 8). However, only 34 banded bats (5.8%) were recaptured between April and November 1995 (*Pipistrellus subflavus*, N=3; *M. lucifugus*, N=16; *M. septentrionalis*, N=12; and *Lasiurus borealis*, N=3). This suggests that there was a large number of bats in the study area, and that individuals are rarely recaptured.

Summary of Captures by Species

***Pipistrellus subflavus* (eastern pipistrelle):** This species was the third most abundant species captured (N=237)(Table 3). *P. subflavus* were caught at four of the six mist net stations and were present throughout the study period (Table 4). Mean body mass was lowest in late May and highest in mid-September (Table 7). Fleas were noted on two individuals; mites were observed on four specimens.

***Eptesicus fuscus* (big brown bat):** *E. fuscus* were captured at two mist net sites; most were caught during the early portion of the study (May-July) (Table 4). Although none were captured in April, their echolocation calls were detected using ultra-sound detectors.

***Myotis lucifugus* (little brown bat):** This was the most commonly captured bat during the study (Table 3). Of the 363 captures, 283 were at the cave entrance (Table 5). This bat was present throughout the study period (Table 4). Average body mass was highest in late September (Table 7). Fleas were observed on 18 individuals; a bat bug (Order Hemiptera: Family Cimicidae) was observed on one individual.

***M. sodalis* (Indiana bat):** Specimens of *M. sodalis* captured in June, July, and August are the first summer records of this federally endangered species in West Virginia (Table 4). Only males were captured in June and July, and all females were captured after 15 August. There was no indication that maternity colonies existed in the immediate vicinity of the study area. *M. sodalis* were captured at the cave entrance and at three of the mist net stations. Male *M. sodalis* probably occur in the study area throughout the year. It is interesting to note, however, that *M. sodalis* were not captured at the entrance of Big Springs Cave in April and May even though they hibernate in the cave. Average mass was lowest in late May and at a maximum in late October (Table 7).

***M. septentrionalis* (northern myotis):** *M. septentrionalis* was the second most commonly encountered bat during the study (N=307)(Table 3); most (N=286) were captured at the cave entrance, but they were also captured at four mist net stations. This is the only species that was captured during every capture session, including late November (Table 4). Mean body weight was lowest in late May and greatest in mid-October (Table 7). Fleas were observed on three individuals; four specimens were infected with mites.

***Lasiurus borealis* (red bat):** A "tree bat," *L. borealis* were captured in mist nets but never at the cave entrance. Most were netted in August and September, but specimens were captured from late June to late October (Table 4). *L. borealis* were netted at four of the mist net stations. Fleas were noted on one specimen.

***L. cinereus* (hoary bat):** Another tree bat, this species was netted at two of the six mist net sites. Three of the four specimens captured were taken in July (Table 4).

***Lasionycteris noctivagans* (silver-haired bat):** Four specimens were netted on 23 October 1995 in a mist net set over a low-water bridge crossing a small stream. All were female, and three of the four were captured during a seven-minute period, the fourth was captured approximately 2.5 hours later. The bats may have been traveling together during migration. Similar concentrations of captures have been observed in Kentucky (John MacGregor, pers. comm.).

Corynorhinus townsendii virginianus (Virginia big-eared bat): This species uses caves in both winter and summer (Barbour and Davis, 1969). This species has never been reported from Big Springs Cave, however, the Arbogast/Cave Hollow cave system, located 8.5 km southeast of Big Springs Cave, harbors both summer and winter populations of this bat. One specimen, a juvenile male, was captured in a mist net set across a small stream below Big Springs Cave on 24 October 1995; a second individual was observed flying over the net at about the same time, but was not captured.

Winter bat survey in Big Springs Cave.

The winter bat survey in Big Springs Cave tallied 990 hibernating bats of four species. *Myotis lucifugus* was the most abundant species (N=652), and *M. sodalis* was the second most abundant species (N=183)(Table 8). Ninety-four bats banded on the Fernow Experimental Forest during this study were observed hibernating in the cave and represent 11% of the banded *Pipistrellus subflavus* (N=8), 36% of the banded *M. lucifugus* (N=81), 86% of the banded *M. sodalis* (N=18), and 2% of the banded *M. septentrionalis* (N=3)(Table 8). It appears that most of the *M. sodalis* found near the cave entrance in the summer hibernate in this cave. However, most individuals of other species, especially *M. septentrionalis*, that were trapped at or near the entrance of Big Springs Cave do not appear to hibernate in the cave. No banded bats were observed in other caves surveyed during the winter 1995-96, but a male *M. lucifugus* banded during this study was recovered from

Hellhole Cave in Pendleton County, WV (a distance of 38 km) during a February 1997 winter bat survey (Stihler, unpub. data).

Summary

The bat fauna of the Fernow Experimental Forest appears to be diverse, and bats are abundant. Nine of the 13 species of bats documented in West Virginia were captured on the Forest between April and November 1995. The only bat expected to occur in the area that was not observed was *Myotis leibii*; in previous years, this species has been observed hibernating in Big Springs Cave (Stihler, 1995). Although there was no evidence of *M. sodalis* maternity colonies, this species was shown to be present during the summer. Two species of tree bats, *Lasiurus borealis* and *L. cinereus*, appear to be summer residents; *Lasionycteris noctivagans* was observed only during the fall migration period.

ACKNOWLEDGEMENTS

Funding for this study was provided by the U.S. Forest Service's Monongahela National Forest and Northeastern Forest Experiment Station and the West Virginia Division of Natural Resources' Nongame Wildlife Fund. Several people contributed to the success of the project. The author particularly wishes to acknowledge the assistance of the follow persons: Ben Auvil, Scott Butterworth, Roger Cottrell, J.C. and Judy Fisher, Scott and Marilyn Freidhof, Andrew Jones, Brendan Kerr, Joseph Miller, Donna Mitchell, Sue Olcott, Harry Pawelczyk, Bill Tolin, Jack Wallace, and Dean Walton. Many other people, including students from Davis and Elkins College (Elkins, WV) and Albright College (Reading, PA), assisted during one or more capture sessions. The manuscript was constructively reviewed by Scott Butterworth, Andrew Jones, and Jack Wallace. The author thanks all citizens of West Virginia who made voluntary contributions to the WVDNR's Nongame Wildlife Fund.

LITERATURE CITED

Barbour, R. W. and W. H. Davis. 1969. Bats of America. Univ. Kentucky Press. 286pp.

Brack, V. W. 1983. The non-hibernating ecology of bats in Indiana, with emphasis on the endangered Indiana bat, *Myotis sodalis*. PhD. Diss., Purdue Univ., W. Lafayette, IN. 280pp.

Clark, B. K., J. B. Bowles, and B. S. Clark. 1987. Summer habitat of the endangered Indiana bat in Iowa. Amer. Midl. Nat. 118:32-39.

Davies, W. E. 1958. Caverns of West Virginia. Geol. and Econ. Survey. Vol. XIX A. 330 pp.

Davis, W. H. 1959. Disproportionate sex ratios in hibernating bats. J. Mammal. 40:16-19.

Davis, W. H. 1966. Population dynamics of the bat *Pipistrellus subflavus*. J. Mammal. 45:645-47.

Dotson, T. L. 1977. The status of bats in West Virginia. M.S. Thesis, Marshall Univ., Huntington, WV. 63pp.

Gardner, J. E., J. D. Garner, and J. E. Hofman. 1989. A portable mist netting system for capturing bats with emphasis on *Myotis sodalis* (Indiana bat). Bat Res. News 30:1-8.

Gardner, J. E., J. D. Garner, and J. E. Hofman. 1991. Summer roost selection and roosting behavior of Myotis sodalis (Indiana bat) in Illinois. Final Rpt. IL Nat. Hist. Sruvey, IL Dept. Cons., Champaign, IL. 56pp.

Hall, J. S. 1962. A life history and taxonomic study of the Indiana bat, *Myotis sodalis*. Reading (PA) Public Mus. and Art Gallery, Sci. Pub. No. 12. 68pp.

Hall, J.S. 1972. The status of *Myotis sodalis*, the Indiana bat, in West Virginia. Unpub. report to WV Dept. Nat. Resour. 9pp.

Hall, J. S. and C. W. Stihler. 1992. Populations of cave-dwelling bats (abstract). Bat Res. News 33:57-58.

Henshaw, R. E. 1972. Niche specificity and adaptability in cave bats. Natl. Speleological Soc., Bull. 34:61-70.

Kretzsch, P. H. 1961. A summer colony of male little brown bats. J. Mammal. 42:529-30.

McKeever, S. 1951. A survey of the mammals of West Virginia. Cons. Comm. of WV. 126pp.

Reese, A. M. 1934. The fauna of West Virginia caves. WV Acad. Sci., Proc. 7:39-53.

Romme, R. C., K. Tyrell, and V. Brack, Jr. 1995. Literature summary and habitat suitability index model: components of summer habitat for the Indiana bat, *Myotis sodalis*. Federal Aid Project E-1-7. IN Dept. Nat. Resour., Bloomington, IN 172pp.

Stihler, C. W. 1995. Virginia big-eared bat/Indiana bat recovery. Federal Assistance Performance Report, Project E-1-12. WV Div. Nat. Resour., Elkins, WV. Pp. 1-22.

Stihler, C. W. and V. Brack, Jr. 1992. A survey of the hibernating bats in Hellhole Cave, Pendleton, County, WV. WV Acad. Sci., Proc. 64:97-103.

Twente, J. W. 1955. Some aspects of habitat selection and other behavior of cavern-dwelling bats. Ecology 36:706-732.

Table 1. Location and description of bat sampling sites on the Fernow Experimental Forest, Tucker County, West Virginia, April - November 1995.

Site Name	Location	Description
Big Springs Cave	4.8 km SSE of city limits of Parsons, WV and 0.45 km NW of the Big Springs Gap trailhead.	Cave is located on a wooded hillside. Harp trap set at entrance of cave. Aspect NNE.
Hickman Slide Hollow	Along Elklick Run approx. 1.7 km N of Big Springs Cave at the junction of USFS Rd. 701 and USFS Rd. 704.	Wooded stream corridor. Mist nets set on low water bridge and over Elklick Run upstream and downstream of the bridge. Aspect N to NW.
Wilson Hollow Weir	Mouth of Wilson Hollow approx. 1.6 km N of Big Springs Cave.	Mist nets set over stream at mouth of hollow above and below the weir. The area is mostly forested with an area of mowed grass near the weir site. Aspect SE.
Below Reservoir	Along Elklick Run below the reservoir dam, approx. 0.9 km NNW of Big Springs Cave.	Mist nets set across Elklick Run and the old road to the dam. The area is wooded. Aspect E.
Reservoir	Upper end of reservoir on Elklick Run, approx. 0.6 km NW of Big Springs Cave.	Mist nets set across upper end of reservoir and across Elklick Run above reservoir. Area around reservoir is forested. Aspect N.
Big Springs Run	Along Big Springs Run approx. 70 m N of Big Springs Cave.	Forested ravine with mist nets set across Big Springs Run near junction with an un-named tributary. Aspect NW.
Big Springs Gap	Along Big Springs Gap Trail in Otter Creek Wilderness Area, approx. 0.5 km SE of Big Springs Cave.	Mist net set over hiking trail in forested area. Aspect N.

Table 2. Dates and equipment used during eleven bat trapping sessions on the Fernow Experimental Forest, Tucker County, West Virginia, 1995.

Session	Nights Sampled	Number Used		
		HarpTrap	Single-tier Net	Double-tier Net
Late Apr	25-26, 26-27	1	0	0
Late May	23-24, 24-25	1	3	2
Late Jun	27-28, 28-29	1	3	2
Late Jul	25-26, 26-27	1	5	2
Mid Aug	16-17	1	0	0
Late Aug	29-30, 30-31	1	5	2
Mid Sep	13-14	1	0	0
Late Sep	28-29, 29-30	1	4	3
Mid Oct	11-12	1	0	0
Late Oct	23-24, 24-25	1	7	4
Late Nov	26-27	1	0	0

Table 3. Total number of bats captured, by species and sex, during the April - November 1995 bat study on the Fernow Experimental Forest, Tucker County, West Virginia.

Species	Sex			Total	% of All Captures
	Male	Female	Unknown		
Pipistrellus subflavus	184	46	7	237	22.5
Eptesicus fuscus	9	6	3	18	1.7
Myotis lucifugus	265	91	7	363	34.4
Myotis sodalis	64	5	0	69	6.6
Myotis septentrionalis	226	75	6	307	29.1
Lasiurus borealis	34	9	8	51	4.8
Lasiurus cinereus	3	1	0	4	0.4
Lasionycteris noctivagans	0	4	0	4	0.4
Corynorhinus townsendii	1	0	0	1	<0.1
Total	786	237	31	1054	100.0

Table 4. Number of bats captured, by species, during eleven trapping sessions on the Fernow Experimental Forest, Tucker County, West Virginia 1995. P. sub. = *Pipistrellus subflavus*, E. fus. = *Eptesicus fuscus*, M. luc. = *Myotis lucifugus*, M. sep. = *M. septentrionalis*, L. bor. = *Lasiurus borealis*, L. cin. = *L. cinereus*, L. noc. = *Lasionycteris noctivagans*, C. tow. = *Corynorhinus townsendii virginianus*.

Session	Species									Total
	P. sub.	E. fus.	M. luc.	M. sod.	M. sep.	L. bor.	L. cin.	L. noc.	C. tow.	
Late Apr	16	0	26	0	9	0	0	0	0	51
Late May	49	2	14	0	5	0	0	0	0	70
Late Jun	1	6	3	1	10	3	0	0	0	24
Late Jul	24	8	34	5	21	6	3	0	0	101
Mid Aug	44	0	20	2	49	0	0	0	0	115
Late Aug	42	2	139	8	93	28	0	0	0	342
Mid Sep	15	0	23	8	36	0	0	0	0	82
Late Sep	39	0	32	16	54	12	1	0	0	154
Mid Oct	3	0	17	16	7	0	0	0	0	43
Late Oct	4	0	25	13	22	2	0	4	1	71
Late Nov	0	0	0	0	1	0	0	0	0	1
Total	237	18	363	69	307	51	4	4	1	1054

Table 5. Bats trapped at the entrance of Big Springs Cave, Fernow Experimental Forest, Tucker County, West Virginia, April - November 1995.

Species	Sex			Total
	Male	Female	Unknown	
Pipistrellus subflavus	175	43	7	225
Myotis lucifugus	205	75	3	283
Myotis sodalis	60	5	0	65
Myotis septentrionalis	212	70	4	286
Total	652	193	14	859

Table 6. Body mass and forearm length data, by species and sex, for nine species of bats captured on the Fernow Experimental Forest, Tucker County, West Virginia, April - November, 1995. Body masses are in grams; forearm lengths are in millimeters. Format is: Mean ± 1 Standard Error (N, Minimum-Maximum). Significant differences between sexes are denoted as * $p < 0.05$ and ** $p < 0.01$.

Species	Body Mass		Forearm Length	
	Male	Female	Male	Female
Pipistrellus subflavus	5.71 ± 0.078** (178, 4.1-9.5)	6.35 ± 0.150** (48, 4.8-9.2)	33.8 ± 0.182 (186, 32.0-38.0)	34.4 ± 0.359 (48, 32.0-38.0)
Eptesicus fuscus	17.94 ± 0.449* (8, 16.0-22.2)	19.78 ± 0.243* (8, 19.0-20.7)	45.5 ± 0.423 (8, 44.0-47.0)	46.6 ± 0.532 (8, 44.0-49.0)
Myotis lucifugus	6.84 ± 0.058 (255, 4.8-9.8)	6.85 ± 0.095 (90, 4.8-9.1)	36.6 ± 0.151 (268, 34.0-39.0)	36.6 ± 0.412 (92, 34.0-39.0)
Myotis sodalis	7.58 ± 0.091 (63, 6.1-9.2)	7.32 + 0.471 (5, 6.8-9.2)	37.8 ± 0.156 (64, 34.0-40.0)	38.6 + 0.245 (5, 38.0-39.0)
Myotis septentrionalis	6.53 + 0.081 (222, 4.7-10.0)	6.81 ± 0.130 (75, 5.2-9.8)	35.8 + 0.076* (235, 33.0-39.0)	36.1 ± 0.105* (77, 34.0-38.0)
Lasiurus borealis	9.98 ± 0.178** (36, 8.5-13.1)	13.87 ± 1.269** (8, 9.1-18.4)	39.8 ± 0.269* (36, 36.0-44.0)	41.1 ± 0.459* (8, 39.0-42.0)
Lasiurus cinereus	25.67 ± 1.150 (3, 22.9-28.1)	32.3 (1)	52.7 ± 0.333 (3, 52.0-53.0)	55.0 (1)
Lasionycteris noctivagans	--	12.73 ± 0.448 (4, 11.5-13.6)	--	41.5 ± 0.500 (4, 40.0-42.0)
Corynorhinus townsendii	10.2 (1)	--	45.0 (1)	--

Table 7. Mean body mass and sample size, by species, during eleven trapping sessions on the Fernow Experimental Forest, Tucker County, West Virginia 1995. P. sub. = *Pipistrellus subflavus*, E. fus. = *Eptesicus fuscus*, M. luc. = *Myotis lucifugus*, M. sep. = *M. septentrionalis*, L. bor. = *Lasiurus borealis*, L. cin. =*L. cinereus*, L. noc. = *Lasionycteris noctivagans*, C. tow. = *Corynorhinus townsendii virginianus*.

Species	Session										
	Late Apr	Late May	Late Jun	Late Jul	Mid Aug	Late Aug	Mid Sep	Late Sep	Mid Oct	Late Oct	Late Nov
P. sub.	5.48 N=16	4.59 N=47	5.50 N=1	5.54 N=12	5.78 N=42	5.74 N=40	7.34 N=15	6.99 N=38	6.03 N=3	5.73 N=3	--
E. fus.	--	--	18.68 N=5	18.94 N=8	16.00 N=1	--	--	--	--	--	--
M. luc.	6.06 N=26	6.26 N=13	7.30 N=3	6.66 N=21	6.55 N=19	6.73 N=161	7.49 N=22	7.56 N=30	7.32 N=14	7.05 N=25	--
M.sod.	--	--	7.60 N=1	7.46 N=5	7.20 N=2	6.76 N=8	7.75 N=8	7.63 N=16	7.57 N=15	7.91 N=13	--
M. sep.	5.47 N=8	5.30 N=4	6.32 N=7	6.24 N=10	6.26 N=46	6.26 N=92	7.19 N=36	7.58 N=51	7.84 N=7	6.93 N=22	6.70 N=1
L. bor.	--	--	12.35 N=2	10.48 N=6	--	10.68 N=21	--	9.73 N=9	--	13.00 N=2	--
L. cin.	--	--	--	28.80 N=3	--	--	--	22.90 N=1	--	--	--
L. noc.	--	--	--	--	--	--	--	--	--	12.70 N=4	--
C. tow.	--	--	--	--	--	--	--	--	--	10.20 N=1	--

Table 8. Results of the winter bat survey conducted in Big Springs Cave on 23 February 1996 and number of bats, by species, banded on the on the Fernow Experimental Forest, Tucker County, West Virginia, April - November 1995.

Species	Number of Bats Observed in Winter	Number Banded			Band Recoveries in Winter		
		Male	Female	Total	Male	Female	Total
Pipistrellus subflavus	146	50	23	73	8	0	8
Eptesicus fuscus	0	1	0	1			
Myotis lucifugus	652	192	36	228	68	13	81
Myotis sodalis	183	17	4	21	15	3	18
Myotis septentrionalis	9	163	63	226	3	0	3
Lasiurus borealis	0	26	5	31	0	0	0
Lasiurus cinereus	0	1	0	1	0	0	0
Lasionycteris noctivagans	0	0	4	4	0	0	0
Corynorhinus townsendii	0	0	0	0	0	0	0
Total	990	450	135	585	94	16	110