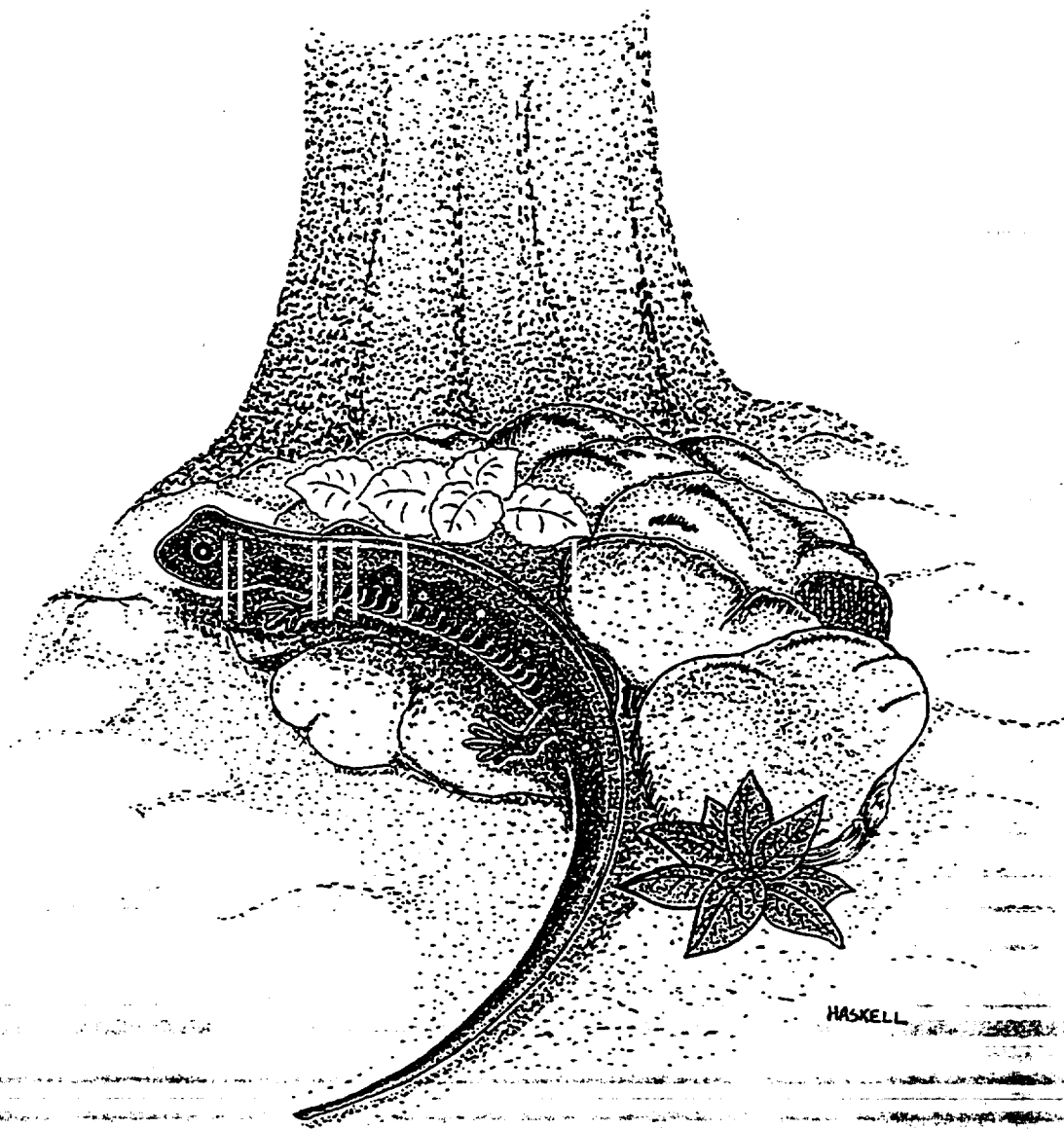


# SHENANDOAH SALAMANDER

*(Plethodon shenandoah)*



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## RECOVERY PLAN

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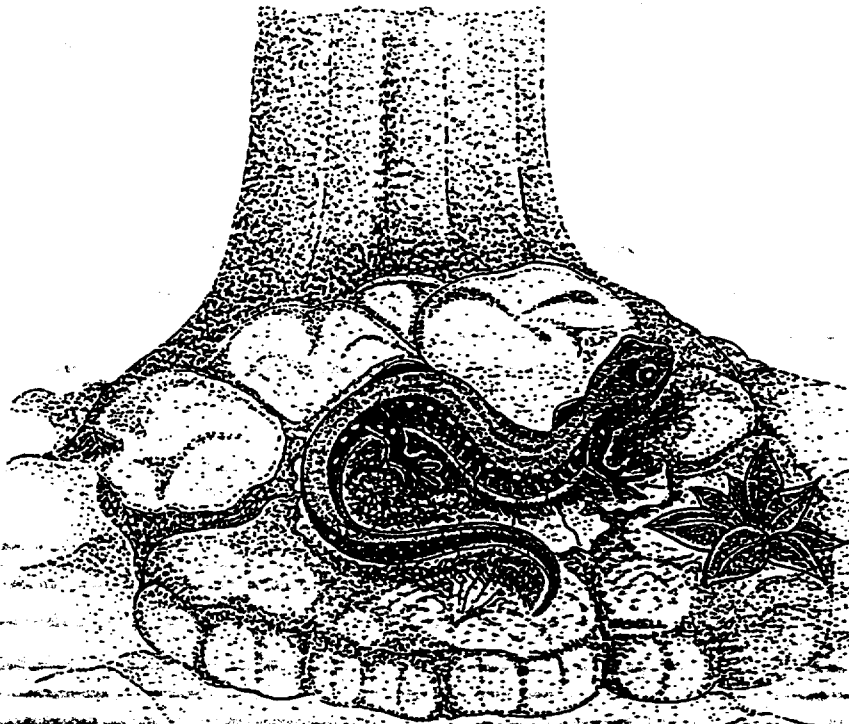
U.S. FISH AND WILDLIFE SERVICE • REGION FIVE • HADLEY, MASSACHUSETTS



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**SHENANDOAH SALAMANDER**  
(*Plethodon shenandoah* Highton and Worthington)

**RECOVERY PLAN**

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in cooperation with

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for:

Region Five  
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Hadley, Massachusetts

Approved: \_\_\_\_\_

  
Regional Director, U.S. Fish and Wildlife Service, Region Five

Date: \_\_\_\_\_

9-29-94

## EXECUTIVE SUMMARY

### Shenandoah Salamander Recovery Plan

**Current Species Status:** *Plethodon shenandoah*, a small, terrestrial woodland salamander, is known from three isolated populations within the Shenandoah National Park in Virginia. It was originally thought to be declining exclusively by virtue of natural causes, primarily interspecific competition with the more aggressive red-backed salamander (*P. cinereus*). It now appears that human-related factors may be threatening the species, e.g., acid deposition and tree defoliation caused by introduced pest insects. The Shenandoah salamander was listed as endangered in August 1989.

**Habitat Requirements and Limiting Factors:** *P. shenandoah* occurs only on relatively dry, rocky, talus slopes, generally of northern aspect and above 800 meters, on three mountains within the boundaries of Shenandoah National Park: Hawksbill, The Pinnacles, and Stony Man. The species is found in forested conditions, where the presence of an overstory promotes some degree of surface moisture, although *P. shenandoah* apparently has a higher tolerance for dehydration than *P. cinereus*. As with all *Plethodon*, the Shenandoah salamander is primarily nocturnal, and its movements are restricted during droughts.

**Recovery Objective:** To stabilize Shenandoah salamander populations by minimizing human impacts on the species and its habitat, while allowing natural competition to continue.

#### **Actions Needed:**

1. Determine boundaries of occupied habitat and determine whether additional populations exist.
2. Monitor known Shenandoah salamander populations on a long-term basis.
3. Determine and minimize the impact of human-related factors on the Shenandoah salamander.
4. Investigate relevant aspects of *P. shenandoah* life history.
5. Ensure the compatibility of park maintenance and management activities with Shenandoah salamander populations.
6. Promote information exchange on the Shenandoah salamander.

#### **Estimated Cost of Recovery (in thousands):**

	<u>NEED 1</u>	<u>NEED 2</u>	<u>NEED 3</u>	<u>NEED 4</u>	<u>NEED 5</u>	<u>NEED 6</u>	<u>TOTAL</u>
FY1	2	15	46	10	0.5	5	78.5
FY2	2	15	23	10	0.5		50.5
FY3	<u>2</u>	<u>6</u>	<u>18</u>	<u>   </u>	<u>0.5</u>	<u>   </u>	<u>26.5</u>
Total	6	36	87	20	1.5	5	155.5

Costs after FY3 not determined.

**Time Frame:** Stabilization means that the salamander will remain listed in perpetuity unless new information indicates a potential for significant improvement in status.

\* \* \*

The following recovery plan delineates a practical course of action for protecting the endangered Shenandoah salamander (*Plethodon shenandoah*). Attainment of recovery objectives and availability of funds will be subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities.

This plan has been prepared by the U.S. Fish and Wildlife Service, in cooperation with the National Park Service. However, recovery plans do not necessarily reflect the views or official position of individuals or agencies involved in their formulation, other than the U.S. Fish and Wildlife Service. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

Literature citations should read as follows:

U.S. Fish and Wildlife Service. 1994. Shenandoah salamander (*Plethodon shenandoah*) Recovery Plan. Hadley, Massachusetts. 36 pp.

Additional copies of this plan can be purchased from:

Fish and Wildlife Reference Service  
5430 Grosvenor Lane, Suite 110  
Bethesda, Maryland 20814  
301-492-6403  
or  
1-800-582-3421

Cost varies according to number of pages.

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## PART I: INTRODUCTION

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The Shenandoah salamander (*Plethodon shenandoah*), a small terrestrial salamander found only within the Shenandoah National Park in Virginia, was listed as endangered by the Commonwealth of Virginia on October 1, 1987 (Wynn 1991), and was designated as Federally endangered on August 18, 1989 (54 FR 34464). Initially, the Shenandoah salamander was believed to be endangered exclusively by natural biological causes, indicating that this species would not benefit from preparation of a recovery plan. However, it now appears that certain human-related factors, such as acid deposition and forest defoliation associated with introduced pest insects, are likely to have adverse effects on the salamander. This recovery plan addresses these factors. In addition, it analyzes how the Shenandoah salamander could be affected by routine management and permitted activities (e.g., trail maintenance, fire management, camping) within Shenandoah National Park in order to minimize potential human impacts to the species. In 1992, the U.S. Fish and Wildlife Service determined that a recovery plan was warranted for the Shenandoah salamander, and plan preparation began at that time.

### DESCRIPTION AND TAXONOMY

Adult *Plethodon shenandoah* measure 40-57 mm in snout-vent length and 85-110 mm in total length. This salamander occurs in two distinct color phases: the striped phase has a relatively narrow red to yellow line along the length of the dorsal surface; the unstriped phase is uniformly dark with scattered brassy flecks. Both color phases have dark undersides with variable amounts of white or yellow mottling (Highton and Worthington 1967). This feature readily distinguishes them from their closely related and widespread competitor, the red-backed salamander (*Plethodon cinereus*), the underside of which is strongly mottled in a "salt-and-pepper" pattern.

*Plethodon shenandoah* was originally described as a subspecies of *Plethodon richmondi* (Highton and Worthington 1967) and later considered to be a subspecies of *P. nettingi* (Highton 1972). Subsequent analyses of electrophoretic data resulted in a determination of full species status for *P. shenandoah* (Highton and Larson 1979).

## DISTRIBUTION

The Shenandoah salamander is known only from talus slopes, generally of northern aspect and above 800 meters, on three mountains, all within the boundaries of Shenandoah National Park in Page and Madison counties, Virginia: Hawksbill, The Pinnacles, and Stony Man (Highton and Worthington 1967). Recent survey work (W. Witt and L. Via, volunteer staff, Natural Resources and Science, Shenandoah National Park, unpubl. data) has more thoroughly defined the boundaries of these populations, and has extended the Stony Man isolate to include Bushytop and a narrow, linear subpopulation below Hemlock Springs Overlook (Figures 1-3).

## LIFE HISTORY AND ECOLOGY

*Plethodon shenandoah* is a member of the family Plethodontidae, the lungless salamanders. The largest and most successful group of living salamanders, the plethodontids appear to have originated in eastern North America, most likely in the Appalachians, which have been elevated since the close of the Paleozoic Era (Hairston 1987). All members of this family lack lungs (Zug 1993); respiration occurs through the skin surface, which must be kept constantly moist for this purpose. The lack of lungs restricts these salamanders' maximum size and is a significant factor in the ecology, particularly of terrestrial species.

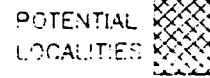
All members of the genus *Plethodon* are terrestrial and are sometimes referred to as woodland salamanders. These salamanders are generally found in forested conditions, where the presence of an overstory promotes surface moisture. They are



# HAWKSBILL ISOLATE, SHENANDOAH SALAMANDER RECOVERY PLAN

PREPARED BY VIA & WITT, 4-OCT-94

TALUS BASED ON JAEGER, 1970, PAGE 635, FIG. 1



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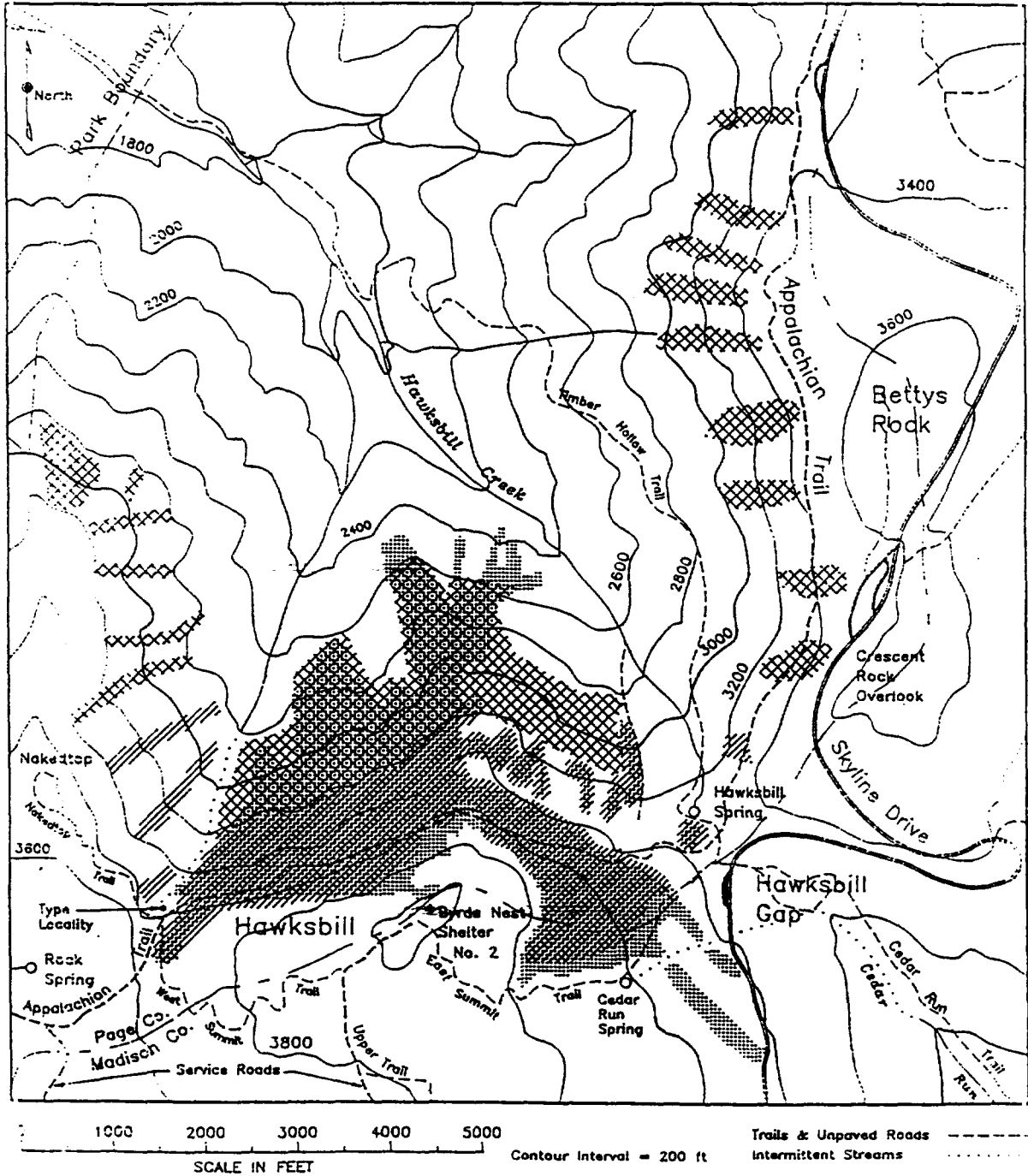


Figure 1. *Plethodon shenandoah* localities on Hawksbill Mountain

Potential localities, i.e., search areas, are based on known vertical range (2580-3985 ft). The areas delineated include mainly unsuitably habitat.

# STONY MAN ISOLATE, SHENANDOAH SALAMANDER RECOVERY PLAN

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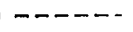
PREPARED BY VIA S. WILSON

26-SEP-94

KNOWN LOCALITIES 

POTENTIAL LOCALITIES 

TRAILS 

FIRE ROAD 

INTERMITTENT STREAMS 

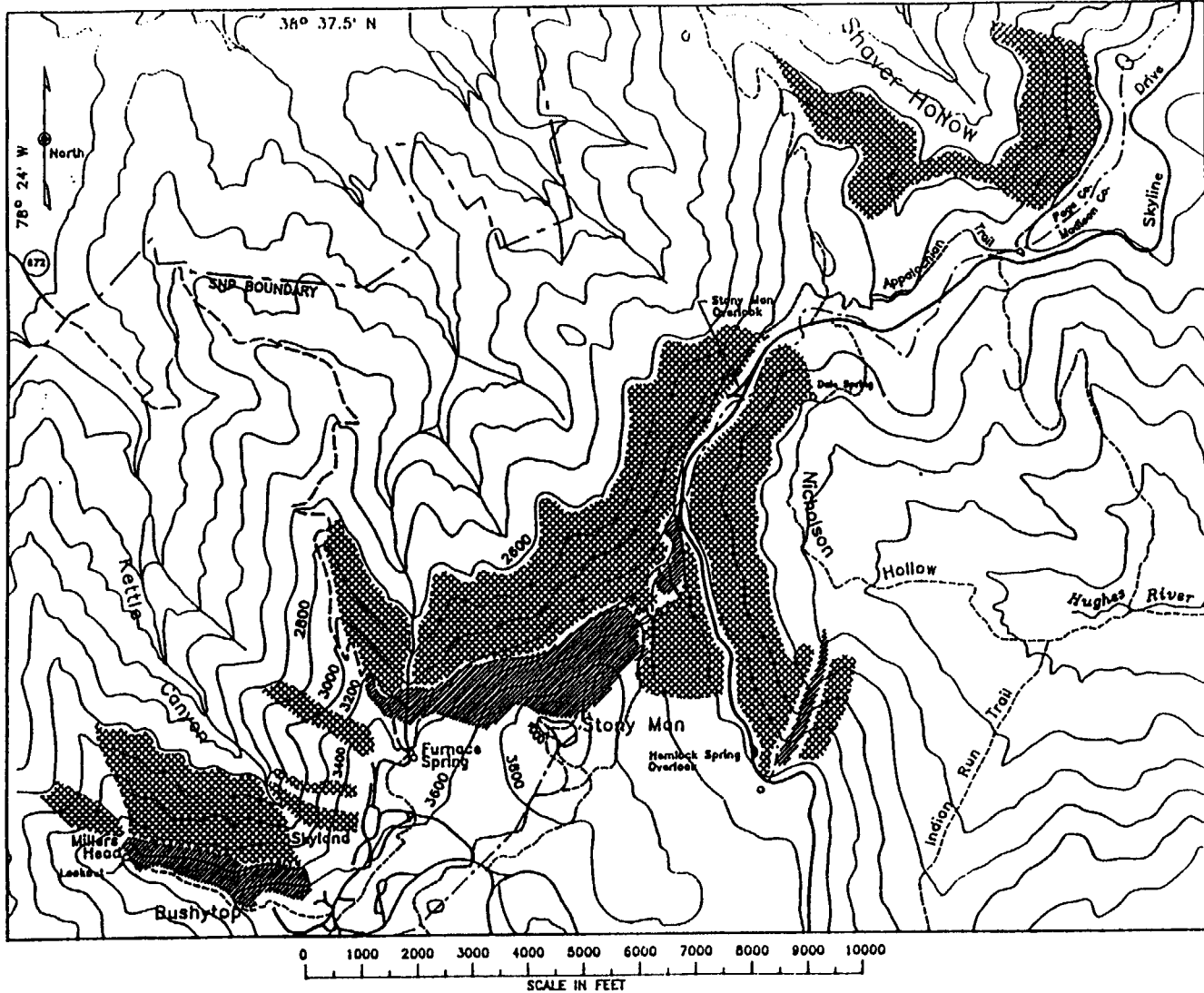




Figure 2. *Plethodon shenandoah* localities on Stony Man Mountain

PINNACLE ISOLATE, SHENANDOAH SALAMANDER RECOVERY PLAN

PREPARED BY VIA & WITT, 4-OCT-94

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KNOWN LOCALITIES  POTENTIAL LOCALITIES   
 (Based in part on C. Pague, per. comm.) (Based on aerial photographs)

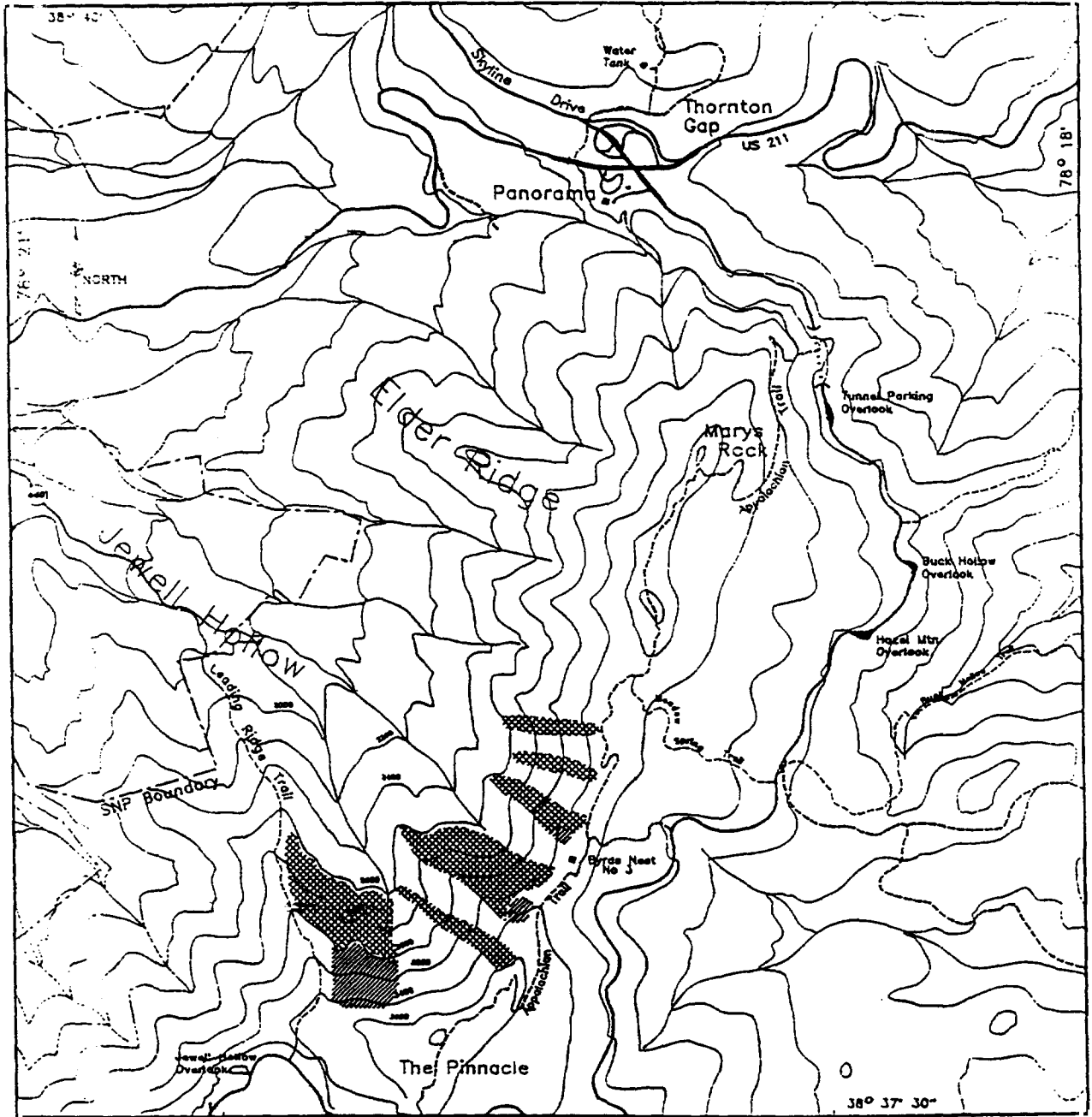


Figure 3. *Plethodon shenandoah* localities on The Pinnacles

primarily nocturnal, spending the day under protective cover objects or in rock crevices; their movements are restricted during droughts.

The diet of woodland salamanders generally consists of mites, springtails, flies, small beetles and other soil invertebrates (Pauley 1980). Breeding typically takes place in late spring or summer; fertilization is internal. In contrast with most other salamanders, woodland salamanders develop completely within the egg (Conant and Collins 1991). The lack of an aquatic larval stage "liberates" these salamanders from a mandatory proximity to open or flowing water. Small egg clusters (3-17 eggs) are laid in damp logs, moss, or other available crevices, and the female generally guards the eggs (Brooks 1948, Behler and King 1979). Incubation lasts one to three months, during which time the female does not forage for food. In a study of *Plethodon jordani*, Hairston (1987) found that females do not breed before the age of four years, and generally breed only every other year thereafter. Adult survival was found to be high, with a small percentage surviving 25 years or longer.

Various studies have elucidated the interspecific competition between *Plethodon shenandoah* and *P. cinereus*, particularly on Hawksbill Mountain. Studies conducted on Hawksbill Mountain by R.G. Jaeger (Jaeger 1970, 1971a, 1971b, 1972) indicated that *Plethodon cinereus* excludes *P. shenandoah* from areas of moist, deep soil. As a result, *P. shenandoah* is restricted to relatively drier, rocky talus slopes. *P. shenandoah* apparently has a higher tolerance for dehydration and is thus able to survive desiccating conditions that are lethal to *P. cinereus* (Jaeger 1971a).

Laboratory experiments conducted in the 1970s and 1980s indicated that the competitive exclusion of *P. shenandoah* by *P. cinereus* may be maintained by interspecific aggression and territoriality (Thurow 1976, Kaplan 1977, Jaeger and Gergits 1979, Wrobel *et al.* 1980, Gergits 1982). These laboratory results were corroborated by field observations of aggressive behavior in *P. cinereus* (Gergits and Jaeger 1990). Removal experiments have shown that *P. cinereus* individuals compete intraspecifically for large cover objects (rocks and logs); soil temperatures beneath larger (> 23cm x 24 cm x 2 cm) objects are lower, thus more suitable for salamanders, than temperatures

under smaller (11 cm x 11 cm x 2 cm) objects (M. Griffis, University of Southwestern Virginia, pers. comm. 1991).

Recent field studies conducted on Hawksbill Mountain (M. Griffis and R.G. Jaeger, University of Southwestern Louisiana, unpubl. data) provide further evidence of *P. cinereus* territoriality in the exclusion of *P. shenandoah*. Near the talus-soil interface, *Plethodon shenandoah* were found to invade territories where *P. cinereus* had been removed more often and more rapidly than where *P. cinereus* had not been removed. However, in preliminary laboratory experiments, *P. shenandoah* and *P. cinereus* were equally aggressive toward each other (M. Griffis unpubl. data; J. Jacobs, U.S. Fish and Wildlife Service, pers. obs.). These laboratory results await further investigation.

The populations of *P. shenandoah* at The Pinnacles and Stony Man have not been studied as thoroughly as those at Hawksbill. Although on Hawksbill the two species are largely non-overlapping in distribution, they appear to be more sympatric at The Pinnacles (Highton and Worthington 1967; W. Witt pers. comm.). This could be due to a different distribution of talus between the two areas (R.G. Jaeger pers. comm.), or may truly represent interpopulational differences in the competitive interactions between the two species. There may also be differences in rates of interspecific hybridization at different isolates (A. Wynn, Smithsonian Institution, pers. comm. 1993). R. Highton and A. Wynn (unpubl. data), using protein electrophoresis, have found evidence of introgression between *Plethodon shenandoah* and *P. cinereus* at one locality on Hawksbill Mountain, although A. Wynn (*in litt.* 1994) is not aware of genetic evidence of hybridization in other localities. Determination of hybridization in other localities is based on the field examination of individual specimens, which should be further verified through electrophoretic studies.

## THREATS TO THE SPECIES

Past effects of naturally-occurring fires, farming, and timbering operations (which occurred prior to the establishment of Shenandoah National Park in 1936) on the current limited distribution of the Shenandoah salamander are unknown. In its present

environment, however, certain threats to this salamander's continued existence appear to be unrelated to human intervention: (1) competition with the aggressive and successful red-backed salamander (*Plethodon cinereus*), which confines *P. shenandoah* to a few relatively dry talus areas that are not occupied by this competitor (Thurow 1976, Jaeger 1974); and (2) eventual succession of this talus, through weathering and soil formation, to moister habitat, more suitable for occupation by red-backs (Jaeger 1970). *Plethodon cinereus* is widely distributed and completely surrounds each of the three isolates of *P. shenandoah* (Highton and Worthington 1967, W. Witt pers. comm.). It appears to be expanding its geographic range at the expense of several other species of salamanders (Highton 1972, Jaeger 1974).

Against this backdrop of naturally occurring threats to the salamander's continued existence, two major, relatively recent anthropogenic factors appear to have the potential of further endangering *P. shenandoah* as well as threatening other faunal and floral components of its ecosystem. These include: (1) defoliation of trees within its habitat, associated with outbreaks of gypsy moths (*Lymantria dispar*), hemlock woolly adelgids (*Adelges tsugae*), or other introduced forest pest species, and (2) further debilitation of overstory vegetation, changes in soil chemistry, and direct impacts to the salamanders associated with acid deposition and other sources of air pollution.

The spread of introduced forest pest species within the range of the Shenandoah salamander is too recent to have documented effects on the salamanders. However, defoliation and tree mortality associated with gypsy moths is well-documented (e.g., Hicks and Fosbroke 1987), and hemlock woolly adelgids are becoming a serious threat to hemlock survival within Shenandoah National Park (K. Watson, Shenandoah National Park, pers. comm.). Habitat changes associated with these insect pests could result in adverse effects to Shenandoah salamanders. For example, in certain sections of Shenandoah salamander habitat where hemlock mortality is high (i.e., Stony Man isolate), the duff layer now consists almost entirely of hemlock needles (J. Jacobs pers. obs.). This will certainly lower substrate pH, which, in turn, may alter soil microbe and invertebrate composition, with unknown effects to salamander physiology and foraging success. Defoliation caused by gypsy moths results in increased ground-level insolation, at least temporarily, with unknown effects to salamanders. One possible

result of defoliation is desiccation of the talus substrate beyond the Shenandoah salamander's tolerance or reproductive limits.

Other potential effects include the possibility that an increase in groundcover following overstory removal could alter the Shenandoah salamander's prey-capturing ability, or "tip the ecological balance" in favor of red-backs. Acid deposition may also act synergistically with forest insect pests, further increasing tree mortality (National Park Service 1990).

Acid deposition and other sources of air pollution are well-documented at Shenandoah National Park (National Park Service 1990). As with forest pests, effects of these factors on Shenandoah salamanders have not been documented; however, numerous studies have indicated that amphibians may be highly vulnerable to the effects of acid deposition, particularly in montane areas (Corn *et al.* 1989, Harte and Hoffman 1989). Although the Shenandoah salamander does not have an aquatic larval stage, acidification of its habitat substrate could affect the species' food supply, or could impair reproduction by directly affecting courtship, egg hatchability, or neonate viability. Because salamanders forage preferentially during rainy or foggy weather, they would be particularly susceptible to any directly irritating effects acid deposition may have on their integument. Salamanders could also be affected by other air pollutants such as formaldehyde. Amphibians have proven to be more highly susceptible to formalin, the dissolved form of this pollutant, than are fish or invertebrates (Hall and Henry 1992).

With regard to soil acidity, Wyman *et al.* (1987) have shown dramatic effects to *Plethodon cinereus*. Under natural conditions, salamander abundance was reduced by 83% at soil pH values below 3.7, and juvenile salamanders were never found at or below this value. In the laboratory, substrate pH values between 3 and 4 were shown to be chronically lethal to *P. cinereus*, and growth and respiration were reduced at low pH levels. Results of the Shenandoah Watershed Study (a monitoring project initiated in 1979) have indicated that acidification is ongoing, and that 60-70% of the sulfate deposited in park watersheds is being adsorbed by watershed soils (National Park Service 1990). It is likely that *P. shenandoah* will be negatively affected by the increasing soil acidity documented at Shenandoah National Park; differential sensitivity

of *P. shenandoah* versus *P. cinereus* to substrate acidity is presently unknown. Again, even minute differences in sensitivity would likely favor one species over the other. Increased soil sulfate levels have also been shown to be associated with decreases in the abundance of insects that could be fed upon by salamanders (Bromenshenk 1980, Leatham *et al.* 1980, McNary *et al.* 1980).

Use of herbicides on powerline rights-of-way within the vicinity of Shenandoah salamander habitat may have some toxic effects on this species, along with other amphibians. Although no specific effects have been documented to date, the chemicals used in herbicides need to be evaluated.

It thus appears that the initial reason for listing the Shenandoah salamander as endangered (i.e., long-term prospect of extinction due to competition with the red-backed salamander) may be overshadowed by the more immediate prospect of extinction or severe population declines from human-related factors such as introduced forest pests and environmental pollution. This contention seems reasonable, given the data available from studies of other amphibians (e.g., Pierce 1985) and the dramatic declines of amphibians now occurring worldwide (Gibbs *et al.* 1971, Barinaga 1990, Phillips 1990).

Finally, although Park management within Shenandoah salamander habitat is conducted with conservation of this species as the overriding objective, the cumulative and/or inadvertent effects of various activities could pose continuing risks to its stability. The effects of trail maintenance and use, and concomitant backcountry camping (despite a prohibition on camping in the vicinity of *P. shenandoah* habitat) are less pervasive than the major concerns outlined above, but they nevertheless need to be considered when developing and assessing long-range management programs for the area. In regard to trails specifically, it is possible that some plethodontid salamanders do not cross roads, and even trails may be effective barriers to their movements (T. Pauley, Marshall University, pers. comm.). This may or may not be the case for the Shenandoah salamander, which can, perhaps, move through deep talus below the surface of many trails. Trails into the talus may also provide the means for *P. cinereus* to penetrate further into these areas than would normally occur, by providing avenues of



soil-filled talus. Although this effect may be negligible, it should be noted that some areas regarded as possible hybrid localities (not mapped) are at or near points where a trail enters a *P. shenandoah* locality. Regardless of whether these are actually areas where the two species hybridize, or just occur together, it suggests that trails into the talus may be affecting the interaction of *P. shenandoah* and *P. cinereus* (A. Wynn *in litt.*).

Illegal camping, with its potential for disturbance of the soils and vegetation within Shenandoah salamander habitat is an ongoing problem, requiring active enforcement of backcountry camping regulations.

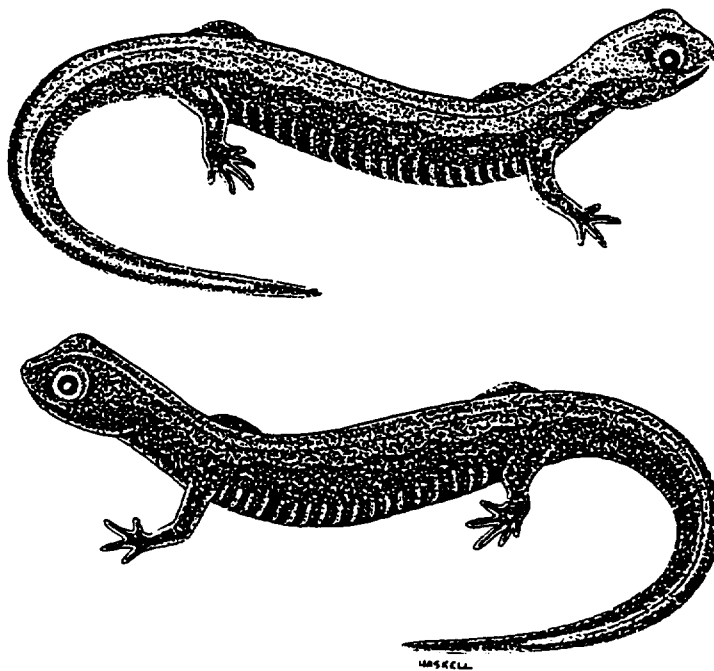
Concerns related to fire management include potential disturbance from construction of fire lines and fire suppression activities in the vicinity of salamander habitat; however, careful timing and management oversight should alleviate most if not all detrimental effects.

## RECOVERY STRATEGY

The apparently major role of a natural factor, interspecific competition, in the endangerment of the Shenandoah salamander sets it apart from most other listed species, and dictates an approach to recovery that differs from that taken in most recovery plans. In the case of the Shenandoah salamander, it is not deemed advisable to undertake management actions aimed at increasing population numbers, transplanting individuals, or reducing naturally occurring competitors. It is unusual to find a situation where interspecific competition (or evolutionary ecology) can be readily observed and studied under natural conditions, and every effort should be made to avoid disrupting the subtle balance of interactions that are being played out. Instead, recovery efforts should be geared towards *minimizing human-related impacts* on the Shenandoah salamander, and on adjacent populations of the red-backed salamander with which it interacts.

Given existing environmental conditions at Shenandoah National Park, the major aims of the Shenandoah salamander recovery program are: (1) to evaluate and attempt to minimize effects of forest pest species and agents used to control them on Shenandoah salamanders; (2) to determine and attempt to minimize the effects of airborne pollutants, including acid deposition, on these salamanders; (3) to minimize the effects of maintenance or other management activities conducted in Shenandoah salamander habitat; (4) to monitor periodically the distribution and abundance of *P. shenandoah* and nearby or sympatric populations of *P. cinereus*; and (5) to tell visitors to Shenandoah National Park the story of this rare, endemic salamander.

It is possible that the Shenandoah salamander once occurred on talus areas between or adjacent to known populations; however, the technique of transplanting Shenandoah salamanders into some of these areas has been determined to be unfeasible, costly, and unnecessary. If at some future time it appears that the Shenandoah salamander is on the verge of extinction, options for gene pool preservation should be considered.



## PART II: RECOVERY

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### RECOVERY OBJECTIVE

Due to the long-term threat of extinction of the Shenandoah salamander through interspecific competition with the red-backed salamander, it is not possible to establish criteria for reclassifying or delisting *Plethodon shenandoah* in the foreseeable future. It is not anticipated that this situation will change, unless future studies of the relationship between *Plethodon cinereus* and *P. shenandoah* indicate that such change is warranted, or additional population discoveries indicate that *P. shenandoah* is much more abundant than previously believed. The recovery objective for this species is, therefore, stabilization of known populations by minimizing human impacts on the Shenandoah salamander.

### RECOVERY TASKS

1. Continue searches of appropriate habitat, to define boundaries of existing populations and to determine whether additional populations exist.

Great strides have recently been made in filling in the details of Shenandoah salamander distribution, thanks largely to the efforts of W. Witt (unpubl. data; Figures 1-3). This information, especially when incorporated into the Geographic Information System (GIS) for the Park, will be very useful in clearly identifying areas where potential conflicts with human use (e.g., roads, trails, campsites) could occur. These areas should then become the focus of more intensive monitoring and management efforts (Tasks 2.2 and 4), to minimize the probability of inadvertent impacts to salamanders. Detailed distribution information will also clarify the relationship between *P. shenandoah* and *P. cinereus*.

2. Monitor salamander populations at Hawksbill, Stony Man, and The Pinnacles on a long-term basis.

The objective of long-term monitoring is to detect any significant changes in size or demographic structure of *P. shenandoah* populations and/or any shifts in distribution between this salamander and *P. cinereus*.

2.1 Determine optimal survey methodology for long-term monitoring. On an experimental basis at one or more isolates, various survey techniques such as pitfall grids, drift fences with funnel traps or pitfalls, night-time transects, or artificial cover objects (T. Pauley *in litt.* 1994) will be evaluated to determine the most appropriate design for long-term monitoring of Shenandoah and adjacent red-backed salamander populations. The methodology will be designed to minimize mortality and will be subject to peer review and approval by the National Park Service, U.S. Fish and Wildlife Service, and Virginia Department of Game and Inland Fisheries.

2.2 Monitor *Plethodon shenandoah* populations at all three isolates on a regular basis. The survey methodology determined in Task 2.1 to yield the most reliable results will be employed at all three isolates for long-term monitoring. In addition to overall population trends at each site, monitoring will allow a comparison of population and distributional variability among the isolates. Collection of baseline data sufficient to determine population trends may take a number of years due to inherent population fluctuations resulting from endogenous and environmental factors. A minimum time frame for monitoring of at least 10 years is also necessary due to the long life span of these salamanders (T. Pauley *in litt.* 1994).

When the monitoring system becomes operational, longer-than-annual monitoring intervals (e.g., every three years) should be sufficient to detect long-term population changes, although more frequent monitoring may be advisable in the event of rapid, short-term ecological changes (e.g.,

fire, defoliation episodes). Monitoring should be conducted at all three isolates during the same year. At the end of each monitoring session, a meeting will be scheduled with the U.S. Fish and Wildlife Service and the Virginia Department of Game and Inland Fisheries to discuss survey results. If *P. shenandoah* numbers, population structure, and/or distribution change significantly from previous years, initiation of Section 7 consultation with the U.S. Fish and Wildlife Service may be indicated.

3. Study the effects of human-related factors that potentially threaten the salamanders.

3.1 Study the effects of air pollution/acid deposition on salamander physiology and ecology. Previous studies at Shenandoah National Park have indicated significant air pollution and acid deposition in the area, resulting in adverse effects to the Park's air quality resource values (Thomas 1993, National Park Service 1990). Amphibians are known to be particularly susceptible to acid deposition (Pierce 1985). The Park should continue to support monitoring and studies of ozone, sulfates, and nitrates within Shenandoah National Park boundaries. Furthermore, high priority should be given to initiating studies of the impacts of acid deposition and soil acidity on all amphibians within Shenandoah National Park, particularly, for the purposes of this plan, on *P. shenandoah* and *P. cinereus*. If severe physiological or reproductive effects are found, the need for remedial action on a large scale will be highlighted.

3.1.1 Compare the preferences and physiological tolerances to acidity of *P. shenandoah* and *P. cinereus*. There is a possibility that, as with temperature and moisture, the physiological tolerance of *P. shenandoah* to acidification of its substrate differs significantly from that of *P. cinereus*. If this is the case, acid deposition may affect the "ecological balance" of these two species. This study could be undertaken in the field as well as under laboratory

conditions (see, e.g., Wyman *et al.* 1987). Acute studies of physiological tolerance should be designed to minimize mortality.

3.1.2 Study reproductive and chronic effects of acidity. These longer-term studies may be more difficult to accomplish under laboratory conditions, but they are crucial to understanding the magnitude of this threat. It may be possible to design a study using *P. cinereus* as a surrogate, depending on the results of Task 3.1.1.

3.1.3 Determine the history and susceptibility of Shenandoah salamander habitat to acidification. There is some evidence that an examination of tree rings can reveal information about previous soil metal ion balance and the history of acid precipitation in a particular area (Bondietti *et al.* 1989, Legge *et al.* 1984, McClenahan *et al.* 1987). Such a study would help to determine trends in soil acidification within Shenandoah salamander habitat. A specific study of factors associated with soil acidification, such as sulfate adsorption capacity (see National Park Service 1990), may be appropriate.

3.2 Evaluate the effects of roads and trails on movements of Shenandoah salamanders and potential population fragmentation. This evaluation will require following movements of marked individuals. The results should allow managers to make informed decisions on locations of existing and proposed roads and trails. A separate study may not be required for completion of this task if data from development of the monitoring protocol (Task 2.1) provide sufficient information to address this concern. Until the results from this study are available, or in lieu of this study, it shall be Park policy that no new roads or trails will be constructed through Shenandoah salamander habitat.

3.3 Evaluate the effects of potentially habitat-altering agents such as forest pest species and fires. Introduced pests, such as gypsy moth and

hemlock woolly adelgid, have reached problem levels in and adjacent to areas of known *P. shenandoah* habitat. Heavy infestations of the adelgid may be directly responsible for mortality of hemlocks in some areas (K. Watson pers. comm.). Repeated defoliation by gypsy moths, added to the effects of native defoliators such as the walkingstick (Order: Phasmida) or fall cankerworm (*Alsophila pometaria*) may weaken the trees' resistance to other stresses and could result in mortality (Hicks and Fosbroke 1987).

There are many unknowns surrounding the effects on Shenandoah salamanders of these forest pests or the agents used to control them. For example, tree defoliation or loss may result in further drying of the salamanders' talus habitat to the point where it is no longer suitable, or, conversely, defoliation of habitat adjacent to the talus may render a competitive advantage to *P. shenandoah*, resulting in its expansion into habitat previously occupied by *P. cinereus*. Alternatively, defoliation or loss of trees may have little long-term impact on these salamanders, due to their largely subterranean habits, their long lifespans, and the general sparsity of the existing overstory in their habitat<sup>1</sup>. The impacts to the salamanders of compounds used to control insect pests constitute another unknown. Some of the wider-spectrum insecticides, such as Dimilin, could decrease the availability of chitinous salamander prey items. The studies recommended below would be designed to address some of these unknown factors.

3.3.1 Conduct a detailed vegetation analysis in Shenandoah salamander habitat. This would allow determination of the susceptibility of the overstory trees to diseases and defoliating insects, and would provide a basis for accurate prediction and fine-tuning of future pest control activities. Analysis of understory

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<sup>1</sup> In this regard, it is worth noting that ice storms, not infrequent in Shenandoah salamander habitat, are another source of natural elimination of the overstory. A recent (1993) ice storm virtually destroyed the canopy at Hawksbill summit (B. Martin, Shenandoah National Park, pers. comm.)

components might be useful in defining Shenandoah salamander habitat, if compared to adjacent areas known not to be occupied by this salamander. The information generated in this analysis would be incorporated into the Park's GIS.

- 3.3.2 Conduct integrated studies to determine how changes in forest cover will affect the soil environment. The soil microenvironment and the invertebrate prey base may be affected by insect- or fire-induced changes to the forest canopy. An understanding of the soil environment will engender a better understanding of how perturbations to it could affect this endangered species. Integrated studies should be undertaken to: (1) describe the current soil conditions (e.g., soil chemistry, distribution of soil depths within each isolate, how soil moisture changes seasonally and with episodic precipitation) in each isolate, and (2) elucidate how the changes in the forest cover such as defoliation affect the soil chemistry, microhabitat and microclimate conditions, and populations of salamander prey. In this regard, a model of ground insolation in Shenandoah salamander habitat under full-leaf and varying degrees of defoliation (at various temperatures and rainfall regimes) would help to determine the importance of the tree canopy in maintaining current ground temperature and moisture conditions of this habitat. In areas where the canopy is sufficiently sparse, its effects on surface and sub-surface microclimate may be negligible.
- 3.3.3 Document the extent and species composition of defoliation and mortality during and following outbreak years. Forest cover determined from aerial photographs taken during defoliation years should be mapped, and the results ground-truthed and factored in with the results of Tasks 3.3.1 and 3.3.2. Defoliation caused by fall cankerworm, chestnut blight, ice storms, or other factors



should also be documented. This information would be entered into the Park's GIS.

3.3.4 Conduct an experiment to determine the impacts of forest defoliators and control agents on Shenandoah salamanders. This course of action will be taken if results from Tasks 3.3.1 through 3.3.3 indicate that Shenandoah salamander habitat is susceptible to defoliation, and that such defoliation can significantly alter the surface environment. The experiment would be designed to answer the following questions: (1) Does the observed habitat desiccation adversely affect the Shenandoah salamander? and (2) Do forest pest control agents themselves adversely affect the Shenandoah salamander? This study would rely upon baseline data collected during regular monitoring (Task 2.2) in specified assessment areas prior to outbreak. In outbreak years, assessment areas should be divided into "treatment" (to be sprayed with a specific biological control agent such as BT or Gypchek) and "control" sections, preferably adjacent to each other and similar in aspect, elevation, and moisture regime, with adequate allowance for drift. Assessment of *P. shenandoah* population density, distribution, and age structure in treatment and control areas should continue at least 10 years post-treatment (Dunson *et al.* 1992), to determine potential longer-term population effects. It should be recognized that the same treatment (or outbreak levels) may have different effects on the salamanders in different years, depending on the temperature and amount of rainfall, particularly during the outbreak year.

3.4 Evaluate the effects of herbicide use in rights-of-way in the vicinity of *Plethodon shenandoah* habitat. Relying primarily on the literature and Environmental Protection Agency data regarding effects, if any, of herbicide use on amphibians, possible impacts on the Shenandoah salamander and other amphibians will be defined. Current practices

within Park boundaries include both aerial and ground applications along powerline rights-of-way. The chemicals used need to be assessed regarding possible toxic effects, as well as the indirect effects of habitat modification, in order to ensure treatments that are the least harmful to this species.

4. Investigate relevant aspects of *Plethodon shenandoah* life history. Although it is not likely that findings from the following studies will be used to develop intervention strategies for altering natural processes, these data should be useful in understanding and responding to natural declines or recoveries, applicable to this and possibly other species.

- 4.1 Study abiotic habitat factors affecting distribution. It is already known that *P. shenandoah* occupies areas of generally north-facing talus, but the specifics of microhabitat preference are not known. A study of specific preferences for temperature, litter depth, cover object, substrate pH, etc. would aid in further delineating the species' distribution and in a better understanding of interspecific habitat differences.

- 4.2 Study behavior and activity cycles relevant to management. Currently available information is not sufficient to determine when, seasonally, Shenandoah salamanders are most active and when they are most (and least) vulnerable to disturbance of their habitat. This information may be highly relevant to the timing of management (e.g., trail maintenance) activities. For example, it is known that the salamanders are generally not surface-active during the winter months, but neither can trail maintenance be conducted then, due to weather and personnel constraints. Censuses to determine Shenandoah salamander abundance during spring, summer, and fall may reveal times of low surface activity, when trail maintenance or other necessary management activities would be least damaging, and may also shed light on the effects of defoliation and increased insolation at different times of year.

- 4.3 Continue to support studies defining the interactions of *Plethodon cinereus* and *P. shenandoah*. These would include further elucidation of competitive and spatial interactions, differences in physiological and ecological tolerances and requirements, and the extent of hybridization. Regarding the latter, hybrid localities are currently defined based on field examination of individual specimens. The reliability of this evidence should be determined through more work using additional characters, such as biochemical markers, to ascertain the degree of gene flow and how it correlates with external appearance (A. Wynn *in litt.* 1994).

Since this work would entail collection of specimens (requiring a recovery permit), the need for these studies must be weighed against their effects on *Plethodon shenandoah* populations. All studies should be designed to minimize mortality of experimental animals, and experimental designs should be coordinated with the U.S. Fish and Wildlife Service and the Virginia Department of Game and Inland Fisheries.

5. Ensure compatibility of Park maintenance and management activities with Shenandoah salamander populations.

As a general policy, the Park will not authorize any human-related activities that might be detrimental to Shenandoah salamanders within this species' known or potential habitat. The tasks that follow will help to implement this policy.

- 5.1 Provide Park employees and volunteers with mandatory Shenandoah salamander training and information updates on a regular basis. Periodic training (preferably yearly, to accommodate new and seasonal Central District employees, fire management personnel, and volunteer trail workers) will be conducted by Park resource management specialists, with the optional assistance of U.S. Fish and Wildlife Service or Virginia Department of Game and Inland Fisheries biologists. This training, which may be included with natural resource seminars or other employee training sessions, will be designed to promote recognition and awareness

of Shenandoah salamanders and heighten understanding of necessary management precautions within Shenandoah salamander habitat.

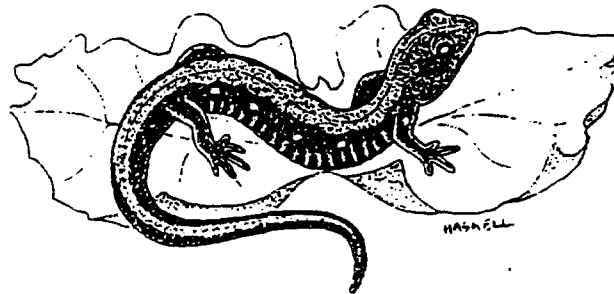
- 5.2 Ensure that trail and road maintenance and fire management personnel inform appropriate specialists about actions that may affect Shenandoah salamander habitat. These personnel should always contact resource management specialists and appropriate Central District personnel before initiating any habitat-altering actions at Hawksbill, The Pinnacles, Stony Man, Bushy Top, Hemlock Springs, or other areas where Shenandoah salamanders are found in the future. Maps identifying the areas of concern should be prepared and distributed to district personnel during training (Task 5.1), and the importance of this communication stressed.
- 5.3 Develop guidelines for trail maintenance and fire management in Shenandoah salamander habitat. Shenandoah National Park, in coordination with the Virginia Department of Game and Inland Fisheries and the U.S. Fish and Wildlife Service's Chesapeake Bay Field Office, will develop these guidelines in order to ensure maximum compatibility between management activities and the species' survival. Completed guidelines will be incorporated into the Park's Trail Maintenance Manual and Fire Management Plan; preliminary trail management guidelines appear in Appendix A to this plan. Initially, the Appalachian Trail and any other trails through Shenandoah salamander habitat will be maintained at their present location and width, and without the use of heavy equipment. Whenever possible, these activities should be conducted during times of low salamander surface activity. Other activities covered by the guidelines include reconstruction of retaining walls, culverts and water bars, areas of fill material, and brushing back vegetation along trails. Fire management considerations might include minimizing fire line construction through Shenandoah salamander habitat.
- 5.4 Prohibit back-country camping and other potentially detrimental activities in Shenandoah salamander habitat. At the present time, much of the

known Shenandoah salamander habitat is protected under the general prohibition of back-country camping within 1/2 mile of any developed area, or within sight of any road or trail. The summit of Hawksbill is also closed to camping. This protection will be extended to include all known areas occupied by Shenandoah salamanders, and any areas where populations are discovered in the future, by revision of the Back Country Management Plan. Efforts will be made to eliminate/rehabilitate all impacts from illegal campsites (see Appendix A).

6. Promote information exchange on the Shenandoah salamander.

6.1 Hold information exchange sessions. These discussions should include individuals conducting research or monitoring, resource management specialists, rangers, naturalists, and other individuals as needed. The Park's Natural Resources and Science Symposium could provide one forum for Shenandoah salamander information exchange.

6.2 Incorporate the Shenandoah salamander into Shenandoah National Park public education programs. The salamander is of natural interest and high educational value as an endangered species that occurs only in Shenandoah National Park. Park naturalists and public education specialists should be directed to develop talks and educational programs highlighting this species. Discretion should be used when referring to localities where the salamanders can be found.



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## PART III: IMPLEMENTATION

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The Implementation Schedule lists and ranks tasks that should be undertaken within the next three years in order to implement recovery of *Plethodon shenandoah*. This schedule will be reviewed annually until the recovery objective is met, and priorities and tasks will be subject to revision. Tasks are presented in order of priority.

### Key to Implementation Schedule Column 1

Task priorities are set according to the following standards:

- Priority 1: Those actions that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.
- Priority 2: Those actions that must be taken to prevent a significant decline in species population, or some other significant impact short of extinction.
- Priority 3: All other actions necessary to provide for full recovery (i.e., stabilization in this case) of the species.

### Key to Agency Designations in Column 5

- |       |  |
|-------|--|
| ES    | - Ecological Services                              |
| FW    | - U.S. Fish and Wildlife Service                   |
| NBS   | - National Biological Survey                       |
| EPA   | - Environmental Protection Agency                  |
| SNP   | - Shenandoah National Park                         |
| VDGIF | - Virginia Department of Game and Inland Fisheries |
| PATC  | - Potomac Appalachian Trail Club                   |

**IMPLEMENTATION SCHEDULE**  
Shenandoah Salamander Recovery Plan

September 1994

Priority	Task Description	Task Number	Duration	Responsible Agency		Cost Estimates (\$000)			Comments
				USFWS	Other	FY1	FY2	FY3	
1	Compare acid tolerance of <i>P. shenandoah</i> and <i>P. cinereus</i> .	3.1.1	1 year	R5 ES	NBS SNP VDGIF	5.0			
1	Study reproductive and chronic effects of acidity.	3.1.2	5 years	R5 ES	NBS SNP VDGIF	15.0	10.0	5.0	+ an additional 10K in subsequent years.
1	Continue to support studies defining relationship/interactions of <i>P. cinereus</i> and <i>P. shenandoah</i> .	4.3	Ongoing	R5 ES	NBS SBP VDGIF				Such studies may receive logistical support and funding based on proposed work.
2	Determine optimal survey methodology for long-term monitoring.	2.1	3 years	R5 ES	SNP VDGIF NBS	15.0	15.0	6.0	
2	Monitor <i>Plethodon shenandoah</i> populations at all three isolates on a regular basis.	2.2	Ongoing	R5 ES	SNP VDGIF				Operational monitoring will begin only following completion of Task 2.1.
2	Determine history and susceptibility of Shenandoah salamander habitat to acidification.	3.1.3	1 year	R5 ES	NBS SNP	4.0			
2	Evaluate the effects of roads and trails on movements of Shenandoah salamanders and potential population fragmentation.	3.2	3 years	R5 ES	NBS SNP VDGIF				Study not required as long as Park policy of no road or trail construction in <i>P. shenandoah</i> habitat is in place.

Shenandoah Salamander Implementation Schedule, September 1994

Priority	Task Description	Task Number	Duration	Responsible Agency		Cost Estimates (\$000)			Comments
				USFWS	Other	FY1	FY2	FY3	
2	Prohibit back-country camping in Shenandoah salamander habitat.	5.4	Ongoing	R5 ES	SNP				Normal operating costs.
3	Continue searches of suitable habitat, to find new populations and define boundaries of existing populations.	1.	5 years	R5 ES	SNP VDGIF	2.0	2.0	2.0	
3	Conduct integrated studies to determine how changes in forest cover will affect the surface environment.	3.3.2	3 years	R5 ES	NBS SNP VDGIF	10.0	5.0	5.0	
3	Document tree defoliation and mortality during and following pest outbreak years.	3.3.3	1 year*	R5 ES	NBS SNP VDGIF	3.0			* Would need to be repeated in successive outbreak years.
3	Hold salamander information exchange sessions.	6.1	Ongoing	R5 ES	SNP VDGIF				Incorporated into bi-annual Science Symposium
3	Incorporate the Shenandoah salamander into SNP public education programs.	6.2	Ongoing	R5 ES	SNP	5.0			First year costs for development of program.

Shenandoah Salamander Implementation Schedule, September 1994

Priority	Task Description	Task Number	Duration	Responsible Agency		Cost Estimates (\$000)			Comments
				USFWS	Other	FY1	FY2	FY3	
2	Conduct a detailed vegetation analysis in Shenandoah salamander habitat.	3.3.1	1 year	R5 ES	NBS SNP	4.0			Will be part of Park's GIS.
2	Conduct an experiment to determine the impacts of forest defoliators and control agents.	3.3.4	5 years	R5 ES	NBS SNP VDGIF	5.0	8.0	8.0	Priority will be elevated to 1 in the case of severe forest pest outbreak.
2	Evaluate the effects of herbicide use in rights-of-way in the vicinity of <i>P. shenandoah</i> habitat.	3.4	1 year	R5 ES	EPA SNP				Normal operating costs.
2	Study abiotic factors affecting distribution.	4.1	2 years	R5 ES	NBS SNP VDGIF	6.0	6.0		
2	Study behaviors and activity cycles relevant to management.	4.2	2 years	R5 ES	NBS SNP VDGIF	4.0	4.0		
2	Provide Park employees with mandatory Shenandoah salamander training and information updates on a regular basis	5.1	Ongoing	R5 ES	SNP VDGIF	0.5	0.5	0.5	
2	Ensure communication between maintenance personnel and resource management specialists before initiating any habitat alteration in Shenandoah salamander habitat.	5.2	Ongoing		SNP				Normal operating costs.
2	Develop guidelines for trail and fire management in the vicinity of Shenandoah salamander habitat.	5.3	1 year		SNP PATC				Implementation of guidelines will fall within normal operating costs.

## APPENDIX A

### Interim Guidelines for Trail Management in Shenandoah Salamander Habitat

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[These will serve as temporary measures, pending development of more thorough guidelines pursuant to Task 5.3. Any deviation from these guidelines will require consultation with the U.S. Fish and Wildlife Service.]

1. All trails through Shenandoah salamander habitat, including Appalachian Trail, will be maintained at their present location and width.
2. Heavy equipment, such as bobcats, loaders or brush hogs, will not be used in Shenandoah salamander habitat.
3. Light or hand-held equipment may be used for trail maintenance in Shenandoah salamander habitat at any time EXCEPT during:  

May 1 to June 30; and September 1 to October 30.
4. When possible, summer trail maintenance work in Shenandoah salamander habitat will be conducted after a minimum of 2-3 days of dry (no rain) weather.
5. Trail crews working in Shenandoah salamander habitat will make every effort to minimize moving or unearthing rocks and logs during trail maintenance activities.
6. Additional trail materials necessary for rehabilitation of trails (i.e., rocks, gravel, and soil) will be brought in from sources outside Shenandoah salamander habitat.
7. Prohibitions against backcountry camping in the vicinity of Shenandoah salamander habitat will be strictly enforced.

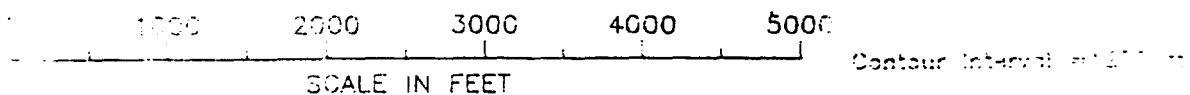
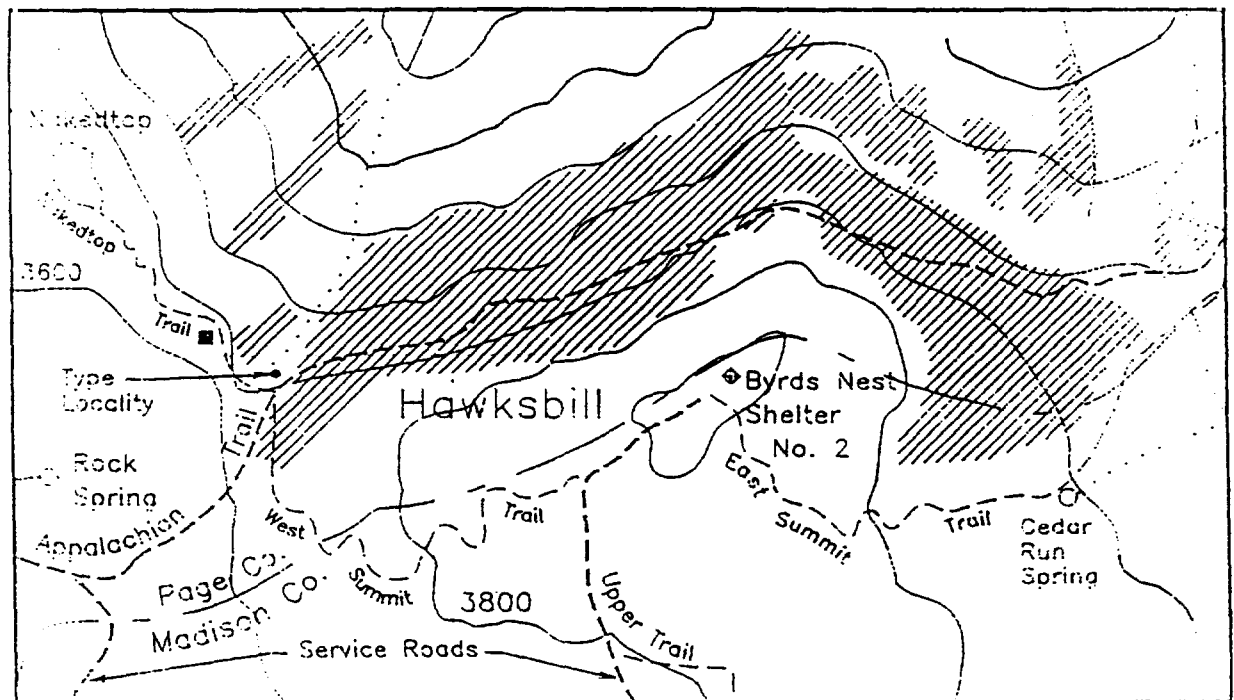
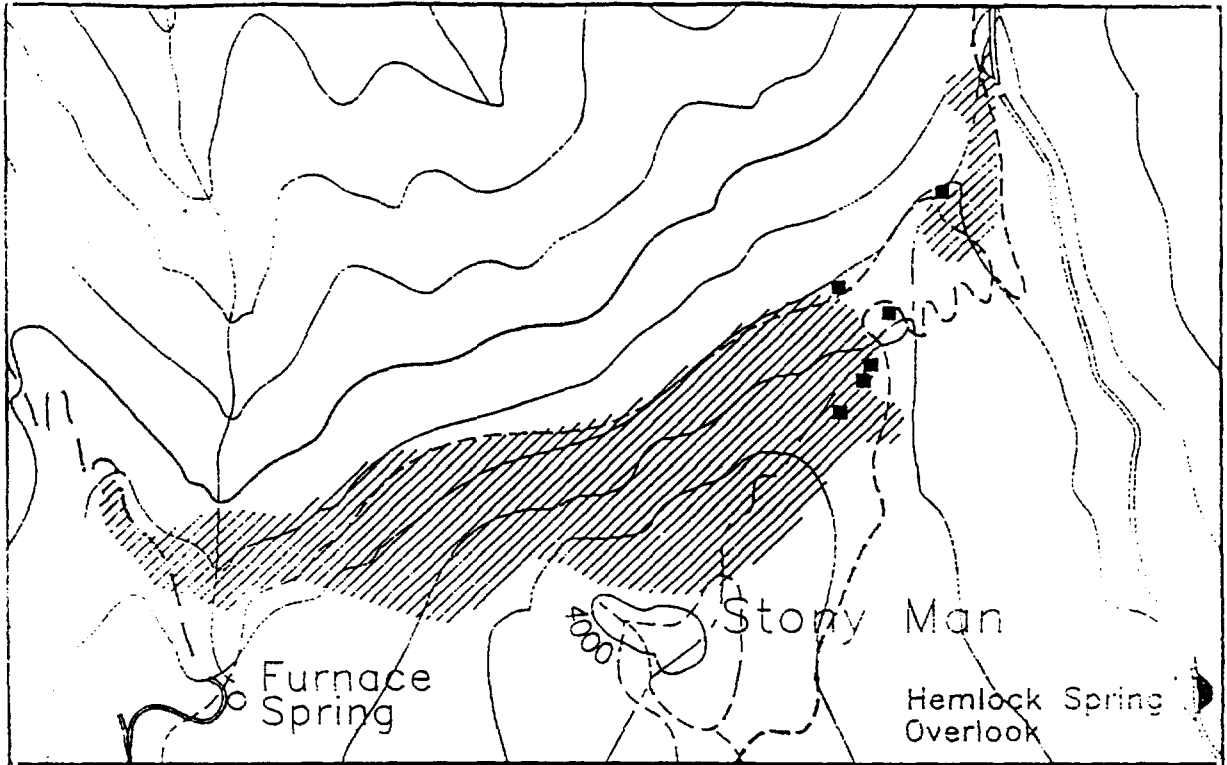
BACKCOUNTRY CAMPSITES, SHENANDOAH SALAMANDER RECOVERY PLAN

KNOWN LOCALITIES



PREPARED BY VIA & WITT, 26-SEP-94  
 Trails & Unpaved Roads - - - - -  
 Backcountry Campsites ■

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## APPENDIX B

### List of Reviewers

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The following agencies and individuals submitted comments on the Technical/ Agency draft Shenandoah salamander recovery plan. These comments have been incorporated to the extent appropriate into this final plan. Copies of the comments, available for agency and public review, are on file in the Chesapeake Bay Field Office of the U.S. Fish and Wildlife Service.

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