DRAFT ENVIRONMENTAL ASSESSMENT OF HEMLOCK WOOLLY ADELGID CONTROL STRATEGIES In Great Smoky Mountains National Park

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1. INTRODUCTION

1.1 Purpose of the Proposed Action

The purpose of this initiative is to preserve hemlock forests by minimizing the impact of hemlock woolly adelgid (HWA) in Great Smoky Mountains National Park. HWA is a non-native insect pest that is quickly decimating hemlocks in the eastern United States. Since the 1980s HWA has spread north from Virginia to Maine and as far south as northern Georgia (USDA Forest Service 2004). HWA is steadily spreading into the oldest and largest hemlock forests of the Southern Appalachians, threatening a unique forest ecosystem and the aquatic communities it shelters. HWA was discovered in Great Smoky Mountains National Park (GRSM) in 2002. Infestation densities indicate HWA may have been in the park since 2000. Light infestations are difficult to detect. Infestations were found in several areas of western North Carolina in 2001, including the Nantahala National Forest. Figure 1 shows the progression of HWA in the eastern U.S.

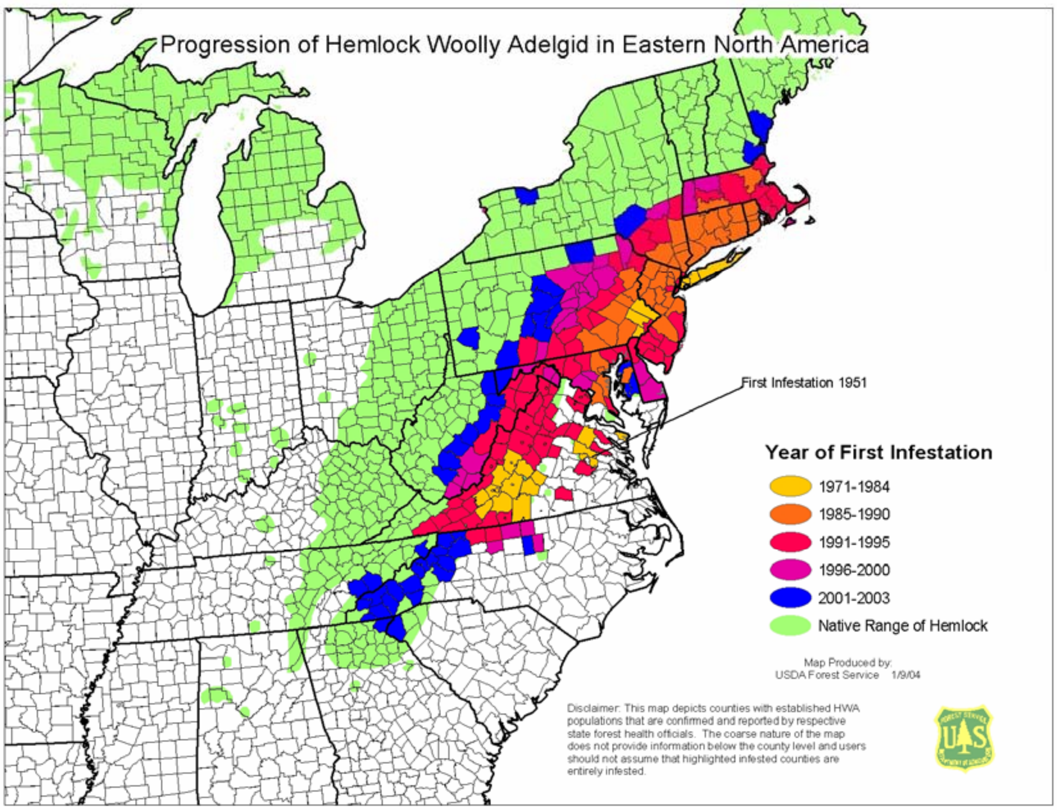


Figure 1. Progression of HWA in eastern North America. Courtesy USDA Forest Service

The National Park Service is proposing to treat selected hemlock forests in GRSM to suppress HWA infestations and reduce hemlock mortality. In May 2002, the park superintendent approved use of insecticidal soap, horticultural oils, systemic insecticides, and the experimental release of predatory beetles as a Categorical Exclusion based on the recommendation of the park's Compliance Management Board. The Compliance Management Board determined that managers could proceed with these experimental control strategies based on requirements set forth by the Department of Interior and the Council on Environmental Quality. Since then, HWA populations have become much more widespread and pose an imminent threat to park resources. In response, the park is proposing to expand treatment efforts. The proposed treatments include the use of insecticidal soap, horticultural oil, systemic insecticides, and biological control agents including several species of predatory beetles. This document outlines proposed alternatives that will best protect and preserve hemlock communities in GRSM.

The National Park Service is committed to protecting hemlock forests in GRSM, but park managers realize that some mortality is likely to occur due to the remoteness of many hemlock resources, the difficulty of treating thousands of individual trees throughout the park, and the probability of re-infestation from sources outside park boundaries. Managers have prioritized attainable goals for best preserving intact hemlock communities throughout the park.

The purpose of this document is to review the potential environmental impacts of the proposed action and alternatives to this action as required by the National Environmental Policy Act (NEPA). This document also provides information necessary to determine if the need exists to develop an environmental impact statement. We are requesting comments from the general public and interested agencies concerning the alternatives presented in this document so that the most appropriate course of action can be selected.

The following specific goals guide the proposed action alternative in this document for consideration:

1. **Minimize losses in hemlock old-growth forests**

Over 700 acres of old growth hemlock have been mapped and field checked in GRSM (Yost et al. 1994). Delineated stands include areas with little or no apparent human disturbance. The average age of hemlocks in old-growth stands sampled in the study was 213 years (dating to 1781), with the maximum age sampled at 435 years (dating to 1559). Many of these stands are in excess of 400 years old and have high ecological significance. Old-growth forests of the park have become increasingly important in recent years as harbors of biodiversity, as preferred habitat of neotropical bird species (Farnsworth and Simons 1999), for research of forest dynamics (Whittaker 1956, Busing and White 1991), and for recreation and aesthetics. Unfortunately, older trees are not as vigorous as younger trees, making them more easily affected by HWA. In addition, many old growth hemlock forests are in remote areas far from trails and roads.

2. **Protect trees in high-use developed areas**

Landscape setting trees are highly valued by the visiting public in campgrounds and picnic areas. If hemlocks are left untreated, decline and mortality are likely to increase creating public safety hazards as well as impacting aesthetics. Hemlocks provide a year-round buffer between campsites, picnic sites, and along roadways. The presence of dying trees along busy roadways and in developed areas increases the risk of injuries, vehicle damage, and facility damage due to falling trees. Hazardous trees are expensive and time-consuming to remove, and many hemlocks in developed sites are very large. Some area and facility closures may be necessary to insure public safety until the removal of hazardous trees can be completed.

3. Minimize losses in hemlock-dominated forests

The park contains over 18,000 acres of hemlock-dominated forests in a variety of habitats. Hemlock-dominated communities were delineated using photogrammetric and GIS techniques (Welch et al. 2002). Forests are considered hemlock-dominated when hemlocks represent 50% or more of total species composition. If hemlock forests are significantly reduced or eliminated in the park, there would likely be a cascade of associated environmental consequences involving species found within these hemlock communities.

Hemlocks provide numerous benefits including nesting bird habitat, moderation of stream temperatures, and unique habitat for numerous plant and animal species. During the winter, hemlocks offer cover for a variety of wildlife including grouse, turkey, and deer. During the summer, hemlocks provide consistent shade and cooling for a variety of species (Evans 2002, Snyder et al. 2002). At a study site at Delaware Water Gap (DEWA), researchers found that summer temperatures in a stream gradually decreased 3^{o} to 4^{o} C as the stream passed through a hemlock ravine (Evans et al. 1996). No other evergreen in the park can fill the critical ecological role of hemlocks in the forest. Hemlocks can also represent an important component of identified cultural landscapes which would be impacted with the loss of hemlocks.

1.2 Need for the Proposed Action

GRSM is mandated to protect the natural resources in the park. The “fundamental purpose” of the national park system, established by the Organic Act (1916) and reaffirmed by the General Authorities Act, begins with a mandate to conserve park resources and values, provide for the enjoyment of these resources and values by the people, and leave them unimpaired for future generations. As stated in NPS Management Policies (USDI NPS 2001), “the NPS will strive to understand, maintain, restore, and protect the inherent integrity of the natural resources, processes, systems, and values of the parks.” The purpose for which GRSM was established includes the preservation and perpetuation of the natural resources of the park in an undisturbed natural condition. NPS Management Policies (2001) state that management of exotic (nonnative) species, up to and including eradication; will be undertaken whenever such species threatens park resources or public health and when control is prudent and feasible.

1.2.1 Hemlock Woolly Adelgid Biology and the Decline of Eastern Hemlock Forests

Hemlock woolly adelgid (*Adelges tsugae* Annand) belongs to the Order: Homoptera Family: Adelgidae. HWA was first reported in North America in Oregon on western hemlock (*T. heterophylla*) in 1924. The non-native insect was likely introduced from Asia on nursery stock of hemlocks (McClure and Cheah 1999). HWA has been known in the eastern U.S. since its discovery in Richmond, VA in 1951 and has spread throughout much of the native range of the eastern hemlock infesting approximately 25% of the 1.3

million hectares of hemlock forests in the eastern United States (Zilahi-Balogh et al. 2002). Periodic HWA observations were reported in several Mid-Atlantic States in the 1960s and 1970s, but it was not until the 1980s that HWA populations began to surge and spread northward to New England at an alarming rate. Unfortunately, by the late 1980s to early 1990s, HWA infestations were reported as the cause of extensive hemlock decline and tree mortality in forests throughout the eastern U.S. (McClure 2001). HWA is known to feed on North American native hemlocks (eastern, Carolina, western, and mountain) as well as hemlock species native to Asia, though it is a relatively minor pest on these species.

Unfortunately, eastern and Carolina hemlocks are very vulnerable to the damage caused by adelgids as they feed on the trees. HWA feed at the base of hemlock needles inserting their piercing-sucking mouthparts and removing the nutrients stored in the plant tissues.

Hemlock woolly adelgids feed on the needles of all sizes of hemlocks from one-year seedlings to 500-year-old, 170 feet tall giants. This feeding action reduces nutrient movement within the tree and eventually needle death occurs. Trees begin to yellow, prematurely lose needles, and stop producing new growth. Tree death can occur within three to five years after infestation (Bonneau et al. 1999). Trees not killed outright by HWA are susceptible to secondary insect pests such as oval, elongate, and circular hemlock scales; hemlock borers; spider mites; and root pathogens such as *Armillaria* spp. fungi. Secondary invasion by these pests often results in tree death. All sizes of hemlock can be infested by HWA.

The HWA life cycle is complex producing two asexual generations and one sexual generation each year (McClure 1987). The sexual generation requires an alternate plant host (spruce species) to complete its life cycle. No spruce species in the eastern United States, native or non-native, have been shown to support this winged generation of HWA (McClure and Cheah 1999). When the winged nymphs (sexuparae) mature and disperse to find suitable spruce trees, they presumably die which can result in significant mortality depending on how many winged nymphs were produced.

In the southeast, white cottony masses (ovisacs) containing adult HWA appear in October which is followed by egg production in February. Each adult can lay up to 300 eggs if high quality food is available. The next life stage after the egg stage is known as the crawler stage. Crawlers can disperse by crawling short distances, but are more readily transported by birds, mammals, humans or wind (McClure 1990). The winged form (sexuparae) hatches in spring and searches for the alternate host (spruce). All life stages of HWA have been documented being dispersed by wind up to 300 m downwind from an infested stand (McClure 1990). HWA are heat intolerant and enter a resting phase (aestivation) from June through September. See the following illustrated life cycle diagram.

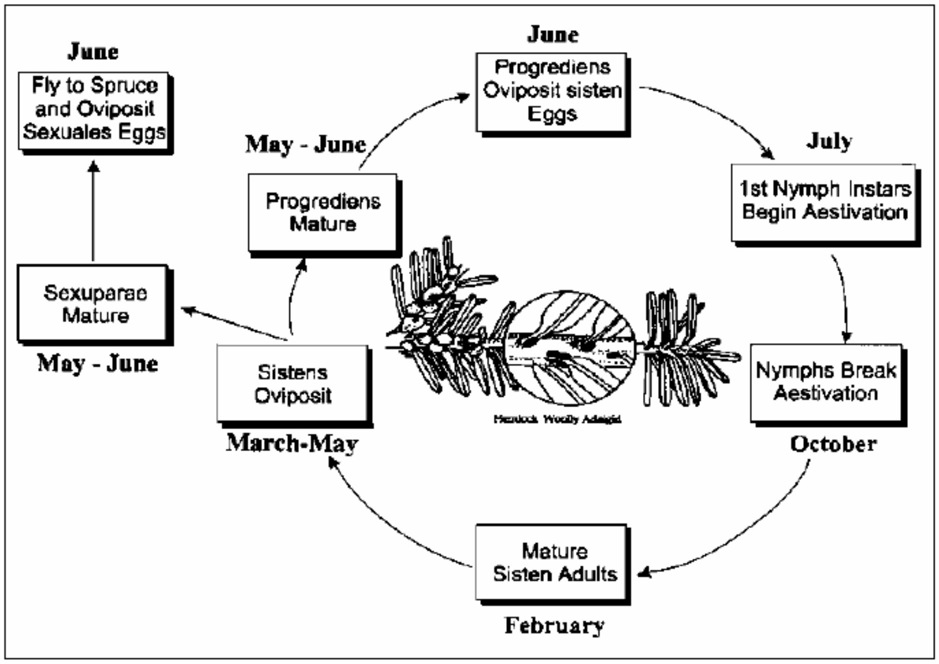


Figure 2. Life cycle of Hemlock Woolly Adelgid (McClure et al. 2001).

HWA mortality of 60%-80% can occur in the egg and first instar (crawler) life stages, but reproduction rates are high enough to ensure species survival (USDA Forest Service 2001). HWA survive the cold temperatures in their home range of the mountainous regions of China and Japan. Significant cold mortality has been observed in the northeastern U.S., but with two generations per year HWA populations rebound quickly. Researchers have found that between 60-70% of adelgids suffer mortality from cold temperatures in the northeastern United States during a normal winter (McClure and Cheah 1999, Skinner et al. 2003). Unfortunately, temperatures common in the park at lower elevations are not low enough to cause cold-induced mortality. However, HWA do begin to lose their tolerance for cold as the season progresses and late cold spells can induce significant mortality (Skinner et al. 2003). Some researchers suggest that heavy rainfall can limit the spread of HWA by dislodging them and knocking them to the ground where they are vulnerable to many ground predators (Skinner et al. 2003).

HWA surveys in 2004 identified infestations in all major watersheds in GRSM. In other locations infested with HWA, populations of eastern hemlock and the geographically restricted Carolina hemlock have suffered immensely. Foresters warn of a potential disaster comparable to the chestnut blight, which radically changed the composition of southern forests. Impacts in Virginia, New Jersey and Connecticut have been severe, with hemlock mortality ranging from 42 to 90 percent among stands. Shenandoah National Park has lost approximately 80% of its hemlock resources in some locations. Recent reports from Delaware Water Gap National Recreation Area (DEWA) indicate that indicate that about 20% of hemlocks in the park are dead, 60% are at various stages of decline, and about 20% are healthy (Lynch 2005). The New Jersey Division of

Forestry has reported only two remaining hemlock stands that have not been heavily impacted by HWA (USDI NPS 2000).

Initial outbreaks of exotic species tend to be non-sustainable over time. The action of HWA feeding causes a decline in tree health, which in turn causes a drop in HWA densities. After initial outbreak and subsequent population crash, some trees may sustain populations at lower densities. The HWA will never die out and the infested trees will never regain full vigor as they were before initial infestation. HWA, like many exotic forest pests, has no native predators or parasites capable of bringing populations down to non-damaging levels.

1.2.2 Ecology

In 2001, researchers found hemlock to be the second most common tree species in the park likely due to its persistence in the understory, midstory, and canopy of several forest types at all but the highest elevations (Shriner 2001). The park supports nearly 700 acres of old growth hemlock, considered the greatest concentration of old growth hemlock in the east. Individual trees 300-600 years old and nearly 170 feet tall are found in old growth stands throughout the park (Yost et al. 1994). The park contains several individual trees that hold current records in tree height. The fourth tallest eastern hemlock in the world was found in the park's Cataloochee area, while several other trees are within a foot of becoming world records. In addition, GRSM contains several unique stands with that are renowned for their age (600+ years), size (greater than 160 feet in height) and structure (W. Blozan, email communication, April 18, 2005).

Hemlock-dominated forests are most common in riparian areas, coves, and along escarpments in the southern Appalachians, especially north-and east-facing slopes. In addition to the 18,000 acres of hemlock-dominated forests, researchers have documented 87,473 acres of GRSM forests having a significant hemlock component (Welch et al. 2002).

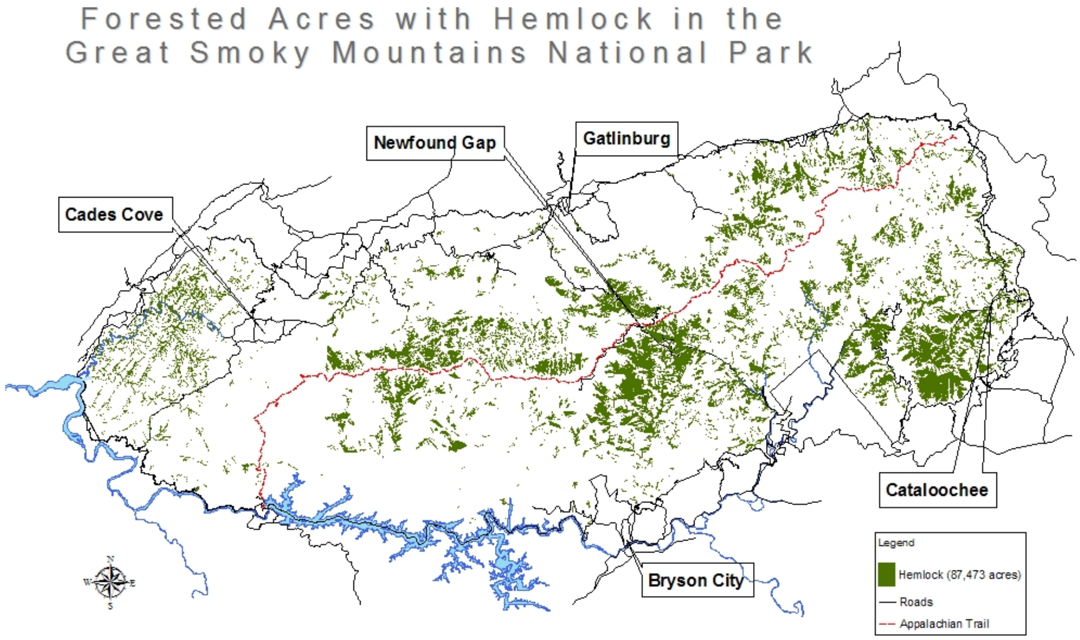


Figure 3. Forested Acres with Hemlock in GRSM (Welch et al. 2002).

The conditions in hemlock-dominated stands are so different from those in cove forests that Whittaker (1956), in his classic study of vegetation in GRSM, describes them as appearing to be “almost unrelated.” Hemlocks are long-lived and extremely shade tolerant. Some healthy, suppressed hemlocks have been documented to be over 350 years old (Hough 1960). Hemlock is the only shade tolerant evergreen species in the park. There are no other native evergreens that can fill the ecological role of hemlock.

A variety of birds, mammals, invertebrates, and plants are associated with hemlock and hemlock-dominated communities. Hemlock’s dense canopy provides food, shelter, and breeding sites across the seasons. Shriner (2001) found that 16 of 30 species of breeding birds were significantly correlated with hemlock. These 16 species included the dark-eyed junco (*Junco hyemalis*), black-throated blue warbler (*Dendroica caerulescens*), wood thrush (*Hylocichla mustelina*), and Canada warbler (*Wilsonia canadensis*). Specifically, Farnsworth and Simons (1999) reported that 84% of wood thrush nests in GRSM were in small hemlocks. Kellor (2004) found that Acadian flycatchers (*Empidonax virescens*), blue-headed vireos (*Vireo solitarius*), black-throated blue warblers (*Dendroica caerulescens*), and black-throated green warblers (*Dendroica virens*) were all positively associated with hemlock forests in GRSM. In New Jersey and Massachusetts, researchers found population declines for black-throated green warblers, Acadian flycatcher, blue-headed vireo, and the hermit thrush due to hemlock mortality (Benzinger 1994, Tingley et al. 2002).

A variety of techniques were used to sample terrestrial insects from GRSM hemlock forests during the late 1990s (Johnson et al. 1999). Arthropod diversity was compared in two old growth stands (27 arthropod families) and two second growth stands (63 families). A subsequent study recorded 281 species of insects from eastern hemlocks (Buck et al. 2003, Buck 2003). In an arthropod diversity study using pitfall traps in two hemlock ravines at DEWA, beetles represented the largest group of terrestrial arthropods associated with hemlock stands, followed by ants and harvestmen. Spiders are found in larger numbers on hemlocks and other conifers than on hardwoods. The hemlock angle, *Semiothisa fissinotata* is an obligate moth species found only with eastern and Carolina hemlock. Additional invertebrate pests of hemlock include two scale insects (elongate and hemlock scale), several mites, needle miners, the hemlock borer, and the hemlock looper. Unfortunately, the exotic elongate scale, *Fiorinia externa*, denotes another significant threat to eastern hemlocks and was discovered in the park on hemlocks as part of an invertebrate inventory (Buck 2003). Scale populations spread much quicker on stressed trees.

Several species in the aquatic community are also likely to be impacted by hemlock declines. Hemlock has been shown to moderate stream temperatures summer and winter thereby easing heat and cold stress on aquatic organisms. Brook trout are found more commonly in streams associated with hemlock ecosystems because of the shaded cooling effect of the hemlock canopy (Ross et al. 2003). Increased water temperatures, as a result of the loss of hemlocks, may increase populations of such non-native species as brown trout and rainbow trout (Evans et al. 1996). Cool waters created by the shade of hemlocks also provide critical habitat for stoneflies, mayflies, caddisflies, and some salamanders (Walasewicz 1995). In a comparison between invertebrate communities in a hardwood drainage and a hemlock drainage, invertebrates were more diverse in the hemlock drainage with several species exhibiting a strong association with hemlock streams and three species showing an exclusive association with hemlock streams (Snyder et al. 2002).

Many plants are commonly associated with hemlocks throughout their distribution. Several species, including rattlesnake plantains (*Goodyeara* sp.), Canada mayflower (*Maianthemum canadense*), and wood sorrels (*Oxalis sp*.), exhibit close associations with hemlock forests (McClure et al. 1996). Shifts in herbaceous species composition are likely to occur as hemlocks decline. Maples, birches, and oaks have begun to dominate former hemlock stands in other eastern forests following hemlock mortality (Kizlinski et al. 2002, Orwig and Foster 1998). Unfortunately, sites disturbed by loss of the overstory are vulnerable to exotic plant invasions. Non-native plants such as tree of heaven and garlic mustard have invaded forested areas disturbed by gypsy moth-induced oak mortality at Shenandoah National Park (SHEN). Similar invasions are observed in HWA-induced mortality areas at SHEN and DEWA and are likely to occur in GRSM.

1.2.3 Economics

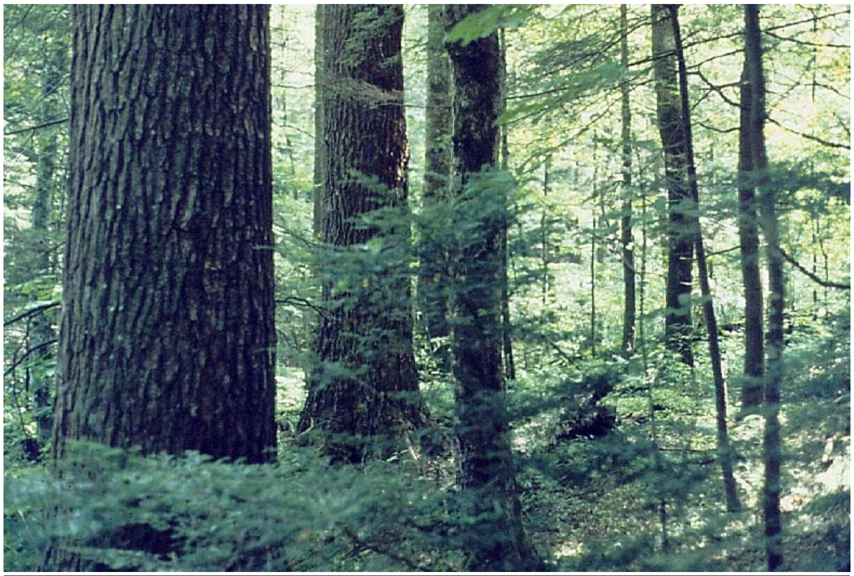
GRSM is the most visited national park with nearly 10 million visitors per year. Both residents and visitors enjoy recreation in the park, including fishing, camping, hiking, and wildlife viewing, in and near hemlock forests. The park's backcountry receives between 500,000 and 700,000 visits each year and contains approximately 850 miles of trail.

In 2004, the backcountry received 65,989 camper nights (one person staying one night). The park's 10 front country campgrounds received 276,468 camper nights in 2004. High tree mortality in these areas will likely reduce the quality of recreational experiences, therefore reducing recreational use and the associated economic benefits of recreation.

As mentioned previously, loss of hemlocks could adversely impact trout populations as a result of higher temperatures in streams (Evans 2002). Hemlock forests help maintain cool temperatures at the headwaters of streams that support trout populations. In addition, nitrate deposition has increased in areas where there has been a rapid loss of hemlock further impacting aquatic life. If trout populations are reduced as a result of hemlock losses, trout angling could be adversely impacted by the loss of hemlocks causing an economic impact to the communities surrounding GRSM.

1.2.4 Aesthetics

Hemlocks in developed areas (campgrounds, picnic areas, visitor centers) are highly valued by visitors for aesthetics, screening, and shade. Dead trees in these areas would alter visitor perception and enjoyment of the sites. Roadside overlooks are an important part of the visitor experience in the park. Visitor experiences will be impacted if many dead hemlocks are visible from these overlooks.



Hemlocks are aesthetically important for park visitors throughout the year, but particularly in the summer for those who enjoy the cool shade a hemlock canopy provides. Several GRSM trails, including Trillium Gap, Maddron Bald, Boogerman, Gregory Ridge and Caldwell Fork, traverse stands of large old hemlock. These trails provide visitor experiences that are unique in the park.

1.2.5 Fuel loading

Additional fuel loading will occur in these areas of hemlock mortality, making fires more likely and changing fire behavior. Dangerous, unpredictable fires may result from the fuel ladders formed by dead under- and mid-story hemlock.

1.2.6 Safety

Standing dead and dying trees pose an unacceptable hazard tree threat in developed areas. Popular recreation areas of DEWA have been closed due to the high number of dead hemlocks and the public safety threat the dead trees pose. Many of GRSM's public use areas contain mature and young hemlock. Closing such areas would be an unpopular, but could be a necessary choice to protect public safety. Removal of these large hazardous trees would be expensive.

1.3 Related Environmental Documents

This Environmental Assessment is written under the authority of NPS policies, GRSM policies, state authorities, and federal authorities. The following list details those policies and authorities:

1.3.1 NPS Policies

- The primary responsibility of the National Park Service is established through the National Park Service Organic Act of 1916 and reaffirmed by the General Authorities

Act, as amended in 1978. The key management-related decision in the Organic Act states that the fundamental purpose of the national parks is “to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.”

- NPS-77, Natural Resources Management Guidelines:
  Integrated Pest Management: The purpose of this section is to “provide managers with an overview of the integrated pest management (IPM) concept, of NPS and departmental policies concerning the use of pesticides, of the various laws and regulations which directly or indirectly affect the use of pesticides, and with directions for applying for approval to use pesticides.” IPM combines compatible techniques to maintain pest damage below an unacceptable injury level while ensuring protection from threats to public health and safety and to the natural environment. Control measures for HWA in GRSM should include IPM strategies such as:
  - monitoring the status of pest populations in order to determine the level at which unacceptable damage is occurring and the threshold where management action must be applied;
  - evaluation of the efficacy and environmental effects of treatment actions;
  - resource education through public programs for both children and adults regarding HWA and its consequences;

  Exotic Species Management: This section offers guidelines and recommendations concerning exotic species management. For the management of already established populations of exotic species, this document sets forth guidelines for species evaluation, developing an information base, monitoring, initiation of management action, need for long-term commitment, and management strategies.

- NPS Management Policies (USDI NPS 2001) is the basic service-wide policy document on the National Park Service. This document is the highest of three levels of the NPS Directives System. This system is designed to provide management with clear and current information on NPS policy and required/recommended actions. The following are relevant sections from the NPS Management Policies.

  4.4.4 Management of exotic species: “Exotic species will not be allowed to displace native species if displacement can be prevented.” GRSM will use integrated pest management techniques to manage HWA.

  > 4.4.4.1 Introduction or Maintenance of Exotic Species: In rare instances the introduction and maintenance of exotic species may be permitted. If the introduction is to meet “specific, identified management needs when all feasible and prudent measures to minimize the risk of harm have been taken, and it is used to control another, already established exotic species.” In the last decade, biological control for HWA using introduced predators has been tested in both laboratory and field settings. Control results are in the early stages, and long-term control effectiveness will take time to evaluate.

4.4.4.2 Removal of Exotic Species Already Present: All exotic plant and animal species not targeted for a specific park purpose are to be managed for eradication if it is feasible and the exotic species meets certain criteria. Examples of these criteria are the interference with "natural processes and the perpetuation of natural features, native species, or natural habitats; disruption of the genetic integrity of native species;" or creation of a public safety hazard. Programs designed to control nonnative species should not cause significant damage to native species, natural communities, ecological processes, cultural resources and human health and safety.

4.4.5 Pest Management

4.4.5.2 Integrated Pest Management (IPM) Program: The Park Service and all park units must use an IPM approach, under which all pesticide use must be reported annually, to manage pest issues.

4.4.5.3 Pesticide Use: The decision to use a pesticide in a management strategy must be made by an IPM specialist and determined to be necessary, and no other available option is acceptable or feasible.

4.4.5.5 Pesticide Purchase and Storage: All pesticide purchases must be approved and expected to be used within one year from the date of purchase. Storage must comply with all federal and state requirements.

- NPS Director's Order 12 - Conservation Planning and Environmental Impact Analysis, and Decision-Making, 2001. The purpose of this order is to establish the policy and procedures that the NPS will use to comply with the National Environmental Policy Act of 1969 (NEPA). These procedures will include open evaluation, impact assessment, alternative approaches, peer review, and the use of an interdisciplinary approach. Under this authority, GRSM is given the guidelines to follow in developing management goals that ensure NEPA compliance.

1.3.2 GRSM Policies

- GRSM general management plan (1982) states that the purpose for the establishment of the park was "for the benefit and enjoyment of the people," as stated in the Congressional act of 1926 that established the Great Smoky Mountains National Park. The general management plan establishes broad strategies for management and divides the park's lands into management zones. The majority of the park's land falls within the "natural" category, and as such, "management practices will be undertaken to restore and/or continue the park's environment in the condition that would have prevailed without interference by nonnative plants and animals and by modern technological man." As evident in national park units located in the northeast and mid Atlantic, HWA (a non-native insect) has caused widespread effects ranging from crown thinning to extensive mortality. In areas that have been classified as proposed wilderness, management practices are to be of "transient nature and non-motorized except in extreme emergencies involving human safety or critical resource protection needs." As stated in the park's IPM plan for HWA, biocontrol will be the best possible option for control in these backcountry areas.

1.3.3 Federal Authorities

- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947 (7 USC 136) as amended. This act requires that all pesticides be registered, and that pesticides be used in accordance with the registration. The act restricts the use of certain pesticides. Some pesticides are regulated as toxic pollutants under the Clean Water Act and the Safe Drinking Water Act. All pesticides used in the control of HWA are registered with the EPA, and all label uses are followed.

- National Environmental Policy Act of 1969 (P.L. 91-190; 42 USC 4321, et. seq.). NEPA is the basic national charter for environmental protection. It contains a provision to ensure that federal agencies act according to the letter and spirit of the law. This act declares that it is the policy of the federal government to "preserve important historic, cultural and natural aspects of our national heritage." It says that all practicable means should be used to improve federal functions so that the nation may "attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences…." NEPA requires an interdisciplinary study of the impacts associated with federal programs.

- Executive Order 11987 Exotic Organisms, 1977. This executive order requires federal agencies to "restrict the introduction of exotic species into the natural ecosystems on lands and waters which they own, lease, or hold for purposes of administration…" and "into any natural ecosystem of the United States,: and to " encourage the States, local governments, and private citizens to prevent the introduction of exotic species into natural ecosystems of the United States" unless the Secretaries of Agriculture and Interior "find that such introduction or exportation will not have an adverse effect on natural ecosystems."

- Executive Order 13112, Invasive Species, dated February 3, 1999, directs each federal agency to prevent the introduction of invasive species, to detect and respond rapidly to and to control populations of such species in a cost-effective and environmentally sound manner, to monitor invasive species populations accurately and reliably, and to provide for restoration of native species and habitat conditions in ecosystems that have been invaded.

- Executive Order 13186, Responsibilities of Federal Agencies to Protect Migratory Birds, dated January 10, 2001. This order requires federal agencies to consider impacts to neotropical migratory bird species in all management actions.

- Cooperative Forestry Assistance Act of 1978 (P.L. 95-313). The purpose of this act is to authorize the Secretary of Agriculture to assist in establishing a cooperative federal, state and local forest stewardship program for management of nonfederal forest lands and achieving a number of goals for the use and protection of forest lands. The forest health protection portion of this act authorizes the Secretary to protect trees, forests, wood products and stored wood on the National Forest System lands and other lands in the U.S. from natural and human threats through the use of an integrated pest management program. This enabling act allows for the U.S. Forest Service to provide funding for forest insect and disease programs to other federal agencies.

1.3.4 State Authorities

- Tennessee Plant Pest Act (TN Code annotated 43-6-101 et. seq.) authorizes the Tennessee Commissioner of Agriculture to proclaim rules and regulations that prevent the introduction of insect pests, pest plants, or plant diseases into the state, and to eradicate and/or suppress and control such pests.

- Plant Pest Law - Article 36, Chapter 106 General Statutes of North Carolina as amended 1971 defines plant pest; outlines authority to inspect plant products, levy fines and control pests. Authorization is given to adopt regulations to implement and carry out the eradication, suppression and prevention of the spread of plant pests. Authorization is also given to the North Carolina Board of Agriculture to enter into agreements with any agency of the United States or any agency from another state for the eradication, suppression, control and prevention of the spread of plant pests.

1.4 Decisions to be Made

In providing for the protection of natural, cultural, and recreational resources in Great Smoky Mountains National Park, the primary decision to be made is whether to treat hemlocks, either with insecticides or biological-control agents, throughout the park in response to the damage caused to the trees from hemlock woolly adelgid. After the alternatives have been fully evaluated and the public has had the opportunity to review and provide comments on the proposed action, the NPS will issue a decision on how to proceed.

1.5 Public Involvement

In March 2005, scoping letters were distributed to a large mailing list of interested groups, including conservation groups, city and county officials, congressional representatives and tourism officials surrounding the park, soliciting public input on the park's use of insecticides and biological releases of predatory beetles to treat HWA. The scoping letter described in detail the combination of insecticides and biocontrol options that are suggested for hemlock stands. In addition, the letter was posted on the park’s website.

The park received twelve written comments from the following agencies and organizations:

- North Carolina Department of Environment and Natural Resources
- North Carolina Wildlife Resources Commission
- United States Environmental Protection Agency
- US Fish and Wildlife Service (Asheville Field Office)

- USFS-Forest Health Protection
- Dept. of Defense Army Corps of Engineers
- Town of Pittman Center (TN)
- Town of Maggie Valley (NC)
- TN Dept. of Environment and Conservation, Div. of Natural Heritage
- Western North Carolina Alliance
- USFS National Forests in North Carolina
- Foothills Land Conservancy

These comments helped shape the following alternatives and evaluate proposed treatments. All comments voiced full support of our efforts to combat the spread of HWA. Some concern was raised regarding pesticide use near water, protection of listed threatened and endangered species, and careful consideration of biological control agents. Park managers are hopeful that this EA will adequately address these noted concerns as managers are equally committed to assuring that park resources are protected.

In addition, educational workshops on hemlock woolly adelgid were conducted by Park staff along with county extension agents in the fall of 2004 at Tremont Institute (near Townsend TN), Waynesville, NC and Bryson City, NC. Internal scoping was conducted by the same letter and by making a first draft available of all park employees on the park's computer network.

1.6 Science Based Management

The HWA threat to eastern hemlocks has been recognized since the early 1990s. Resource managers and researchers from state and federal agencies, universities, and special interest groups led by United States Department of Agriculture Forest Service (USFS) specialists got together and formed the Hemlock Woolly Adelgid Working Group to develop priorities and focus resources. The first HWA review in October 1995 was an assemblage of presentations of known HWA biology, potential controls, impacts, and detection methods. The USFS - Forest Health Protection branch is the leading source of knowledge for forest pests. GRSM relies on the expertise of USFS specialists for knowledge of HWA and its management. The Hemlock Woolly Adelgid Working Group continues to meet to share knowledge and develop united strategies for a pest that affects large areas of eastern forests.

1.7 Methodology – Determination of Impacts

Impacts to resources were determined using a combination of reference materials and consultation with park staff, subject matter experts in the Forest Health section of the USDA Forest Service, university entomologists, and state agency personnel. The reference materials include manufacturer product information, peer-reviewed journal articles, along with federal and non-profit agency reports and publications.

1.8 Issues and Impact Topics

1. **Insecticide Use on a Park-wide Basis:** The use of insecticides, including insecticidal soap, insecticidal oil, and systemic insecticides, are considered in relation to effects on the surrounding

environment and to the visiting public. Techniques, chemicals, and impacts are evaluated in Section 2 and Section 4.

2. **Non-Native Biocontrol Agents:** Concerns regarding the use of non-native, biocontrol agents in Alternatives 4 and 5 are carefully considered to ensure that release insects will not pose a future problem for the park or private landowners. Members of the community in this area are familiar with non-native ladybeetles (*Harmonia axyridis*) in their homes that gather en masse and cause a nuisance. The public does not want another ladybug that becomes a nuisance to be introduced for control of HWA. In addition, the park must consider the chance that the biocontrol insects would eat adelgids other than HWA, native or not, or other native insects. Both of these issues are discussed in Alternatives 4 and 5. Alternative 3 excludes the use of biocontrol insects.

3. **Terrestrial Communities:** Terrestrial communities likely to be impacted by HWA and potential treatments are described in Section 3.2. Community level effects caused by loss of hemlock due to HWA are considered in Section 4.2.

4. **Aquatic Communities:** Aquatic communities likely to be impacted by HWA and potential treatments are described in Section 3.2. Community level effects caused by loss of hemlock due to HWA are considered in Section 4.3

5. **Rare, Threatened and Endangered Species:** Four plants and sixteen animals in GRSM are listed as federally threatened or endangered which are described in section 3.3. Impacts of all alternatives are considered in Section 4.4

6. **Water Quality:** NPS Management Policies (2001) require protection of water quality consistent with the Clean Water Act of 1972. Loss of hemlock could impact water quality which is described in Section 4.3. Section 2.1.3 describes specific measures to protect aquatic resources from insecticides toxic to aquatic invertebrates that may be used throughout the park to combat HWA.

7. **Visitor Use and Park Operations:** Dead hemlocks in heavily visited areas create a public safety hazard. In at least one other NPS unit, Delaware Water Gap National Recreation Area, public use areas with dead hemlock had to be closed until the dead trees could be removed. Treatment operations could cause temporary closures for public safety. These issues are discussed in Sections 3.4 and 4.5.

8. **Cultural Resources:** GRSM was created through acquisition of private land including mountain farm communities. Some of these home sites are still preserved while others have been absorbed into the landscape. The park currently identifies 42 historic landscapes and component landscapes (See Appendix N). Artifacts from European settlement and Native American habitation are evident in the park. Cultural resources are described in Section 3.5 and impacts to cultural resources are discussed in Section 4.6.

Any actions that could potentially affect the cultural resources of the park must be addressed as outlined in 36 Code of Federal Regulations (CFR) and in regulations issued by the Advisory

Council on Historic Preservation implementing Section 106 of the National Historic Preservation Act (NHPA) of 1966. The NPS, in consultation with the North Carolina and Tennessee State Historic Preservation Officers, will review potential impacts to cultural resources.

9) **Exotic Plant Management:** Loss of hemlock forest canopy would allow more light to reach the forest floor. Exotic plant species can rapidly colonize this newly open area which has occurred at other NPS units affected by loss of forest canopy. Sections 1.2.2 and 4.1.1 discuss exotic plant concerns.

10) **Fire:** The fire suppression that occurred in the 20th century changed the composition of GRSM forests. Hemlock survived in areas that would have had naturally ignited fires. Significant loss of hemlock resources would increase fuel loads and, during high fire danger episodes, increased risk of fire danger. Section 1.2.5 discusses fuel-loading concerns.

1.9 Impact Topics Considered and Dismissed

1) **Future Insect and Disease Infestations:** New forest pests are arriving in North America with increasing frequency. Gypsy moth has been expected to arrive in GRSM for more than a decade. In Shenandoah NP heavy gypsy moth defoliation of oak trees may have contributed to the severity of the HWA infestation due to the nitrogen fertilization effect of gypsy moth droppings. HWA thrive in high nitrogen environments.

The arrival of gypsy moth in GRSM has been delayed by environmental factors and suppression programs and it may not be the same threat in GRSM as it was in the northeastern states. Other forest pests are expected to arrive in the future. Their arrival is neither guaranteed nor dismissed, but their impact on HWA management in GRSM is not considered here due to the unknown impact of these pests as they relate to HWA.

2) **Air Quality:** The impact of any of the listed alternatives is not expected to have an impact on the park's air quality. Loss of hemlock under the no-treatment alternative would reduce the amount of carbon fixing by hemlock, but replacement vegetation would soak up this deficit.

3) **Environmental Justice:** Executive Order 12898, Federal Actions to Address Environmental Justice in Minority and Low-Income Populations, mandates all federal agencies to determine if a proposed federal action would have an adverse or disproportionate impact on minority and /or low income populations. The proposed project is within the boundary of GRSM where minority or low-income populations do not exist. Visiting members of this demographic group would not be affected any differently than the rest of the visiting public therefore no impact to these demographic groups exists under this project.

4) **Geologic Resources:** This project does not involve disturbance of geologic resources in any of the alternatives. Extensive loss of hemlock on steep slopes could temporarily contribute to an increase in localized landslides, however, these landslides already occur in the park on slopes with unstable geology whether they are vegetated or not. Replacement vegetation would likely colonize dead hemlock areas by the next growing season which would reduce landslide risk.

2. ALTERNATIVES

This section outlines details of each proposed alternative. The National Park Service has considered four alternatives to manage HWA infestations. The alternatives were developed based on currently available management techniques. Specific areas to be treated are not detailed in the alternatives.

2.1 Alternatives Under Consideration

2.1.1 ALTERNATIVE 1: No Treatment

GRSM would apply no treatments to prevent the spread of HWA throughout the park. HWA populations would be allowed to increase and decrease naturally without intervention. In addition, current chemical and biological treatments would be discontinued. Because HWA has a high reproductive capacity and has demonstrated the ability to rapidly spread in recent years, it is expected that HWA populations would continue to increase throughout the currently infested area and accelerate their spread to currently non-infested areas. Significant losses of hemlock in all associated forest types would be expected with this alternative and HWA populations in the park could affect hemlocks outside the boundary. Population densities would likely fluctuate periodically depending on the severity of winters and quality of hemlock foliage available for HWA reproduction. However, HWA populations can rebound quickly - even after severe winters.

2.1.2 ALTERNATIVE 2: No Action

Under this alternative GRSM would continue to treat at the current level. Chemical treatments would be used primarily along roadways, developed areas, and backcountry campsites as part of a hazard tree management plan. The biological controls would be released when available. Because it may take up to ten years for the biocontrols to become established and control HWA populations, those forest stands infested early on are expected to have high mortality without chemical intervention.

In 2005, GRSM biologists followed hemlock monitoring protocols established at Delaware Water Gap National Recreation Area. This long term monitoring in GRSM will be analyzed to determine effectiveness of biological, chemical, and no control.

2.1.3 ALTERNATIVE 3: Chemical Control Only

GRSM resource managers will use integrated pest management (IPM) techniques to manage HWA. The IPM process requires decisions to be based on knowledge of pest biology, the environment, unacceptable levels of pest damage, and available control technology that poses the least possible risk to people, resources, and the environment. NPS policy establishes IPM as the preferred method for managing pests in parks and monuments. The development of this program is based on, and directed by, various policies, laws, regulations, executive orders, and a presidential memorandum.

Other NPS units have treated HWA using chemical controls and biocontrol insects. Delaware Water Gap National Recreation Area (DEWA) in Pennsylvania and Shenandoah National Park (SHEN) in Virginia have had HWA since the 1990s. DEWA has treated a total 125 trees with horticultural oil and 36 trees with imidacloprid. In 2004, SHEN treated 68 acres with insecticidal soap and 18 acres with imidacloprid via stem injection. In 2004, the Blue Ridge Parkway (BLRI) in Virginia and North Carolina treated 828 trees in a landscape setting with insecticidal soap and imidacloprid.

GRSM would use insecticidal soap, horticultural oils, and systemic insecticides to control HWA.   See Appendices A through L for label information and material safety data sheets for chemicals currently approved for use in GRSM to control HWA. The pesticides proposed for chemical control of HWA in GRSM are the same that have been used by states, national forests and other national parks that are managing HWA. Insecticidal soap and oils have been used for aphid and adelgid control since the 1980s and their effects on non-target insects and vegetation are well understood.

GRSM technicians would chemically treat infested roadside and developed area hemlocks using insecticidal soap and horticultural oil sprayed from truck-mounted spray units. High-pressure sprayers greatly increase the ability to reach the upper branches of each tree. Technicians can adequately spray up to 80 feet into the canopy of roadside trees using these sprayers.

A farm utility vehicle with an attached sprayer can be used to access administrative roads too narrow for trucks. This sprayer can reach up to 45 feet into the canopy.

The soap and oil have been shown to be 95%-99% effective at controlling adelgid populations when sprayed on hemlock foliage (Rhea 1996, McClure 1987). However, they control only the insects that are present on the tree at the time of application so any future re-infestation must be treated as well. Adelgids must be present in order to be controlled and coverage must be thorough. Roadside treatment extends only about 50 feet from the pavement so re-infestation from nearby untreated trees would continue. Since HWA has two generations per year, soap and oil applications may be needed up to twice per year. Oil treatment may damage foliage during periods of prolonged high temperature and high relative humidity (Sunoco, Inc. 2000) limiting oil spraying operations to the dormant season.

Under the chemical control only alternative, systemic insecticides would be used to treat hemlocks that are not candidates for foliar insecticidal soap or horticultural oil treatments for various reasons. Trees that cannot be treated with foliar spray include hemlocks that are too tall to be adequately reached with the foliar spray, high-value hemlocks that are inaccessible to truck-mounted spray units, and hemlocks near water. Trees that are an adequate distance from water and in suitable soils (i.e. not rocky or boggy) would be treated with a systemic insecticide via soil drenching or soil injection. Imidacloprid is the chemical name of a systemic insecticide used to control HWA in the park (USEPA 1994). Imidacloprid is a neonicotinoid insecticide in the chloronicotinyl subgroup. Nicotine has historically been used as an insecticide for sucking insects because of it properties as a nerve poison. Imidacloprid is packaged differently for various applications. GRSM technicians would use both the water soluble powder (WSP) and liquid formulation depending on specific treatment.

The water soluble powder would be used for both soil drenching and soil injecting methods. Imidacloprid, packaged under the brand name Merit®, is currently approved for use in GRSM to treat HWA. In the soil drench method, technicians temporarily remove the duff (organic matter) layer from around the base of the tree then pour an Imidacloprid and water mixture around the base of the tree within a foot of the trunk. The organic matter is then replaced. The same Merit® mixture can be used in a hand-operated soil injecting device that injects the insecticide under low pressure into the soil approximately three inches below the soil surface. This method does not disturb the duff layer. Imidacloprid bonds with soils containing sufficient organic matter, which greatly restricts movement through soil (Cox et al. 1997). Non-target effects of soil (drench or inject) treatment include unwanted death of soil invertebrates in the immediate area of application. Scientific studies of soil invertebrate impacts are limited.

The amount of imidacloprid used to soil drench or soil inject a tree is dependent on the tree diameter at breast height (DBH). The treatment lasts up to 2-3 years (Cowles and Cheah 2002). According to a study in Massachusetts, the chemical takes 8 to 12 weeks to reach the foliage of trees 10 to 18 inches DBH (Tattar et al. 1998). This method shows good control of HWA (Rhea 1996, Cowles et al. 2004) and tree health recovery from infestation (Webb et al. 2003).   One study found 98% control of HWA using the soil injection of imidacloprid (Steward et al. 1998). The cost of the material alone is approximately 50 cents per inch of tree diameter.

A liquid formulation of imidacloprid (Ima-Jet) can be injected directly into the stem of a tree in areas not suitable for soil treatments. Imidacloprid is highly toxic to aquatic invertebrates (Bayer 2000) and, therefore, cannot be used as a soil treatment for trees near water or in rocky, boggy or sandy soils where it can leach into aquifers and waterways (Cowles et al. 2004). Such situations require that imidacloprid be directly injected into the tree stem to eliminate the chance of the chemical leaching into water sources. This method has been shown to control HWA (Doccola et al. 2003), but may not last as long soil injection or soil drenching (USDA Forest Service 2004). Stem injection uses less chemical compared to the other treatment methods and limits the exposure of beneficial predators to the chemical (Cowles et al. 2004). Tattar et al. (1998) found that the chemical reached the foliage faster using this method than the soil drench or injection (four weeks as opposed to 12). However, it is much more expensive (cost of material is $3.00 per inch of tree diameter) and the method is labor intensive. Stem injection requires multiple drilling sites on the lower trunk and is not as reliable in reducing HWA populations as compared with other methods (Cowles et al. 2004). This method would only be used for trees near water or where other methods would not be appropriate.

Other systemic insecticides may be available for HWA control in the future. If these insecticides prove effective, pose an acceptable environmental risk, and are affordable, they may be considered for use in the future. Currently, however, imidacloprid is the only systemic insecticide that has proven useful for HWA control and poses acceptable environmental risk when used according to label directions.

2.1.4 ALTERNATIVE 4: Biological Control Only

Under this alternative, GRSM would introduce insect predators of HWA to control HWA populations. Currently two beetle species are available for release into GRSM, with several more expected to be available in the future. Biological control of HWA has been investigated for over a decade, starting with existing native and non-native predators. Researchers found native insects that prey on the adelgid, but none have significantly reduced HWA populations (Montgomery and Lyon 1996, Wallace and Hain 2000). Even though HWA has been reported from Virginia since the 1950s, no effective native or naturalized predators have emerged that are abundant enough to control HWA or prevent tree mortality. Pathogens have been identified and continue to be evaluated, but no active biocontrol program using pathogens is in use. Currently, the only biological control available for treatment is predatory beetles.

Non-native beetles that complete their life cycle using HWA as a food source have been investigated since the early 1990s. Techniques to rear these predators in laboratory settings have been developed for several species. However, lab rearing is a labor intensive process. No artificial diet has been successfully developed to feed these predators so live branches with high densities of healthy HWA must be field collected and brought back to the lab to support rearing activities. As HWA infestations degrade tree health and cause a resultant HWA population crash, the populations of HWA in an area used for predator food will not be suitable for predator food in the future. Costs to produce one species of predator beetle have been estimated at $1-$2 for each individual. This price may seem exorbitant, but, if successful, would be less expensive over the long term than regular application of insecticides. Successful predator insects would be self sustaining once established. Insecticidal operations are costly because of the pesticides, equipment, vehicles, and labor needed to annually. In addition, many stands of old-growth hemlock are remote and difficult to access, making them even more costly, if not, impossible to treat using insecticides.

The ability of predator insects to control HWA on a landscape scale is not well known. The first released predators have been scattered throughout the eastern range of hemlock for only ten years. The monitoring of these predators shows definite promise as they must feed on HWA to complete their life cycles. In the field, many factors conspire to affect HWA and predator populations such as fluctuating winter warm and cold spells and minimum low temperatures. Other predators including native and non-native species can also affect HWA-specific predator survival. The species discussed below are the currently known best choices for HWA biocontrol. In their homeland, these predators do not single handedly control HWA populations. Several species of invertebrate predators and diseases, as well as some inherent resistance to HWA, combine to make HWA a minor pest on Asian and western North American hemlock species. One species of non-native HWA predator will not likely save eastern hemlocks. The following predators are potential biocontrol agents for use in GRSM:

Sasajiscymnus tsugae

S. tsugae (formerly named *Pseudoscymnus tsugae*), a tiny black ladybird beetle (Coccinellidae) about the size of a poppy seed, was imported from Japan to the U.S. and put into quarantine in 1992. Since then *S. tsugae* has been laboratory screened in feeding preference tests and field-testing began in 1995.

S. tsugae has been released into forested areas for HWA control since 1997 (McClure 2001). States where releases have occurred include Connecticut, New Jersey, Virginia, Maryland, Rhode Island, Massachusetts, New York, Pennsylvania, North Carolina, West Virginia and Tennessee. Releases were in state and national forests and NPS units, including Delaware Water Gap National Recreation Area. Control results are in the early stages. In Connecticut, a 47%-87% reduction in HWA densities in five months was reported with a starting population of 2400-3600 *S. tsugae* which were released at densities of 30 per branch (McClure et al. 2000). Long-term control effectiveness will take time to evaluate. After 4-7 years of hemlock recovery following heavy infestation in a Connecticut study, recovery rates were variable and were tied to factors such as soil (rocky or shallow), drought stress, and co-infestations of either elongate hemlock scale or hemlock borer (Cheah et al. 2004).

A total of 87,024 *S. tsugae* was released at 31 HWA-infested sites in GRSM from 2002 through 2004. Evaluation of the released beetles and their control of HWA are ongoing. Evaluation (monitoring) involves "beat-sheet" sampling for *S. tsugae* and counting HWA on the terminal 25 mm of hemlock foliage. In a follow-up study evaluating the dispersal of *S. tsugae*, researchers recovered beetles at 3 of 10 release trees in the park (Lambdin and Gwinn 2003). A low recovery rate of this biological control agent at ground level has been reported from studies in Connecticut, Pennsylvania, and New Jersey. A researcher in Connecticut found *S. tsugae* recovery was highest at 6 meters above ground level. In GRSM, collecting information for one study involving egg releases now involves sampling for *S. tsugae* adults using bucket trucks so that higher branches may be reached. Conclusions as to success or failure of these egg releases are pending.

The Connecticut Agricultural Experiment Station has the longest history of evaluations on *S. tsugae*. Dr. Mark McClure imported *S. tsugae* from Japan and studied it for years to determine food preferences, non-target effects, and ability to manage HWA populations. He and his staff found *S. tsugae* to significantly reduce HWA populations in areas near release trees (McClure et al. 2000). These results allowed for the mass rearing that continues today. Effectiveness of *S. tsugae* for HWA control may vary from north to south and from site to site. Ongoing evaluations over years will ultimately show how effective *S. tsugae* is at HWA control.

Laricobius nigrinus

L. nigrinus, a beetle belonging to the family Derodontidae, is native to British Columbia and the Pacific northwest, and has been studied as a control for HWA in the eastern US (Zilahi-Balogh et al. 2002, Lamb et al. 2002, Lamb et al. 2005). *L. nigrinus* shows high specificity for HWA and has a synchronous life cycle with HWA becoming active in the fall and winter (Zilahi-Balogh et al. 2003). *L. nigrinus* larvae feed on HWA eggs, while adults feed on immature and adult stages of HWA (Zilahi-Balogh et al. 2002, 2003). A study in Virginia showed significant reductions of adelgid populations with release of *L. nigrinus* (Lamb et al. 2002). *L. nigrinus* has been experimentally released for HWA control in 11 locations in five eastern states since 2003, including one location in GRSM in 2004. Efficacy evaluations are ongoing.

Others

Other biocontrol insects are being evaluated and rearing procedures are being developed. Three species of *Scymnus* beetles (*S. ningshanensis, S. sinuanodulus* and *S. camtodromus*) from China are being evaluated. Managers at Coweeta Hydrological Lab in North Carolina experimentally released *S. sinuanodulus* in a caged study and researchers think it is more suitable for southern areas, while *S. ningshanensis* might be more suitable for northern areas (M.E. Montgomery, email communication, April 7, 2005). All three *Scymnus* species beetles prefer to feed on adelgids but have fed on some aphid species. *S. sinuanodulus* feeds on all life stages of HWA and requires HWA to complete its life cycle (Cheah et al. 2004). *Scymnus* beetles are available for release in limited supplies on an experimental basis and have been released in 2005 in the Pisgah National Forest. All three species have potential to control HWA and will be considered for release in GRSM.

Both *S. tsugae* and *L. nigrinus* show no undesirable traits that would cause them to be a nuisance or otherwise poor candidate for release. *S. tsugae* is expected to attack only HWA and other adelgids such as the balsam woolly adelgid (a non-native pest of Fraser fir that occurs in GRSM), pine bark adelgid, and Cooley spruce gall adelgid (not known from GRSM). *S. tsugae* cannot reproduce unless it consumes HWA eggs. Therefore, if HWA populations were to drop, *S. tsugae* populations would also decline. HWA will not be eliminated by *S. tsugae* or *L. nigrinus*, but will rather be suppressed to the point of allowing hemlocks to survive and hopefully reproduce. BLRI has introduced 12,500 *S. tsugae* predator beetles since 2002.

Currently HWA predator rearing facilities exist in New Jersey (NJ Department of Agriculture), Pennsylvania (Eco-Scientific Solutions- a private company), North Carolina (NC Department of Agriculture), South Carolina (Clemson University) and in Tennessee (The University of Tennessee- Knoxville). The University of Tennessee lab has been in production since late 2003 and was started specifically for the control of HWA in GRSM and surrounding public lands. None of the predator beetles can presently be raised using an artificial diet. The need for constant supplies of healthy HWA for food as well as precise climate control in the rearing facility contribute to the expense and difficulty of production.

Due to the limited availability of beetles, sites for treatment in the park would be prioritized based on HWA density, hemlock density, presence of T&E species, and watershed protection values. There is no guarantee that sufficient numbers of biological control agents can be released, or that they will successfully reproduce to levels adequate to control HWA. While the predator beetles were released in many areas of the mid-Atlantic states, HWA was already well established and the trees already beginning to decline. Long-term monitoring has begun in some of those areas, but no comprehensive results are available. However, biological control remains the only feasible alternative for the extensive remote hemlock stands.

Problems can arise in biological control when the introduced agent is a generalist, i.e. preys on a range of hosts, some of which may be beneficial. The multicolored Asian lady beetle *Harmonia axyridis,* introduced in the late 1970s for control of various crop pests, has become a nuisance pest in houses. *S. tsugae* does not aggregate in large numbers prior to overwintering as was the case with the nonnative *H. axyridis.* *S. tsugae* does not leave the forest to overwinter and observations suggest that this species hibernates in the leaf litter. *S. tsugae* is incapable of transferring to non-adelgid prey and populations are expected to decrease as HWA densities decline. In contrast, *H. axyridis*, a generalist predator, maintains high densities by switching over to other more abundant prey. *H. axyridis* will consume HWA when it comes across it, but it will eat many other insects as well, including HWA biocontrol insects. The beetles used to control HWA are host specific on HWA, do not mass congregate and are, therefore, unlikely to become a pest themselves. However, some of the general public remains confused about the identity of various ladybeetles and complains about the park and/or national forest having introduced the pesky *Harmonia.*

2.1.5 ALTERNATIVE 5: Both Chemical and Biological Control

GRSM managers have identified **Alternative 5: Chemical and Biological Control** as the preferred alternative. Under this alternative GRSM would use a combination of chemical and biological controls to best fit individual hemlock sites throughout the park.

Using a combination of chemical and biological controls will allow more areas throughout the park to be treated. The use of biological controls allows the treatment of trees in the backcountry and trees along waterways. The use of chemical controls allows the treatment of trees in areas accessible from the road. While some chemical controls can be done in the backcountry, it is not feasible for widespread use. By using a combination of treatments, park managers can more effectively use limited funds and resources to treat a greater area across the landscape.

If this Action Alternative is selected, GRSM would use a combination of IPM strategies. Park technicians would scout GRSM for HWA on roads, trails, and off-trail in areas identified as having a significant hemlock component. Scouting surveys would be prioritized according to HWA infestation potential, hemlock dominance, and old-growth hemlock component. Treatment decisions would be made accordingly. High priority areas would be scouted annually, while the remainder would be scouted biennially. Scouting information will greatly enhance our ability to plan and prioritize treatment of hemlocks throughout the park. Management of HWA would be conducted everywhere that is technically and financially feasible. A combination of insecticides and biocontrol options are listed below for hemlock stands depending on forest condition and location.

High-Use Developed Areas

Technicians would chemically treat infested hemlocks in high-use developed areas using insecticidal soap and horticultural oil. Generally, high-use areas are easily accessible by vehicles allowing for the use of high pressure sprayers.

High-value trees that are either too tall to be adequately treated with foliar spray or are near water would be treated with systemic chemicals. Imidacloprid would be applied either through soil treatment or stem injection depending on soil condition and proximity of the site to water.

Old Growth Hemlock Forests or Backcountry Hemlock-Dominated Forests

GRSM would treat backcountry hemlock-dominated sites or old-growth hemlock forests primarily with biological controls. Predatory beetles or eggs would be released throughout the park at these inaccessible sites depending on beetle availability. Some stands not selected for biological release would be treated chemically as funding allows. A subset of trees at these priority sites would be selected for chemical treatment. Soil drenching or soil injection would be used to treat these trees with imidacloprid. Trees of all size classes would be treated to maintain structural diversity for birds, lichens, invertebrates, etc. By treating a wide range of tree sizes, more genetic material would be maintained throughout the site.

2.2 Alternatives Reviewed But Removed From Further Consideration

1) Foliar Application of broad-spectrum pesticides

Using pesticides that injure or kill a broad variety of insects would pose an unacceptable risk to the protection of natural resources in GRSM.

2) Silvicultural Alternative –

Cutting infested trees or using fire in an attempt to slow or halt the spread of HWA is not an effective control method and would merely reduce the available hemlock gene pool. HWA are wind and animal dispersed and move easily from one tree to another

Since HWA attacks all sizes of hemlock, replanting native hemlocks with existing HWA populations in the area would not preserve the park’s hemlock resources. Additionally, the gene pool of the park's existing hemlock would change if seeds or seedlings from other locations were planted in the park. Non-native or hybrid species of hemlock may be resistant to HWA but they would change the park's hemlock forest the same way. Preservation of existing resources is mandated by the Organic Act of 1916, which allowed for the creation of the NPS, and is part of NPS management policy.

2.3 Environmentally Preferred Alternative

The environmentally preferred alternative is defined as the alternative that would promote the national environmental policy expressed in NEPA. This alternative would have the minimum environmental consequences of the alternatives under consideration, including the no-treatment alternative.

The environmentally preferred alternative is **Alternative 5: Chemical and Biological Control**. Under this alternative GRSM would use a combination of chemical and biological controls to best fit individual hemlock sites throughout the park. This environmentally preferred alternative promotes the national environmental policy by meeting the following criteria:

- Alternative 5 best protects park resources for future generations. More hemlock communities can be safely treated following Alternative 5, including those forests found in the backcountry, in high-use areas, areas near water, and old-growth communities. By using a combination of techniques, mangers have the flexibility to best address specific habitat concerns by individual site allowing the treatment of diverse communities across the park protecting a wide array of sites for the future.

- Alternative 5 best ensures that park employees and visitors enjoy a safe, healthful, productive, and esthetically and culturally pleasing surrounding. Being able to use both chemical and biological controls assures that heavily used areas will be treated as aggressively as possible while still protecting the safety of employee applicators.

- Biological and chemical control, used in combination as described in Alternative 5, allow managers to tailor treatments to areas that best protect water resources, non-target species, and T & E species.

- The impending loss of hemlocks without treatment threatens the unique cultural and natural resources in GRSM. Alternative 5 best allows protection of our natural heritage and hemlock environments that support diversity throughout the park.

- Alternative 5 ensures that the visiting public will be able to continue to enjoy park campgrounds, overlooks, roads, and picnic areas with little disruption.

- Hemlock dominated forests and the communities that have developed within them will be best protected with Alternative 5. Specific site treatments can be developed ensuring that the maximum number of hemlocks are treated across the park. By using environmentally sensitive chemicals and biocontrol agents, the quality of resources within hemlock forests will be best protected and enhanced for future generations.

2.4 Summary of Alternatives

ACTIVITY	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
No treatment	YES	NO	NO	NO	NO
Use insecticidal soap and oil and systemic insecticides	NO	YES	YES	NO	YES
Use biological controls	NO	YES	NO	YES	YES
Use both insecticides and biological controls	NO	YES	NO	NO	YES

Table 1 – Summary of Alternatives

None of the action alternatives require mitigation activities. The No-Treatment Alternative might result in the need of restoration in devastated habitats, although reintroducing hemlocks into the natural environment would be futile without HWA control measures in place. In addition, potential impacts to cultural resources under the No-Treatment Alternative will be subject to review under Section 106 of the National Historic Preservation Act.

3. AFFECTED ENVIRONMENT

GRSM is part of the large Appalachian Mountain system, which consists of a series of mountain ridges trending northeast to southwest from Maine to Georgia. The Unaka Range, a major unit of the Appalachians encompassing the mountains of the park, lies wholly within the Mississippi River drainage. The Unaka Range is cut into segments by northwesterly flowing tributaries of the Tennessee River. The Pigeon River cuts the main ridge of the Unakas on the northeast and the Little Tennessee cuts the main ridge of the Unakas on the southwest (USDI NPS 1982).

The mountain remnants seen today are principally the result of stream erosion. The dominant topographic feature of the park is the northeastward-trending ridgeline that forms the boundary between North Carolina and Tennessee. For 36 of its 71 miles, the main divide stands more than 5,000 feet above sea level. Lower ridges form radiating spurs from the central ridgeline. The moderately sharp-crested, steep-sided ridges are separated by deep valleys that occasionally widen along the sides of higher ridges. Many of the ridges branch and subdivide, creating complex drainage systems that abound with fast-flowing mountain streams (USDI NPS 1982).

Individual hemlock trees can be found in nearly all forested habitats up to 5,000 feet in elevation across the 523,000 acres that comprise the park. All hemlocks will presumably be exposed to the threat of HWA mortality. Of course, this threat will be much more significant in the hemlock-dominated forests (over 18,000 acres) and hemlock old-growth forests (over 700 acres).

Elevations in the park range from 840 feet at the mouth of Abrams Creek to 6,643 feet at the top of Clingmans Dome.

Eight counties encompass or lie close to boundaries of GRSM: Blount, Sevier, Cocke and Monroe counties in Tennessee are situated on the northern end, and Graham, Jackson, Swain and Haywood counties in North Carolina occupy the southern vicinity of the park. The area surrounding the park is comprised of two national parkways, three national forests, a Cherokee Indian reservation, an extensive system of lakes developed by the Tennessee Valley Authority (TVA) and the Aluminum Company of America (ALCOA), and land belonging to private individuals and organizations. The US Forest Service has recently completed an Environmental Assessment for the Suppression of HWA infestations for the national forests adjacent to the park boundary (2004).

Land surrounding the park is mostly rural, consisting primarily of forested foothills and mountains. Approximately 84 percent of the land within a six-mile radius of GRSM boundary is forested. The remaining areas consist mostly of agricultural land (10 percent) and urban development (2 percent). Small towns and communities, some adjacent to the park, are scattered throughout the region. The mean human population density of the eight county region is +/- 80 individuals / square mile. The majority of the people in the eight county region are employed in retail trade, manufacturing, and personal services. Much of the economy is tourism-related and land traditionally used for forests and agriculture is increasingly being replaced by resort communities, vacation homes, and retail business (GRSM 2002).

3.1 Botanical Resources

The forests of GRSM have been described as the most complex and diverse in North America. Due to its topographical relief, complex soils, and position in the continent, GRSM supports an enormous diversity of vegetation. Almost 95 percent of the park is forested. The park has more vascular plant species than any other unit in the national park system, while the number of nonvascular plant species ranks among the highest of any area in North America north of Mexico (Rock and Langdon 1991). More than 1,600 species of vascular plants have been identified in the park, including over 100 native tree species. Of these, 160 species are considered rare and over 350 species are nonnative. More than 4,000 nonflowering plant species are present including species of mosses and liverworts, 2,250 species of fungi, and 302 species of lichens. About 10 plant taxa new to the park are discovered each year. Approximately 100,000 acres of old-growth forest are found in the park. This is one of the largest blocks of virgin temperate deciduous forest in North America.

Whittaker (1956) identified 15 vegetation types along complex gradients of moisture and elevation. However, eight vegetation types are considered dominant; these are:

- Pastures and cultivated fields
- Heath and grassy balds (above 4,000 feet in elevation)
- Spruce / fir forest (above 4,500 feet in elevation)
- Northern hardwood forest (3,500 to 5,000 feet in elevation)

- Cove hardwood forest (below 4,500 feet in elevation)
- Hemlock forest (3,500 to 4,000 feet in elevation)
- Closed oak forest (predominantly below 4,500 feet in elevation)
- Open pine / oak forest (found along dry ridges)

3.2 Terrestrial and Aquatic Wildlife Resources

GRSM contains a number of diverse wildlife species due to the parks size, topography, vegetation, and human land uses. Current inventory data documents the following number of species occurring in the park:

Amphibians	**43**
Birds	**253** (32 of these are historic records*)
Fish	**86** (20 of these are historic records)
Mammals	**70** (6 of these are historic records)
Reptiles	**40** (1 of these is a historic record)
Mollusks	**132**
Spiders	**481**
Beetles	**1500**
Butterflies, Skippers, & Moths	**1500**
Dragonflies, Mayflies, Stoneflies, & Caddisflies	**365**
True Flies	**500**

* *These species were historically documented in GRSM, but have not been seen for at least 50 years.*

The park is located in one of the highest precipitation regions of the United States averaging 64 inches annually. This rainfall equates to some 890 billion gallons of which 500 billion gallons are discharged as runoff by the many streams that drain the Park (USDI NPS 1982). There are 2,115 miles of stream within GRSM ranging from 1st to 6th order (Parker and Pipes 1990). Watershed areas range from 1.7 to 109.3 square miles (Parker and Pipes 1990). There are 333 streams (+/- 1,000 miles) in the park large enough to be classified as fishable. The average elevation drop per mile of stream channel is 400 feet. Headwater slopes are steep, increasing as much as 2,000 feet per mile (38%).

Surface water quality in the park is considered good but slightly acidic (pH range from 5.9 to 7.5) and low in dissolved solids. Exceptions to this are streams associated with the Anakeesta geologic formation, which have a pH of about 4.5. The streams have a low natural buffering capacity and are therefore sensitive to acid precipitation. Surface water is clear during normal and low flow but turbid during storm events. Historically, water samples from most of the park streams indicate a low level of coliform bacteria indicating the presence of organic matter and possibly fecal contamination (USDI NPS 1982).

3.3 Threatened and Endangered Species

3.3.1 Plants and Lichens

There are four plants indigenous to the GRSM listed under the authority of the Endangered Species Act of 1973 as federally endangered or threatened; these are:

- Rock Gnome Lichen (*Gymnoderma lineare*) Endangered
- Spreading Avens (*Geum radiatum*) Endangered
- Virginia Spiraea (*Spiraea virginiana*) Threatened
- Small-Whorled Pogonia (*Isotria medeoloides*) Endangered

3.3.2 Animals

There are 16 animals (vertebrates and invertebrates) indigenous to the GRSM listed under the authority of the Endangered Species Act of 1973 as federally endangered or threatened; these are:

- Bald Eagle (*Haliaeetus leucocephalus*) Threatened
- Red-Cockaded Woodpecker (*Picoides borealus*) Endangered
- Northern Flying Squirrel (*Glaucomys sabrinus coloratus)* Endangered
- Gray Bat (*Myotis grisescens*) Endangered
- Indiana Bat (*Myotis sodalis*) Endangered
- Panther (Mountain Lion) (*Felis concolor*) Endangered
- North Carolina Funnelweb Tarantula (*Microhexura montivaga*) Endangered
- Spotfin Chub (*Hybopsis monacha*) Threatened
- Duskytail Darter (*Etheostoma percnurum*) Endangered
- Smoky Madtom (*Noturus baileyi*) Endangered
- Yellowfin Madtom (*Noturus flavipinnis*) Threatened
- Appalachian Elktoe (*Alasmidonta raveneliana*) Endangered
- Oyster Mussel (*Epioblasma capsaeformis*) Endangered
- Fine-rayed Pigtoe (*Fusconaia cuneolus*) Endangered

- Green-blossom Pearly Mussel (*Epioblasma torulosa gubernaculum*) Endangered
- Little-wing Pearly Mussel (*Pegias fabula*) Endangered

In addition to the federally listed species, GRSM maintains a database of 320 plant and animal species listed by the states of North Carolina and Tennessee. Management of these plant and animal species will be according to the guidance established by the respective state (See Appendix M).

3.4 Recreational Resources

The broad management goals of the park are to preserve the park's diverse resources while providing for public benefit and enjoyment. GRSM is the most heavily visited park of the national park system with nearly 10 million visitors annually (9,167,044 for 2004). Most visitors to the region travel in private automobiles. In addition to roads providing access to and within the park, numerous foot and horse trails provide access to the park's backcountry. The principal use of GRSM is recreational. Activities include viewing wildlife and scenery from motor vehicles, hiking, biking, camping, horseback riding, kayaking, and fishing.

Park visitation rates vary seasonally, peaking between June and October. Visitation tends to be heavier during weekends and holidays, and backcountry use is high during college breaks. The park's natural features are the main attraction for visitors, with most activities restricted to driving through the park, or picnicking, rather than backcountry camping and hiking (USDI NPS 1982). The park's backcountry contains approximately 850 miles of trail with 102 campsites and 18 shelters. Camper nights numbered 276,468 at the 10 developed campgrounds (GRSM 2005) The park had 73,786 camper nights at backcountry campsites in 2004 (GRSM 2005). In 2004, GRSM had an annual budget of $15.4 million (GRSM 2005).

The GRSM is noted for its outstanding vistas. These vistas include:

- Forest resources
- Mountain streams
- Wildlife
- Flowering plants
- Historical resources
- Scenic roads
- Scenic trails

3.5 Cultural Resources

3.5.1 Archaeological Resources

Humans have been a part of the Southern Appalachian ecosystem for the past 15,000 years (USDI NPS 1982). Archaeological evidence of people utilizing the abundant natural resources of the Smokies begins 12,000 years ago and continues until the formation of the Great Smoky Mountains National Park in 1934 (E.S. Kreusch, GRSM Archeologist, personal communication). In the Smokies, archeological resources consist of prehistoric and aboriginal sites that represent several southeastern cultural periods, as well as historic sites related to mountain culture and the Park development period.

Cherokee Indians occupied the mountains and the adjoining lowlands before white European settlers forced them out in the 1800s. While over 300 archeological sites have been found within the Park boundary, the total remains unknown (E.S. Kreusch, GRSM Archaeologist, personal communication).

3.5.2 Historic Structures

Over 197 structures are listed on the park's List of Classified Structures (LCS). These structures include historic buildings and early park infrastructure including roads, bridges, and visitor centers.

3.5.3 Cultural Landscapes

The National Park Service maintains a database of historically significant landscapes in the National Park Service known as the Cultural Landscape Inventory (CLI). The park contains 42 landscapes and component landscapes currently listed on the CLI. These include both landscapes that are documented or certified as cultural landscapes and those that have been identified for further study as cultural landscapes (D. Flaugh, GRSM Landscape Architect, personal communication). Elkmont is one of the landscapes identified for further study and has the potential to include over 60 component landscapes that are not yet listed on the CLI.

3.5.4 Other Cultural Resources

Over 150 known cemeteries are located within the park's boundaries. Most of these cemeteries are bounded by forest cover and, in some cases, by stands of hemlock. In addition other historic features including abandoned Civilian Conservation Corps (CCC)-era hemlock nursery stock exist at some of the old CCC campsite locations. It is unknown at this time the extent of these resources, but two areas (the camp at Sugarlands and the camp at Cades Cove) are known to have hemlock stands.

4. ENVIRONMENTAL CONSEQUENCES

The following sections address the environmental consequences of the alternatives and are organized by resource topic. The determination of impacts is discussed using the following terms as defined.

Negligible Impact: Impacts occur, but are barely detectable. Impacts are so minute that they have no observable effects on plants and animals and the ecosystems supporting them.

Minor Impact: Impacts are slight, but detectable. Population numbers, population structure, genetic variability, and other demographic factors for species may have small, short-term changes, but long-term characteristics remain stable.

Moderate Impacts: Impacts are readily detectable and apparent. Population numbers, population structure, genetic variability, and other demographic factors for species may have small to moderate, short-term declines, but rebound to pre-impact numbers. Species are not at risk of being extirpated from the park and habitats for all species remains functional.

Major Impacts: Impacts are readily detectable and produce severe changes. Population numbers, population structure, genetic variability, and other demographic factors for species may have large, short-term declines with long-term population numbers considerably depressed. In extreme cases, species may be extirpated from the park and habitats for any species could be rendered not functional.

Short-term Impact: An impact limited to the treatment period that is *not* expected to extend more than two years.

Long-term Impact: An impact that extends past the treatment period and is expected to extend more than two years.

4.1 Botanical Resources

4.1.1 ALTERNATIVE 1: No Treatment

Impacts: Without a viable method for long-term control of HWA, there will likely be long-term, major impacts to hemlock-dominated communities as eastern hemlocks are lost across the park. We can assume that, along with hemlock genotypes, we will also be losing some flora and fauna that depend on hemlock-dominated communities. Canopy openings will allow increased light to fall in these stands, decreasing soil moisture. Solar drying of soil will occur until the gaps are replaced by other vegetation. Plant species composition will likely shift, as has been documented in areas with Fraser fir and beech mortality dominance.

Invasive, non-native vegetation is expected to move into the sunnier areas created by dying hemlocks as the structure of the vegetation community changes. Non-native plant species affect areas by altering species composition and diversity. In Delaware Water Gap National Recreation Area, healthy hemlock-dominated stands are relatively free of invasive alien plants, but declining stands are being invaded by alien species such as Japanese stilt-grass, Japanese barberry, garlic mustard, and tree-of-heaven (Lynch 2005). Additionally, moss, lichen and other bryophyte species that are associated with hemlock, especially old growth hemlock, will likely suffer reduced populations.

Cumulative Impacts: As hemlocks decline increased solar radiation will dry soils and shade- dependent flora, particularly bryophytes, will suffer. Cumulatively, these impacts would likely be far-reaching. Dry site species that require light will invade, including aggressive, non-native flora. Hardwoods and invasive species would likely colonize habitats now dominated by hemlock forests.

Conclusion: With Alternative 1, **long-term, major impacts** would occur in hemlock-dominated communities throughout the park. Eastern hemlock forests will continue to decline with resulting ecological changes to the forests.

Impairment: There would be no impairment to the park's botanical resources under this alternative.

4.1.2 ALTERNATIVE 2: No Action

Impacts: At this level of treatment hemlocks would still die, but at a reduced level compared to the No-Treatment alternative. The same impacts in Alternative 1 would be expected to occur in this alternative, but at a reduced level.

Cumulative Impacts: The same cumulative impacts as Alternative 1 are expected to occur in this alternative, but on a smaller scale.

Conclusion: With Alternative 2, **long-term, major impacts** would occur in hemlock-dominated forests throughout the park but, treated areas would have a reduced impact. Ecological changes would occur in untreated areas as the result of hemlock loss.

Impairment: There would be no impairment to the park's botanical resources under this alternative.

4.1.3 ALTERNATIVE 3: Chemical Control Only

Impacts: No direct effects causing plant injury would occur from using imidacloprid as a soil drench. Imidacloprid is not toxic to plants. Trees injected with imidacloprid might be injured from repeated stem injections due to damage in the cambium layer. However, this doesn't seem to be a significant threat to tree survival (M. Montgomery, email communication, March 18, 2004). Repeated tree wounding would cause localized minor injury that could accumulate over time. This injury could allow fungal rot agents to enter the tree, however this type of injury is common in trees and compartmentalization of damage is a standard wound response in healthy trees. Injections would occur no more frequent than annually. This impact is, therefore, minor in nature.

Trees treated with imidacloprid in a soil drench or through an injection might be more susceptible to secondary pests. This would be a short term effect that could have moderate impacts to tree health. Researchers (Raupp et al. 2004) found that hemlocks treated with imidacloprid suffered more injury from spruce spider mites and hemlock rust mites than non-treated hemlock trees. In addition, their research found that terminal needles on imidacloprid-treated hemlocks were approximately nine times more likely to have severe needle damage than untreated trees. Unfortunately, some pesticide applications for a primary pest such as HWA may contribute to the development of a secondary pest. In some instances, it might be worthwhile to treat secondary pests, but another set of impacts would require evaluation.

Foliage on trees treated with horticultural oil may be damaged during periods of prolonged high temperature and high relative humidity (Sunoco, Inc. 2000). However, this threat will be completely avoided in GRSM as trees will only be treated with oil during the dormant season.
Researchers did not find phytotoxic effects (injurious or lethal effects) on Fraser firs after treating trees with a 1.5% insecticidal soap solution (Hastings et al. 1984). Insecticidal soap caused some foliar discoloration in a study done on a Fraser fir plantation indicating that succulent foliage (June growth) may be sensitive to soap treatments. However, multiple sprays of either high or low concentrations could be used with little discoloration at times later than June (Hastings et al. 1986). Appropriately timed spray operations of either insecticidal soap or horticultural oil should not cause any foliage injury to hemlocks. Therefore, these impacts can be avoided. Further, hemlocks would not be treated when suffering from drought stress or under excessive heat and humidity conditions.

In general, non-target vegetation sprayed incidentally should not suffer foliage damage according to the label of the horticultural oil (Sunoco, Inc. 2000) and insecticidal soap (Southern Agricultural Insecticides, Inc. 2005) used in the park. However, plant species have different sensitivities to chemicals and special care will be taken to avoid directly spraying in rare plant communities. Some plants are sensitive to oils. Plant sensitivity can be influenced by environmental conditions, plant vigor, spray concentration, and spraying repetition (Southern Agricultural Insecticides, Inc. 2005). These impacts to non-target vegetation would be short term and minor to moderate in nature. Of course, all incidental spray reaching non-target plants would be the result of minimal drift and dripping from the hemlocks foliage. Treatments will be timed to avoid hot, dry conditions when foliage is most susceptible to damage.

Cumulative Impacts: Repeated tree wounding would cause localized minor injury that could accumulate over time. This injury could allow fungal rot agents to enter the tree, however this type of injury is common in trees and compartmentalization of damage is a standard wound response in healthy trees. Injections would occur no more frequent than annually. This impact is therefore minor in nature.

Short term increases in secondary pests could occur but would not continue for years. No secondary pest population increases have been observed in the three years that chemical treatments have been administered in GRSM.

Conclusion: With Alternative 3, some **minor to moderate impacts** could occur directly to hemlock trees. Systemic pesticides can make trees more susceptible to secondary pests. Minor, short-term impacts could affect sensitive, non-target vegetation as a result of contact with drift from insecticidal soap applications.

Impairment: There would be no impairment to the park's botanical resources under this alternative.

4.1.4 ALTERNATIVE 4: Biological Control Only

Impacts: We do not anticipate any impacts to the botanical community as these beetles do not feed on vegetation. Further, their feeding behavior and habits do not cause harm to vegetation.

Cumulative Impacts: If predatory beetle releases are successful, hemlock mortality would be reduced. Hemlock stands occur on both private and public lands bordering the park. Thus, if predatory beetles become established, they would likely attack HWA infestations on other public and private lands.

Conclusion: With Alternative 4, **no impacts** to botanical resources are anticipated other than the expected beneficial impact to hemlocks.

Impairment: There would be no impairment to the park's botanical resources under this alternative.

4.1.5 ALTERNATIVE 5: Both Chemical and Biological Control

Impacts: Insecticidal soap and horticultural oil treatments will be timed for cooler periods during the year when the risk of potential injury to hemlocks and non-target vegetation is avoided.

Cumulative Impacts: Over time, chemical controls would have a minor localized impact to park resources. This impact would be negligible since application timing would be adopted and used as standard operating procedure. No impacts to botanical resources are expected from biological controls.

Conclusion: With Alternative 5, we anticipate **short-term, minor to moderate impacts** to the botanical community from the use of chemical controls. **No impacts** are expected as a result of biological controls.

Impairment: There would be no impairment to the park's botanical resources under this alternative.

4.2 Terrestrial Wildlife Resources

4.2.1 ALTERNATIVE 1: No Treatment

Impacts: Over time, the effects of the increasing number of declining and dying hemlocks throughout the park will magnify. As previously stated the park has more than 18,000 acres of hemlock-dominated forests (Welch et al. 2002) including more than 700 acres of old growth hemlock (Yost et al. 1994). All hemlocks of all age and size classes are vulnerable to HWA. Some terrestrial wildlife would be directly impacted through loss of habitat. Particularly impacted would be species that have close associations with hemlock such as several species of neotropical migratory birds and certain arthropod species. Additionally, certain mammals may move out of hemlock habitat into other hardwood forests. Some bats such as the endangered Indiana bat may temporarily benefit from the increase in dead hemlock that still have attached bark. Some bats nest under loose bark in the summer.

As more trees die, fewer birds will nest in what live trees remain unless they switch to another species of tree to nest. It is expected that, of those birds that prefer to nest in hemlock, fewer bird offspring will be produced. More dead trees will be available for cavity nesting birds and bats. Invertebrate diversity in hemlock is significant (Buck 2003) and these species would not find a similar substitute tree species in all habitats.

Some species that use dead trees will benefit in the short term until the dead hemlocks break apart and fall. Insects that live in and feed on dead trees will benefit in the short term. Species that use hemlock for food and cover, especially winter cover, will decline. Neotropical migratory birds that are associated with hemlock will suffer.

Hemlock provides direct cover and food for a variety of wildlife species and hemlock forest type provides habitat for many associated plants and invertebrates that these wildlife species depend on. The no-treatment alternative would provide no protection of these hemlock resources with a resultant health decline and mortality of hemlock. Yamasaki et al. (1999) reported 96 species of birds and 47 species of mammals are associated with hemlock forests in the northeastern U.S. The hemlock forests of GRSM include these species. In Massachusetts, researchers found population declines for black-throated green warblers, Acadian flycatcher, blue-headed vireo, and the hermit thrush due to hemlock mortality (Tingley et al. 2002). Farnsworth and Simons (1999) reported that 84% of wood thrush nests in GRSM were in small hemlocks. Full impacts of hemlock decline and mortality are still being studied in northeastern areas affected by HWA.

The distribution and abundance of bird species would likely decline. Those neotropical birds that nest in hemlock stands would likely decline or continue their decline at a faster rate. Terrestrial arthropod species that are dependent upon hemlocks would be lost or decline in numbers. Mammal species that use hemlocks for food and cover would likely find other food sources, although the quality of these resources might decline and negatively affect their populations.

Cumulative Impacts: Vertebrate and invertebrate populations that have close associations with hemlock will be impacted at a moderate to major extent over the long term. Bat populations, woodpeckers, wood boring insects and wood decay fungi may receive a temporary beneficial impact as the number of dead hemlocks increases. Invasive plants would become more prevalent in some areas.

Conclusion: Under Alternative 1, terrestrial wildlife resources would suffer **long-term moderate to major impacts** as hemlock forests decline and die.

Impairment: There would be no impairment to the park's terrestrial wildlife resources under this alternative.

4.2.2 ALTERNATIVE 2: No Action

Impacts: Vertebrate and invertebrate populations that have close associations with hemlock would suffer habitat loss under Alternative 2 at a slightly lower level than in Alternative 1. Organisms that use dead and decaying trees as habitat would experience a short term benefit as the result of dying and dead hemlocks.

Cumulative Impacts: Over the long term, loss of hemlock in untreated areas would result in significant losses to hemlock-dependent organisms. Invasive plants would become more prevalent in some areas. Organisms that rely on dead and dying trees would experience a short-term benefit as the result of dying hemlocks.

Conclusion: Under Alternative 2, terrestrial wildlife would experience **long-term moderate to major impacts**. Pockets of live hemlocks that were treated would become highly sought after by hemlock dependent organisms.

Impairment: There would be no impairment to the park's terrestrial wildlife resources under this alternative.

4.2.3. ALTERNATIVE 3: Chemical Control Only

Impacts: Impacts to non-target invertebrates would occur with chemical treatments. Soft bodied insects contacted by the spray of either insecticidal soap or horticultural oil would be affected. Both sprays dry within hours and recolonization from adjacent untreated trees could occur with no impact. Non-target insects feeding on hemlock roots, stems or foliage would be affected by systemic insecticides. Soil dwelling arthropods would be affected by systemic insecticides administered into the soil for several weeks until concentrations of the insecticides diminished. Stem injected insecticides would not affect soil arthropods.

Cumulative Impacts: Impacts to non-target insects that feed on hemlock or are present on foliage at time of foliar treatment would occur every time treatment was done. Insecticidal soap is used one to two times per year- once during the dormant season- and oil is used once during the dormant season, usually in place of a one soap treatment. Imidacloprid treatments are much less frequent with no less than two years between treatments.

Conclusion: Short-term minor to moderate impacts to terrestrial insects are expected with Alternative 3.

Impairment: There would be no impairment to the park's terrestrial wildlife resources under this alternative.

4.2.4 ALTERNATIVE 4: Biological Control Only

Impacts: Biological control insects considered for release to control HWA will have been screened for other possible food preferences. This includes no-choice food tests of other adelgids and aphids. *S. tsugae* and *L. nigrinus* do not feed upon or attack other arthropod fauna known to be associated with hemlock. *S. tsugae* was found to try balsam woolly adelgid (BWA), a non native species that has killed much of the Fraser fir in the southern Appalachians. *S. tsugae* was shown to prefer HWA in these tests but could feed incidentally on BWA. Other biological control agents may incidentally feed on pine bark adelgid, a native but not threatened pest of pines. Other aphid species may be tried by biological control agents but the control insects cannot survive and reproduce unless they have the eggs of HWA to feed on. Based on these considerations, in the event that either beetle attacks other adelgids, any indirect or cumulative effects are likely to be beneficial. Therefore impacts to non-target insects are expected to be minor.

Recently, potential competition between *L. nigrinus* and a native beetle, *L. rubidus*, was examined to determine if the introduction of *L. nigrinus* would pose any threat to the native population of beetles. *L. rubidus* is native to the eastern United States and feeds primarily on the native pine bark adelgid *Pineus strobi*. In various trials, *L. nigrinus* was unable to complete its life cycle feeding only on *P. strobi* (Zilahi-Balogh et al. 2002) indicating that the two congeners will not compete for native resources. Further, *L. rubidus* showed distinct preference for feeding on *P. strobi* rather than HWA. Unfortunately, this native predator will not likely contribute much to reducing HWA populations, but it also will not face competition from the introduced predator, *L. nigrinus* (Zilahi-Balogh et al. 2002).

Cumulative Impacts: Biological control agents could feed on non-target insects infrequently at any time, but they require HWA to thrive and reproduce so this impact would be negligible.

Conclusion: With Alternative 4, impacts are expected to be **negligible** due to host specificity of the predator insects on HWA.

Impairment: There would be no impairment to the park's terrestrial wildlife resources under this alternative.

4.2.5 ALTERNATIVE 5: Both Chemical and Biological Control

Impacts: Short term impacts to soft bodied insects on hemlock foliage could result from foliar sprays of insecticidal soap or horticultural oil. Soil arthropods would experience short term impacts in the small area around soil treated trees. No impacts from biological controls.

We do not anticipate any permanent impacts to the terrestrial wildlife community from the use of biological or chemical controls. As discussed earlier, all of the predator beetles considered for release have restricted diets. These beetles only feed on HWA in our area. Chemical controls will impact all soft-bodied insects that are exposed to the treatment. The park does not contain any terrestrial wildlife species that is dependent on hemlock for its survival and are likely found on several other woody species. Untreated trees in the vicinity of treated areas will serve as a reservoir for non-target species.

Cumulative Impacts: No permanent impacts to terrestrial wildlife are expected with Alternative 5.

Conclusion: Chemical control would have **short-term minor to moderate impacts** to terrestrial insects are expected with Alternative 5. No other terrestrial wildlife impacts are expected as a result of chemical use. Biological control would have **negligible impacts** to terrestrial insects and no impacts to other terrestrial wildlife.

Impairment: There would be no impairment to the park's terrestrial wildlife resources under this alternative.

4.3 Aquatic Wildlife Resources

4.3.1 ALTERNATIVE 1: No Treatment

Impacts: Soil erosion and increased surface runoff of rainfall could occur. Year-round shading of streams will be reduced. The loss of streamside hemlock-dominated communities will impact the entire aquatic system. Temperature and hydrologic regimes of streams will become more variable and less stable (Evans 2002). This could result in a decline in brook trout. Rates of nitrogen mineralization and nitrification will increase, with some depletion of soil nutrients (Evans 2002).

The heavy shade that hemlock provides along streams keeps those streams cooler. In a stream temperature monitoring study at Delaware Water Gap National Recreation Area, a several degree F decrease in summer stream temperature was documented as the stream flowed through a hemlock-dominated section of the stream. Stream temperature directly affects dissolved oxygen content. Certain vertebrate and invertebrate species are very sensitive to dissolved oxygen content and may be lost as hemlocks along streams lose needles, thereby allowing more sunlight to fall on streams.

Under the No-Treatment alternative, changes in stream quality may occur as a result of hemlock loss. Likely changes to the aquatic community include increased water temperatures, altered species composition, and changes in biotic densities and diversity.

Cumulative Impacts: Permanent changes in aquatic wildlife resources could occur as the result of extensive loss of hemlock. Water and soil chemistry changes could also occur.

Conclusion: Aquatic wildlife would experience **long term moderate to major impacts**.

Impairment: There would be no impairment to the park's aquatic wildlife resources under this alternative.

4.3.2 ALTERNATIVE 2: No Action

Impacts: The No-Action Alternative would result in significant loss of hemlock resources, which would cause detrimental changes in water quality. These changes would likely affect population size and the number of species of aquatic organisms.

Cumulative Impacts: Water temperatures may rise causing decreased oxygen concentrations, which would affect the aquatic invertebrate and vertebrate population densities and diversity.

Conclusion: Long-term moderate to major impacts to aquatic wildlife is expected to occur with the No-Action Alternative.

Impairment: There would be no impairment to the park's aquatic wildlife resources under this alternative.

4.3.3 ALTERNATIVE 3: Chemical Control Only

Impacts: Imidacloprid, horticultural oil, and insecticidal soap are toxic to aquatic invertebrates and precautions would be taken to avoid contamination of waterways. Foliar and soil treatments are not to be administered within 20m of a waterway and spray operations will be stopped in windy conditions likely to cause drift. Mature riparian hemlocks can be stem injected and, thereby, avoid water contamination. GRSM will not conduct any soil drenching or soil injections within 20 meters of ground surface water. The risk of run-off from treated areas into water sources is largely eliminated due to the properties of imidacloprid which readily bind the chemical to organic matter and most soils (USDA 2002). Monitoring data collected in 2001 by the Asian Longhorned Beetle eradication program in a pond in Corona Park, Flushing, New York, indicates no measurable run-off from nearby treatments. Groundwater monitoring studies conducted in a variety of sites have shown that imidacloprid does not significantly leach under actual field-use conditions, although, leaching can occur in areas with sandy soils (USDA 2002).

If directly introduced into water systems, the pesticide is slightly toxic to many fish species, while toxicity for aquatic invertebrates varies by species (USDA 2002). The toxicity of imidacloprid to fish is moderately low. The 96-hour LC50 (lethal concentration required to kill 50% of the test population) of imidacloprid is 211 mg/l for rainbow trout, while the 48-hour EC50 (effective concentration to cause toxicity in 50% of the test organisms) was 85 mg/l for the aquatic invertebrate Daphnia (Kidd and James 1991).

The recommended application of imidacloprid in the park occurs in a nearly closed treatment system which greatly reduces the risk of introduction of the chemical into water systems. The USDA completed a formal risk assessment (2002) for imidacloprid and concluded that the likelihood of exposure to the chemical during and following treatment is minimal and indicates no risk to human health or the environment.

Cumulative Impacts: Proposed chemical controls are not expected to accumulate in the aquatic environment, therefore, no short term or long term impacts are expected.

Conclusion: Under Alternative 3 impacts to aquatic wildlife resources would be **negligible**.

Impairment: There would be no impairment to the park's aquatic wildlife resources under this alternative.

4.3.4 ALTERNATIVE 4: Biological Control Only

Impacts: None of the biocontrol insects have known associations with aquatic insects or aquatic vertebrates. No impacts to aquatic resources are expected as biological controls are predators of terrestrial adelgids.

Cumulative Impacts: No cumulative impacts to aquatic wildlife are expected with Alternative 4.

Conclusion: No impacts to aquatic wildlife are expected with Alternative 4.

Impairment: There would be no impairment to the park's aquatic wildlife resources under this alternative.

4.3.5 ALTERNATIVE 5: Both Chemical and Biological Control

Impacts: Chemical treatments will not be conducted near aquatic areas unless in a closed system (trunk injection). Predator beetles would have no impact on the aquatic community as they are terrestrial and feed only on terrestrial prey.

Cumulative Impacts: No cumulative impacts to aquatic wildlife resources are expected with Alternative 5.

Conclusion: Negligible impacts to aquatic wildlife resources are expected with Alternative 5.

Impairment: There would be no impairment to the park's aquatic wildlife resources under this alternative.

4.4 Threatened and Endangered Species

4.4.1 ALTERNATIVE 1: No Treatment

Impacts: Federal T&E species are listed in section 3.4. Only federal T&E species will be discussed in this section. Appendix M has TN and NC T&E species. Some of these species are found in hemlock forests, but are not exclusive to hemlock forests. The no-treatment alternative has implications for species in hemlock communities. As hemlocks die, more light will reach the forest floor resulting in drier soils.

T&E plant species will be only slightly likely be impacted by the loss of hemlock as very few of these species occur in hemlock communities. The rock gnome lichen may suffer under the drier conditions. The T&E animal species that utilized dead trees may benefit under this alternative, while the other species are not likely to suffer any impacts. Impacts are unknown for five of the species of T&E mussels that are not known in the park but have suitable habitat.

Plants and Lichens

The endangered rock gnome lichen, *Gymnoderma lineare*, is found on boulders in areas of high moisture and low solar radiation (USFWS 1997). This habitat occurs at high elevations where fog bathes the landscape, and in deep gorges at lower elevations. Hemlocks can be found in deep gorges therefore *G. lineare* could be found in some hemlock areas of the park. In the no-treatment alternative loss of hemlock in these areas could allow more light to reach the ground making the habitat for *G. lineare* less suitable.

Spreading avens (*Geum radiatum*), is an endangered high elevation flowering plant that is not likely to be in areas of hemlock resources. No impact is expected in the no-treatment alternative.

Virginia Spiraea (*Spiraea virginiana*) is a threatened shrub that is found on damp rocky streambanks and gravel bars in sunny locations. Loss of hemlock will have no to slightly positive effects on *S. virginiana* populations, unless excessive flooding or landslides occur.

Small-Whorled Pogonia (*Isotria medeoloides*) is a threatened orchid that lives in acidic soil of dry, open deciduous woods. No impact on *I. medeoloides* is expected.

Animals

The bald eagle (*Haliaeetus leucocephalus*) is a threatened bird that generally inhabits areas around large bodies of water. The no-treatment alternative would likely have little impact on this species.

The red-cockaded woodpecker (*Picoides borealus*) is an endangered woodpecker of open old growth pine forests. Loss of hemlock would likely have no effect on *P. borealus.*

The northern flying squirrel (*Glaucomys sabrinus coloratus)* is an endangered squirrel of high elevation spruce-fir forests. No effect on this species is expected.

The gray bat (*Myotis grisescens*) is an endangered bat. Impacts to *M. grisescens* are likely to be minimal as it is primarily a cave dwelling species. Forest habitat around caves is important for avoiding predators (owls) and for flying insect habitat. Loss of hemlock would decrease habitat for hemlock-associated night flying insects but could increase populations of other flying insects that prefer sunnier open areas.

Dead hemlocks may benefit cavity nesting bird species and the federally endangered Indiana bat, *Myotis sodalis* is known to seek shelter under bark of dead trees during the summer.

The mountain lion (*Felis concolor*) is an endangered large cat that is largely considered extirpated from the area. However, park managers do receive occasional reports of sightings every year. The status of breeding populations within the park is unknown. Subsequently, the impact of the no-treatment alternative on mountain lions is not fully known. Mountain lions are known to prey on deer, coyote and small mammals. If any, the impacts of the no-treatment alternative could be beneficial due to increased forest openings and downed woody debris increasing small mammal populations.

The North Carolina funnel web tarantula (*Microhexura montivaga*) is an endangered spider of the high elevation spruce fir forests. No impact is expected to *M. montivaga* from the no-treatment alternative.

The smoky madtom (*Noturus baileyi*) is an endangered fish species previously found only in Abrams Creek and in Citico creek of the Cherokee National Forest. No *N. baileyi* are currently known to be in Abrams Creek.

The spotfin chub (*Hybopsis monacha*) is a threatened fish that was common in Lower Abrams Creek before 1957 and in the Tuckasegee River prior to the impoundment of Fontana Reservoir. Efforts are ongoing for the reintroduction of the spotfin chub to Abrams Creek, using captive reared specimens from the upper Little Tennessee River population. Spotfin chubs were first released into Abrams Creek in 1988 and wild-spawned young-of-the-year fish were observed in 2000 (P. L. Rakes and J. R. Shute, Conservation Fisheries, Inc. Knoxville, Tennessee, personal communication). The diet of the spotfin chub includes a variety of aquatic insects including midges, blackflies, and caddisfly larvae.

Yellowfin madtom (*Noturus flavipinnis*) is a threatened fish in GRSM. Species information about *N. flavipinnis* from NatureServe (2005) has the following statement: "Although there are no historical records from Abrams Creek, Blount County, Tennessee, Lennon and Parker (1959) reported that the brindled madtom (the name given by early collectors for the yellowfin) was collected during a reclamation project of lower Abrams Creek in 1957. Based on this observation, Dinkins and Shute (1996) and others concluded that the species once occurred in the middle and lower reaches of Abrams Creek." In addition, Rakes et al. added (1998) "CFI has reintroduced the species into Abrams Creek, and a population is apparently becoming reestablished". The Yellowfin madtom is an insectivore that stays concealed during the day and uses live and dead trees for cover (Natureserve 2005). Additional dead hemlock could benefit the population of *N. flavipinnis*.

Several freshwater mussels are found in nearby park waters including the Appalachian Elktoe (*Alasmidonta raveneliana*), Oyster Mussel (*Epioblasma capsaeformis*), Fine-rayed Pigtoe (*Fusconaia cuneolus*), Green-blossom Pearly Mussel (*Epioblasma torulosa gubernaculums*), and Little-wing Pearly Mussel (*Pegias fabula*). Presumably, hemlock death along the streambanks will change the character of the stream. It is unclear how each of these particular mussel species will respond to potential changes. These mussels have not been reported within the park boundaries, although the park does contain suitable habitat.

Cumulative Impacts: No T&E species are known to exclusively inhabit hemlock forest resources. Impacts to T&E species that may be found in hemlock habitat would be variable depending on species.

Conclusion: Under the No-Treatment Alternative, the effects on T&E species could be mixed. Some of these species are found in hemlock forests, but are not exclusive to hemlock forests. Some of these species may be able to shift to another habitat, while others may not. Dying hemlocks would allow more light to reach the forest floor, causing drier soils. Species that are now in the shade of hemlock which require more light would benefit. Overall, impacts would likely be **negligible to minor**.

Impairment: There would be no impairment to the park's threatened and endangered species under this alternative.

4.4.2 ALTERNATIVE 2: No Action

Impacts: As with Alternative 1, the no-action alternative has implications for species occurring in hemlock communities because of potentially drier soils. Under Alternative 2, individual hemlock trees and isolated stands will be protected, although, hemlock communities across the park will be impacted by the widespread loss of trees.

One lichen species may suffer, two plant species will not be impacted and one plant species will have no to slightly beneficial impacts as the result of loss of hemlock. Two animals may benefit with this alternative while eight others may have no impacts. Impacts are unknown for five of the species of T&E mussels that are not known in the park but have suitable habitat.

Plants and Lichens

As with Alternative 1, the endangered rock gnome lichen, *Gymnoderma lineare*, found on boulders in areas of high moisture and low solar radiation, could be impacted by the loss of hemlock forests. Alternative 2 would not impact Spreading avens (*Geum radiatum*), Virginia Spiraea (*Spiraea virginiana*), or Small-Whorled Pogonia (*Isotria medeoloides*).

Animals

As with Alternative 1, we would not expect this alternative to have any impacts on the bald eagle (*Haliaeetus leucocephalus*), red-cockaded woodpecker (*Picoides borealus*), or the northern flying squirrel (*Glaucomys sabrinus coloratus)*.

Gray bats (*Myotis grisescens*) are likely to be minimally impacted as by Alternative 2 as the loss of hemlock forests in surrounding habitat may decrease available prey along with hiding spots from predators. Again, dead hemlocks may benefit cavity nesting bird species and the federally endangered Indiana bat, *Myotis sodalis*, which is know to seek shelter under bark of dead trees during the summer.

Alternative 2 is not expected to impact the mountain lion (*Felis concolor*), North Carolina funnel web tarantula (*Microhexura montivaga*), smoky madtom (*Noturus baileyi*), spotfin chub (*Hybopsis monacha*), or yellowfin madtom (*Noturus flavipinnis*).

Several freshwater mussels are found in nearby park waters including the Appalachian Elktoe (*Alasmidonta raveneliana*), Oyster Mussel (*Epioblasma capsaeformis*), Fine-rayed Pigtoe (*Fusconaia cuneolus*), Green-blossom Pearly Mussel (*Epioblasma torulosa gubernaculums*), and Little-wing Pearly Mussel (*Pegias fabula*). Presumably, hemlock death along the streambanks will change the character of the stream. It is unclear how each of these particular mussel species will respond to potential changes. These mussels have not been reported within the park boundaries, although the park does contain suitable habitat.

Cumulative Impacts: No T&E species are known to exclusively inhabit hemlock forest resources. Impacts to T&E species that may be found in hemlock habitat would be variable depending on species.

Conclusion: Under the No-Action Alternative, the effects on T&E species could be mixed. Some of these species can be found in hemlock forests, but are not exclusive to hemlock forests. Some of these species may be able to shift to another habitat, while others may not. Dying hemlocks would allow more light to reach the forest floor, causing drier soils. Species that are now in the shade of hemlock which require more light would benefit. Overall, impacts to T&E species would be **negligible to minor** under this alternative.

Impairment: There would be no impairment to the park's threatened and endangered species under this alternative.

4.4.3 ALTERNATIVE 3: Chemical Control Only

Impacts: No T&E species of non-target invertebrates are known to occur on hemlock. There are no arthropod species federally or state-listed as endangered or threatened that utilizes HWA as a food source. In addition, there are no T&E soil-dwelling invertebrates identified in the park. Chemical treatments will not impact T&E species due to lack of T&E species on hemlock trees or in the soil around hemlocks.

Cumulative Impacts: No cumulative impacts to T&E species are expected under Alternative 3.

Conclusion: With Alternative 3, we anticipate **no impacts** to T & E species. There are no soft bodied, hemlock-feeding T & E species that would be impacted by either chemical or biocontrol treatments. Presumably, by actively protecting hemlock forests, species found within these communities will benefit by remaining in an intact forest system.

Impairment: There would be no impairment to the park's threatened and endangered species under this alternative.

4.4.4 ALTERNATIVE 4: Biological Control Only

Impacts: None of the invertebrate species that *S. tsugae* or *L. nigrinus* are known to feed on are threatened or endangered. No impacts to T & E species are expected.

Cumulative Impacts: No cumulative impacts to T&E species are expected under Alternative 4.

Conclusion: No impacts to T&E species are expected under Alternative 4.

Impairment: There would be no impairment to the park's threatened and endangered species under this alternative.

4.4.5 ALTERNATIVE 5: Both Chemical and Biological Control

Impacts: No T&E species of non-target invertebrates are known to occur on hemlock. Further, none of the invertebrate species that *S. tsugae* or *L. nigrinus* are known to feed on are threatened or endangered. No impacts to T & E species are expected.

Cumulative Impacts: No cumulative impacts to T&E species are expected under Alternative 5.

Conclusion: No impacts to T&E species are expected under Alternative 5.

Impairment: There would be no impairment to the park's threatened and endangered species under this alternative.

4.5 Recreational Resources

4.5.1 ALTERNATIVE 1: No Treatment

Impacts: Under the No-Treatment Alternative, impacted areas with stands of dying hemlocks would lose recreational values. Large blocks of dead and dying hemlocks would detract from the aesthetics and the productivity of the area. Outdoor recreation use that is linked to the ecologic, aesthetic, and/or wildlife habitat benefits of hemlock would be displaced to lower quality sites or lost altogether. Loss of hemlock in the headwaters of streams will likely reduce fish habitat and fish populations; angler success and satisfaction would, therefore, also be reduced.

Hazardous trees will become very common in developed areas such as campgrounds and roadsides. Increased numbers of dead trees will create more tree hazards in areas where hemlocks are near trails, backcountry campsites and developed areas. Dead and dying hemlock trees add significantly to the challenges of managing hazard trees. Dead standing trees would compromise safety and negatively impact aesthetics in front country situations. Dead hemlocks in high-use areas will become unacceptable safety hazards. Removing hazard trees will place an additional burden on the park maintenance division in order to remove these trees in a timely fashion. In addition, park management may decide that the threat from hazard trees warrants facility closures due to safety concerns. Visitors may experience area closures until hazard trees can be removed. More dead trees and limbs will fall on backcountry trails and need to be removed which will increase trail maintenance workloads.

GRSM contributes substantially to local economies through visitor travel expenditures. Local tourism industries that depend on visitors to view or recreate in and near hemlock forests could suffer. In some areas, hemlocks are important contributors to historic properties and cultural landscapes. The loss of trees can detract from the overall character of these sites. Loss of popular hemlock dominated recreation areas could contribute to a decrease in local economies, but the full potential of such losses has not been studied in detail.

Cumulative Impacts: Short term to long term minor to major impacts would occur to recreational resources under Alternative 1. These impacts would be variable depending on area.

Conclusion: Under Alternative 1 impacts to recreational resources are expected to be **long term** and would vary in scale from **minimal to major** depending on the amount of hemlock resource in the particular recreation area.

Impairment: There would be no impairment to the park's recreational resources under this alternative.

4.5.2 ALTERNATIVE 2: No Action

Impacts: With limited HWA control hemlocks will still die in numbers sufficient to impact recreation. Impacted areas with stands of dying hemlocks would lose recreational values. Large blocks of dead and dying hemlocks would detract from the aesthetics and the productivity of the area. Outdoor recreation use that is linked to the ecologic, aesthetic, and/or wildlife habitat benefits of hemlock would be displaced to lower quality sites or lost altogether. Loss of hemlock in the headwaters of streams will likely reduce fish habitat and fish populations; angler success and satisfaction would, therefore, also be reduced.

Hazardous trees will become very common in developed areas such as campgrounds and roadsides. Increased numbers of dead trees will create more tree hazards in areas where hemlocks are near trails, backcountry campsites and developed areas. Dead and dying hemlock trees add significantly to the challenges of managing hazard trees. Dead standing trees would compromise safety and negatively impact aesthetics in front country situations. Dead hemlocks in high-use areas will become unacceptable safety hazards. Removing hazard trees will place an additional burden on the park maintenance division in order to remove these trees in a timely fashion. In addition, park management may decide that the threat from hazard trees warrants facility closures due to safety concerns. Visitors may experience area closures until hazard trees can be removed. More dead trees and limbs will fall on backcountry trails and need to be removed which will increase trail maintenance workloads.

GRSM contributes substantially to local economies through visitor travel expenditures. Local tourism industries that depend on visitors to view or recreate in and near hemlock forests could suffer. In some areas, hemlocks are important contributors to historic properties and cultural landscapes. The loss of trees can detract from the overall character of these sites. Loss of popular hemlock dominated recreation areas could contribute to a decrease in local economies, but the full potential of such losses has not been studied in detail.

Cumulative Impacts: Long term or short term facility closures due to hazard trees, increased maintenance cost for hazard tree removal, and loss of recreational value would occur to recreational resources under alternative 2.

Conclusion: Long term minor to major impacts to recreational resources would occur under Alternative 2 depending on the hemlock resource at a particular area.

Impairment: There would be no impairment to the park's recreational resources under this alternative.

4.5.3 ALTERNATIVE 3: Chemical Control Only

Impacts: Temporary impacts to recreational activities may occur in some areas where foliar treatments are being conducted due to area closures for visitor safety. In order to conduct spray operations, some heavily visited areas may need to be temporarily closed to allow technicians unobstructed access to trees. Area closures should never be in excess of 24 hours. These inconveniences are infrequent as treatments are planned to minimize such interference. Closing spray-treatment areas is done primarily to protect employees and visitors from potential vehicle accidents as the spray truck and operators may be blocking normal driving lanes. Potential visitor contact with foliar sprays is less of a concern, but still a consideration in area closure. While not harmful to humans, the dilute solutions may cause eye or nasal irritation. When feasible, areas will remain open to visitors and traffic control will be used to prevent visitor's exposure to soap or oil.

Foliar treatments can be done in the late fall and winter during low visitation times. Soil injection, soil drenching, and stem injection should have no impact on recreation. Treatments can be done in developed areas when closures are in effect and backcountry treatments can be done when visitors are not nearby.

Cumulative Impacts: For reasons of public safety users may experience short term area closures for treatment in developed areas where foliar treatments are occurring. These treatments would be planned to minimize area closures.

Conclusion: Short-term, negligible impacts to recreational resources are expected with Alternative 4.

Impairment: There would be no impairment to the park's recreational resources under this alternative.

4.5.4 ALTERNATIVE 4: Biological Control Only

Impacts: Predator beetles are not likely to have impacts on visitors. Biocontrol insects for HWA are small and feed specifically on HWA. The insects currently released are both small beetles that stay on or near hemlock trees and do not congregate as some other beetles do. Visitors may encounter NPS employees releasing these insects and may ask questions, but otherwise no impact to the visitor experience is expected.

Cumulative Impacts: No cumulative impacts to recreational resources are expected with Alternative 4.

Conclusion: No impacts to recreational resources are expected with Alternative 4.

Impairment: No impairment to recreational resources is likely to occur.

4.5.5 ALTERNATIVE 5: Both Chemical and Biological Control

Impacts: Occasional, temporary closures of campgrounds, picnic areas, and roads may be necessary to facilitate spraying operations. Predator beetles are not likely to have impacts on visitors.

Cumulative Impacts: For reasons of public safety in chemical treatment areas users may experience short term area closures for treatment in developed areas where foliar treatments are occurring. These treatments would be planned to minimize area closures. Biological controls would likely have no impact to recreational resources.

Conclusion: In chemical treatment areas, **short-term, negligible impacts**, in the form of area closures, would occur with Alternative 5. The severity of these impacts (area closures) would be dependent on the individual visitor and their willingness to visit an alternative area. Biological treatments would likely have **no impact** to recreational resources under Alternative 5.

Impairment: There would be no impairment to the park's recreational resources under this alternative.

4.6 Cultural Resources

4.6.1 ALTERNATIVE 1: No Treatment

Archaeological Resources

Loss of hemlock would not affect archaeological resources. No disturbance of archaeological sites would occur.

Historic Structures

Hemlock does not figure as prominently in GRSM historic landscapes as some other tree species such as black walnut and eastern red cedar. Hemlock is found at some historic structures and loss due to HWA would be evident until other vegetation replaced it. If hemlock at a historic structure could be linked to the structure, moderate impacts would occur.

Cultural Landscapes

Cultural landscape characteristics would be affected with the loss of hemlock including: Natural Systems and Features, Spatial Organization, Vegetation, and Views and Vistas (D.L. Flaugh, GRSM Landscape Architect, personal communication). Newfound Gap Road and Roaring Fork Motor Nature Trail are examples of cultural resources from the park development period that would be adversely impacted. Both of these roads were constructed to provide opportunities to view the landscape while driving and both pass through areas where the predominate tree species is hemlock. Loss of hemlock would change the driving experience by altering views and spatial organization as well as the vegetation type. These are only two of the cultural landscapes listed on the Cultural

Landscape Inventory (CLI) that would be impacted by the extensive loss of hemlock. It should be noted that there exists the potential for other park cultural landscapes that are not currently listed on the CLI and these too would be impacted by the extensive loss of hemlock. For example, the extensive trail system in the park has not been evaluated as a cultural resource. These trails date to the park development period. Many are based on farm roads and logging routes that pre-date the park as well as footpaths that pre-date European occupancy of the area. Many of these trails pass through forest types dominated by hemlock. One example of a potential cultural landscape is the Appalachian Trail. It and other trails (Chimney Tops Trail) in the park date to the 1930s and 1940s, and pass through forest types dominated by hemlock. Scenery (views, vistas, spatial organization) along trails would also be impacted with this alternative. Below are examples of views that would be affected.

View from Chimneys Overlook, Newfound Gap Road- dark green along ridges is hemlock and red spruce.

Hemlock dominates the canopy at the beginning of the Chimney Tops Trail.

<u>Other Cultural Resources</u>

Ethnographic resources related to the park are only now beginning to be identified and studied. Physical elements strongly tied to ethnographic resources are cemeteries. There are at least 151 cemeteries in the park some of which are also considered to be component cultural landscapes on the CLI. Some of these 151 cemeteries are located in areas where hemlock trees predominate. While it has not been documented, it is possible that some hemlock trees associated with cemeteries were planted by descendants of those buried in park cemeteries.

Cumulative Impacts: Impacts would depend on the location of the cultural resource and period of the resource. For example, impacts would occur to a cultural resource tied to park development where forest re-establishment was part of the development and views and appreciation of the forest are important to the design and development. In this case cumulative impacts would include decline and loss of hemlocks with replacement by other tree species, most likely hardwood species. In some areas hemlock loss would allow non-native vegetation to invade.

If a cultural resource exists in an altered landscape where the resource has changed because of reforestation (i.e. farmstead formerly surrounded by open field), the impacts occurring due to the loss of hemlocks in these areas would be negligible as these forests already do not represent the appropriate cultural landscape.

Conclusion: If cultural resources are located in a forest dominated by hemlock and forested conditions can be tied to the actual resource, these resources would suffer **moderate impacts** with the loss of hemlocks.

Impairment: There would be no impairment to the park's cultural resources under this alternative.

4.6.2 ALTERNATIVE 2: No Action

Impacts: Some cultural landscapes and historic structures would receive treatment, but most areas would be left untreated due to the limited treatment schedule under the No-Action Alternative.

Cumulative Impacts: Cumulative impacts to cultural resources would include loss of hemlocks in the cultural landscape and at some historic structures.

Conclusion: If cultural resources are located in a forest dominated by hemlock and forested conditions can be tied to the actual resource, these resources would suffer **moderate impacts** with the loss of hemlocks.

Impairment: There would be no impairment to the park's cultural resources under this alternative.

4.6.3 ALTERNATIVE 3: Chemical Control Only

Impacts: The only disturbance to surface soil involves the soil drench method under the chemical control alternative. In that method, surface organic matter including leaves and twigs are temporarily moved to allow pouring of the imidacloprid mixture onto the soil in the area around the base of the tree. This material is then replaced in the same area that it was moved from.

Cumulative Impacts: No cumulative impacts are expected.

Conclusion: No impacts to cultural resources are expected.

Impairment: There would be no impairment to the park's cultural resources under this alternative.

4.6.4 ALTERNATIVE 4: Biological Control Only

Impacts: Release of biocontrol organisms would not affect GRSM's cultural resources. No impacts to cultural resources are expected.

Cumulative Impacts: No cumulative impacts to cultural resources are expected.

Conclusion: No impacts to cultural resources are expected.

Impairment: There would be no impairment to the park's cultural resources under this alternative.

4.6.5 ALTERNATIVE 5: Both Chemical and Biological Control

Impacts: The only disturbance to surface soil involves the soil drench method under the chemical control alternative. In that method, surface organic matter including leaves and twigs are temporarily moved to allow pouring of the imidacloprid mixture onto the soil in the area around the base of the tree. This material is then replaced in the same area that it was moved from. Release of biocontrol organisms would not affect GRSM's cultural resources. No impacts to cultural resources are expected.

Cumulative Impacts: No cumulative impacts to cultural resources are expected.

Conclusion: No impacts to cultural resources are expected.

Impairment: There would be no impairment to the park's cultural resources under this alternative.

4.7 Summary Impact Table

	Alternative 1 **No-Treatment Alternative**	**Alternative 2** **No-Action Alternative**	**Alternative 3** **Chemical Control Only**	**Alternative 4** **Biological Control Only**	**Alternative 5** **Both Chemical & Biological Control *(Preferred Alternative)***
Botanical Resources	Increasing damage and death of hemlock from HWA across the park. Eventual loss of hemlock from the majority of the park.	Reduced damage and death of hemlocks from HWA across the park.	Reduced damage and death of hemlocks from HWA across the park.	Reduced damage and death of hemlocks from HWA across the park.	Reduced damage and death of hemlocks from HWA across the park.
Terrestrial Wildlife Resources	Hemlock associated wildlife (birds, invertebrates) would suffer.	Hemlock associated wildlife (birds, invertebrates) would suffer, but not to the extent as Alternative 1.	Short term minor to moderate impacts to non target insects feeding on hemlock (systemic treatments) or on other insects while on hemlock (foliar treatment only).	Negligible impacts due to predator's host specificity.	Short term minor to moderate impacts to invertebrates from chemical controls and negligible impact from biological controls.
Aquatic Wildlife Resources	Long-term moderate to major impacts due to loss of hemlock.	Long-term moderate to major impacts due to loss of hemlock.	Negligible impacts expected as chemical treatments are not labeled for use near water.	No impacts expected.	Negligible impacts from chemical controls and no impact expected from biocontrols.

	<u>Alternative 1</u> **No-Treatment Alternative**	**<u>Alternative 2</u>** **No-Action Alternative**	**<u>Alternative 3</u>** **Chemical Control Only**	**<u>Alternative 4</u>** **Biological Control Only**	**<u>Alternative 5</u>** **Both Chemical & Biological Control *(Preferred Alternative)***
Threatened & Endangered Species	Impacts would be mixed depending on species. No T&E species are dependent on hemlock.	Impacts would be mixed depending on species. No T&E species are dependent on hemlock.	No impacts expected- no T&E species on hemlock.	No impacts expected- no T&E species on hemlock.	No impacts expected- no T&E species on hemlock.
Recreational Resources	Area closures due to hazard dead hemlocks. Loss of hemlock aesthetic value. Possible impacts to fishing.	Some area closures due to dead hazard hemlocks. Loss of hemlock aesthetic value in some areas. Possible impacts to fishing in some areas.	Foliar treated areas may have temporary closures.	No significant impacts expected.	Temporary area closures for foliar treatments, otherwise no impacts from biological controls expected.
Cultural Resources	Moderate impacts to resource if resource can be historically linked with hemlock.	Moderate impacts to resource if resource can be historically linked with hemlock.	No impacts	No impacts	No impacts

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-USDA Forest Service-Forest Health Protection (Rusty Rhea and Brad Onken, Entomologists)

-Dept. of Defense Army Corps of Engineers

-Southern Appalachian Man and the Biosphere Program (SAMAB) Environmental Coordination Committee Template and Guidance Environmental Assessment of Hemlock Woolly Adelgid (HWA) Control Strategies

-TN Dept. of Environment and Conservation, Div. of Natural Heritage

-Western North Carolina Alliance

-USDA Forest Service - National Forests in North Carolina

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