| USDA-FOREST SERVICE | 1. NUMBER | 2. STATION |
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| | FS-SRS-4202 | Southern Research Station |
| RESEARCH WORK UNIT DESCRIPTION | | |
| | 3. UNIT LOCATION | |
| Ref: FSM 4051 | Blacksburg, Virginia 24061-0321 | |

4. RESEARCH WORK UNIT (RWU) TITLE
Coldwater Streams and Trout Habitat in the Southern Appalachians

5. PROJECT LEADER (Name and Address)
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6. AREA OF RESEARCH APPLICABILITY
Forested watersheds of the Appalachian Mountains

7. ESTIMATED DURATION
5 years

8. MISSION
To acquire new knowledge about factors that influence the distribution, abundance, and production of trout and other coldwater fish in the southern Appalachians and to provide the technical basis for protecting, enhancing and restoring coldwater streams and their fauna.

9. JUSTIFICATION AND PROBLEM SELECTION (Continue on attached pages as needed)

Coldwater streams and the wild trout that live in them are among the most important resources found on public forest lands in the southern Appalachians. There are over 19,000 miles of existing and potential trout streams, occupying about 15,500 square miles of area in the southern Appalachians. Coldwater streams in this region originate in mountainous, generally tree-covered terrain where waters flow clear and recreational use can be intense. In the southern United States, nearly one-third of all residents fish, and in 1991, nearly 9.8 million anglers fished for trout. By 2010, human populations in the Southern Appalachian Assessment (SAA) area (Virginia to east Alabama) are expected to grow an additional 12.3% over the 1990 level of 102 persons per square mile. The increased demand for forest products and forest-derived amenities will strain the capacity of southern Appalachian streams to support high quality habitats and trout populations.

In addition to providing recreational opportunities, the USDA Forest Service has numerous environmental obligations and policies that affect the lands surrounding the nearly 8,000 miles of existing and potential wild trout streams that are currently under Forest Service management in this region. Under provisions of the National Forest Management Act (NFMA), aquatic environments must be managed to maintain viable populations of all native species. The presence or absence of trout,

| SIGNATURE | TITLE | DATE |
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| RECOMMENDED: | ASSISTANT DIRECTOR FOR RESEARCH | |
| | ASSISTANT TO STAFF DIRECTOR | |
| | STAFF DIRECTOR | |
| | STATION DIRECTOR | |
| | DEPUTY CHIEF FOR RESEARCH | |

changes in trout population characteristics, or changes in the composition of communities containing trout or other aquatic management indicator species may trigger a series of regulations or restrictions on activities within a watershed. A combination of factors -- including habitat change or fragmentation associated with changes in land use, poor water quality (acidification, fine sediment accumulation), and introduction of exotic species and non-native trout strains -- are likely responsible for the documented decline in range of brook trout and many other indigenous aquatic species. One of the major challenges to managers of mountain forests in the southern United States is how to maintain or increase trout production and protect or restore the structure and function of habitats and native fish assemblages. Before managers can restore watersheds, enhance stream habitats, or manage fish populations to protect or increase productivity, research is needed to determine which of the factors that most limit trout populations can and should be manipulated.

The capacity of streams to produce fish is influenced by a wide variety of physical, chemical, and biologi cal factors. Some factors such as climate, precipitation, geology, land use, and riparian inputs are largely a func tion of watershed or regional influences. Others such as water temperature and chemistry and depth, gradient, cover, food, and interspecific interactions are associated with the fishes' immediate stream environment. All are interrelated, most are influenced by human activities, and all must be systematically examined to determine how to most effectively manage trout habitats and populations. To address the most probable limiting factors, research must determine how the distribution, abundance and production of trout in the southern Appalachians are influenced by various environmental factors. (Problem area 1). Knowledge of the relationships among the various factors will allow managers to manipulate habitat features to benefit populations of aquatic organisms. Identification of factors operating at different scales will enable managers of the National Forest System and other public lands to develop the most appropriate, accurate, and cost effective methods for monitoring trout and trout habitats in compliance with NFMA. Analytical approaches developed for examining trout distribution and abundance at the regional scale will provide more accurate and cost effective methods for conducting Resources Planning Act assessments of coldwater fisheries resources.

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Central to the theme of management of aquatic ecosystems in forested landscapes is the identification, evaluation, and correction of water quality problems that threaten aquatic habitats. Some water quality problems have a long history and have achieved widespread public and scientific notoriety; stream acidification and sedimentation, for example, are major issues affecting thousands of miles of trout habitat. Although much information about acidification has accumulated over the last 30 years, particularly regarding the direct toxicity of acid water to trout and other fish, little effort has been expended to evaluate the more subtle ways that low pH affects stream ecosystem dynamics. Changes in the species and age-class composition of fish communities and changes in the quality of the food supply, for example, may help managers identify potential problems and allow them to take remedial action before fish populations collapse. Similarly, much is known about how sedimentation results from logging and road building and maintenance. Silvicultural best management practices (BMPs) and improved road design, placement, and stream crossings have curtailed a major portion of the inorganic sediment inputs to streams. Despite this knowledge and the widespread acceptance and use of silvicultural BMPs, there is still much that we do not know about how aquatic organisms and populations react to sedimentation.

In addition to acidification and sedimentation, trout and other organisms may be affected by many other water quality issues that have not been investigated in the southern Appalachian region. Examples include nutrient addition related to cattle grazing, use of silvicultural and agricultural chemicals (primarily insecticides and herbicides), aerial deposition of contaminants released from coal-fired power plants (e.g., selenium and beryllium in addition to mercury), and deposition of wood ash residues from both wild- and prescribed fire. Moreover, the effects of multiple stressors and cumulative effects are largely unknown. There is a need to expand our knowledge of the sublethal or chronic effects of impaired water quality on fish and macroinvertebrates in coldwater streams (Problem area 2). Studies proposed in this problem area provide a comprehensive, cost-effective approach for identifying and addressing key water quality issues. Research will identify and test bioindicators of water quality degradation and develop and refine ecosystem-based approaches for assessing impacts and risks from chemical, physical, and biological stressors associated with forest management. The intent is to develop reliable, field-validated methods that can be used by technical and semi-technical personnel involved in aquatic monitoring and assessment projects. These methods should be applicable to a broad range of wetlands and aquatic systems, and will facilitate the planning process that guides ecosystem management decisions for southern forests.

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Historical evidence suggests that 100-200 years ago riparian habitats in the Southeast, like those in other parts of the country, were structurally more complex than at present. Few watersheds in the eastern United States have not been disturbed by human activity; understanding of pre-disturbance conditions for habitat and fish populations is lacking or based on conjecture. Timber production, livestock grazing and other agricultural activities, mining, and road building frequently led to removal of riparian vegetation and loss of coarse woody debris (CWD), accelerated soil

erosion and the accumulation of fine sediments, and changes in the shape of stream channels. Changes in temperature regimes and atmospheric deposition of acidifying pollutants has reduced the capacity of many Appalachian streams to support fish and other organisms. Centuries of intensive use also have influenced the response of watersheds to natural disturbances. Available evidence suggests that changes in riparian and instream habitat caused by natural disturbances such as floods may be intensified in watersheds where habitat has been simplified by past land use. There is a need for research to develop and test techniques for restoration of aquatic and streamside habitats (Problem area 3). Knowledge of the factors that influence trout resistance and resiliency to disturbance will guide land management strategies for restoration of habitat and populations of fish and macroinvertebrates.------

The three problem areas address the issue of coldwater stream integrity and trout biology from different but complementary perspectives. All approaches contribute to defining the most important factors influencing or limiting trout distribution, abundance, production, and resistance to disturbance in the southern Appalachians. Ultimately, this research will provide land managers with guidelines on how to maintain, recover, or increase the quantity and quality of trout and other native fishes both for their contributions to biotic integrity and for the benefit of anglers and other recreationists. Specific topics under each problem address needs and issues identified in the Strategic Framework for the Southern Research Station (SRS) and contribute to at least four of the six SRS cross-cutting research themes: 1) Southern Appalachian Ecosystem Research and Sustainability; 2) Ecology and Management of Forested Wetlands, Bottomland Hardwoods, and Riparian Zones; 3) Inventory and Monitoring; and 4) Landscape and Regional Integrated Assessments and Modeling. The research strategy and planned accomplishments are consistent with issues and needs outlined in other strategic planning documents, including: Forestry Research: A Mandate for Change, and Land Resource Management Plans for national forests of the Southern Region. In addition, findings from the three research problems are directly related to needs identified in enacted laws, including the NFMA; the Forest and Rangeland Renewable Resources Planning Act; the Acid Precipitation Act; and the Endangered Species Act.

Previous results from the RWU have been used or adopted by public land managers, environmental and professional groups, state agencies, and the general public. The same users will benefit from solution of research topics identified in all three problem areas. Information from Problems 1 and 2 is critical to managers at local, regional, and National levels in the development of management strategies and monitoring protocols associated with land management activities and increasing recreational use. Methods and outputs generated by this research will help develop or modify guidelines for fisheries habitat management and forest planning activities and will contribute to the basis for restoration and recovery of forested aquatic ecosystems. Based on past RWU accomplishments and success with technology transfer, the likelihood of successful resolution for problems 1 and 2 is high. Research under problem 3 builds on the previous accomplishments of the RWU and others. Restoration research addresses two of the most pressing issues associated with southern coldwater streams -- the linkage of instream and riparian habitat, particularly related to CWD, and potential mitigation for acidification. Scientists, land managers, and the public will benefit from this research, that seeks to identify appropriate strategies and techniques for restoring habitat and biota of southern coldwater streams. Because population dynamics are inherently variable, the response to restoration must be evaluated over several generations of the target organisms. Hence, the likelihood of solution to this problem within five years is moderate.

## 10. APPROACH TO PROBLEM SOLUTION

Problem Area 1 - Determine how the distribution, abundance and production of trout in the southern Appalachians are influenced by various environmental factors.

Research will build on past RWU studies that have focused on identifying trout and habitat relationships at scales ranging from landscapes to individual streams and habitats. Results published by the RWU demonstrated that the distribution and abundance of trout is highly variable both within and among watersheds and across ecoregions and that the regional distribution patterns for the three trout species are associated with latitude and elevation, which are surrogates for temperature. Research by the RWU has produced or modified guidelines for sampling of fish habitat and fish populations and has led to the development of models of fish distribution and habitat relations. Other RWU research found different CWD loadings in old-growth vs second-growth forests, and correlated trout distribution with CWD in pools and riffles. Manipulative experiments to confirm these correlations and to determine the mechanisms of the CWD-trout connection are underway. These and other studies have identified probable limiting factors for fish production in the southern Appalachians. New studies will expand the scope of this research to address specific habitat relationships and establish direct linkages to forest and fisheries management practices. New studies will focus on determining the impact of physical and chemical disturbances on population persistence and resilience and on the development of new sampling techniques and protocols. Population studies will describe

annual and seasonal population dynamics, including reproduction, growth, survival, and age and size distribution in relation to both natural and human-caused disturbance. Habitat studies will describe patterns of habitat selection and movements for the different age/size classes and species of trout and other coldwater species such as blacknose dace. Behavioral studies will be conducted both in natural and experimental settings to examine how resources are partitioned among trout and other potential competitors as well as how the behavior or population dynamics of one species is influenced by factors such as the presence of other fish species, loading of CWD, acidity, and habitat complexity. Additional new studies will use GIS and other spatial tools to examine how landscape-scale attributes influence trout and macroinvertebrate production.

Accomplishments planned for the next five years include:

1. Determine the role of fish movement in pioneering and recolonizing habitat.
   Recent research in the western US and by the RWU has demonstrated that while trout tend to remain within a small home range for the majority of the year, seasonal movements for spawning or dispersal of young can be extensive. We need to examine the mechanisms responsible for initiating these punctuated movements to identify potential bottlenecks for dispersal and colonization.

2. Determine possible changes in regional trout distribution due to global change.
   Global change, including possible changes in temperature regime, hydrologic processes, and land use are of particular concern for trout populations at the margins of their range. In the southern Appalachians, where changes may further marginalize suitable habitat for trout, we need to understand how climate change and habitat interact to fragment and isolate trout populations. Recently developed GIS datasets and models for predicting effects of temperature changes will be extended to evaluate potential effects of other global changes.

3. Determine associations of southern Appalachian trout streams with roads and recreational settings.
   Roads are both sources of sediment and principal avenues for recreational access to trout streams. Recreational settings further indicate access and suitability of areas for anglers. Datasets developed by the RWU and others (including the Southern Appalachian Assessment), will be analyzed using GIS and coupled with knowledge of angler behavior to produce a regional analysis of trout distribution.

4. Develop statistical models relating trout distribution and abundance to habitat, stream, and watershed influences.
   Field research conducted by the RWU during the past several years has produced datasets that will be statistically analyzed to determine the relations between trout distribution and abundance and various habitat factors, including characteristics of individual habitat units, streams, and whole watersheds.

5. Determine relationships of stream macroinvertebrate communities in forested streams of Virginia to watershed characteristics.
   Stream macroinvertebrate communities are indicators used in monitoring by the Forest Service and State and other agencies. These monitoring programs are based on knowledge about macroinvertebrate species? tolerances and the stressors presented by various land use and human activities. But little is known about how community structure varies in streams with different forest type and age structure, size, and other characteristics of forested watersheds. This study will analyze the large body of data collected by personnel of the George Washington and Jefferson National Forest to determine the utility of macroinvertebrates for validation monitoring.

6. Develop or modify and test procedures for estimating and monitoring populations of benthic and non-conspicuous fish in southern Appalachian coldwater streams.
   At least half of the fish species typically found in coldwater streams are not amenable to identification or enumeration by standard techniques because they occupy interstitial spaces on the streambed or in cover or are cryptically colored. In addition, circumstances such as the presence or likely presence of threatened species or need for inventory in proclaimed wilderness areas either severely limit or preclude the use of standard techniques such as electrofishing. We need to develop alternative sampling methods that yield statistically reliable results that minimize risk to target species.

7. Determine the influence of sequencing and juxtaposition of habitat types (pools and riffles) on trout population dynamics.
   The importance of travel corridors and proximity of complementary habitat units is relatively unknown. Efforts to reconstruct degraded habitat for brook trout must provide not only for specific seasonal

microhabitat needs but also for access among the suite of available microhabitats at appropriate times of the year. This research will identify the role of habitat juxtaposition in the process of microhabitat selection by individual trout.

8. Evaluate and compare the specific uses of coarse woody debris by trout and macroinvertebrates.
   This research will focus on identifying specific ways that trout use CWD in streams. This research will address how CWD benefits trout: through increased reproduction, growth, and immigration or decreased intra- and interspecific interaction of individuals, energetic costs, and angling success?

9. Examine the distribution, quality, and use by trout of gravel substrate patches for spawning.
   The transport and deposition of management generated fine sediment has drastically altered the composition of gravel patches in many coldwater streams. Trout in particular depend on accumulations of the correct size gravel for spawning. This research will examine the availability of gravel that is appropriate for use by spawning trout and will relate recruitment of swim-up fry from stream reaches having different configurations of spawning habitat.

Environmental consideration: The studies in this problem area are expected to have little or no potential for soil movement, water quality degradation, or impact on sensitive resource values and are therefore covered under FSH 1909.15, Chapter 30, "Categorical Exclusion from Documentation in an EIS or EA." Environmental concerns about particular studies will be evaluated within individual study plans, or by Environmental Assessments or Impact Statements prepared with and approved by cooperating District or Forest staffs.

Problem area 2 -- Expand our knowledge of the sublethal or chronic effects of impaired water quality on fish and macroinvertebrates in coldwater streams.

Research in this problem area will determine biological consequences of water quality degradation and establish guidelines for evaluating impacts to coldwater resources. Results will yield new methods and measurement endpoints for monitoring and assessment of sublethal effects and recovery trajectories for sedimentation and acidification impacts to macroinvertebrates and fish in southern Appalachian aquatic habitats and wetlands.

Accomplishments planned for the next five years include:

1. Develop guidelines for predicting and evaluating the impact of sedimentation on trout food organisms.
   Determine the physical characteristics of sediment from different sources and soil types, examine effects on water quality and substrate conditions in streams, and document effects on the growth, survival, and ecology of aquatic insects. The objective is to measure responses of aquatic insects exposed to specific amounts and types of sediment and associated water quality/substrate conditions and develop quantitative guidelines for assessing effects in southern Appalachian streams.

2. Determine effects of stream acidification on the nutritional value of trout food organisms.
   Field and laboratory studies will be conducted to determine: (a) if reduced pH causes a reduction in the nutritional value (caloric content) of insects; and (b) the potential for changes in food quality to influence the nutritional status, growth, and reproduction of brook trout. A food nutritional value index will be developed and incorporated with indicators of physio-chemical habitat quality into a comprehensive habitat suitability index.

3. Evaluate toxicity and disease hazards to aquatic insects from nutrient enrichment associated with livestock wastes.
   The phenomenon of nutrient-induced bacterial gill disease in aquatic insects will be evaluated and the threat from various livestock management practices will be assessed. This research will result in publication of a field manual of guidelines and procedures for determining nutrient impacts in streams and wetlands.

4. Conduct aquatic hazard assessment of metals and trace elements such as mercury, cadmium, lead, arsenic, selenium, and beryllium.
   Aquatic chemistry data will be used to develop a regional assessment of the threat contaminants pose to the reproduction and survival of fish populations in Appalachian streams.

5. Evaluate impacts (e.g. siltation, changes in water chemistry) of prescribed burning on stream insects.

6. Determine regional patterns of vulnerability of trout streams to acidification.
   This study will combine spatial data about atmospheric input of sulfate and nitrate with qualitative information about geologic vulnerability to assess overall vulnerability for trout streams in the southern Appalachians.

7. Develop a macroinvertebrate community model to efficiently monitor trends in the acidification of forested streams.
   This research will use various measures of macroinvertebrate abundance and community structure in statistical models to predict vulnerability to acidification.

8. Determine association of hazardous waste sites, landfills, mining, and wastewater discharge with southern Appalachian trout streams.
   Some trout streams in the southern Appalachians are located in close proximity with hazardous waste sites, landfills, mines, and wastewater discharges. This study will compare distribution of these various stressors with distribution of trout streams in the southern Appalachians to evaluate the impact of these sites on the trout resource.

9. Describe basinwide trends in the populations of brook trout and blacknose dace in acid-sensitive streams.
   The presence of high-quality habitat and chemically stable refugia have slowed the decline of some trout and blacknose dace populations in acid-sensitive streams. However, if the trend of increasing acidification continues as predicted, the mitigative capacity of these refugia may be overcome and populations they protect eliminated. This research will document the basinwide distribution, abundance, and condition of fish and the distribution and quality of refugia in acid-sensitive watersheds.

Environmental consideration: The studies in this problem area are expected to have little or no potential for soil movement, water quality degradation, or impact on sensitive resource values and are therefore covered under FSH 1909.15, Chapter 30, "Categorical Exclusion from Documentation in an EIS or EA." Environmental concerns about particular studies will be evaluated within individual study plans, or by Environmental Assessments or Impact Statements prepared with and approved by cooperating District or Forest staffs.

Problem area 3 ? Develop and test techniques for restoration of aquatic and streamside habitats.

Previous work by the RWU has established the historical context for CWD, analyzed loadings of CWD in wilderness and old-growth watersheds, and begun experimental manipulations of CWD in several Appalachian streams. Other published RWU research demonstrated that fish distribution and relative abundance in a southern mountain watershed were relatively unaffected by floods and CWD loading associated with Hurricane Hugo despite significant changes in habitat. New research will expand the scope and geographic distribution of experimental manipulations and address specific cause and effect relationships linking CWD to fish and macroinvertebrates. Research with other RWUs and cooperators (i.e. FIA, SRS-4351, National Forest System, Virginia Tech, University of Georgia, state Wildlife and Fisheries agencies) will examine CWD recruitment processes and strategies for restoring historic rates of CWD recruitment from riparian areas. Additional new research in this problem area will yield techniques and strategies to restore or enhance fish populations and instream habitats by manipulating the physical, chemical or biological structure of both instream and riparian areas. For example: research will address the applicability of chemical restoration (liming) to restore or slow the deterioration of water quality in acid sensitive mountain streams. This RWU will continue to conduct research on the Wine Spring Creek Ecosystem Management project with an emphasis on integrating the response of stream biota to physical changes induced by experimental manipulations.

Accomplishments planned for the next five years include:

1. Use available historical evidence, current CWD inventories, and results from controlled experiments to determine optimal CWD loadings (tree species composition, size, and amount) for Appalachian streams.
   This research is corollary to the CWD studies described in Problem 1 and is the experimental component of RWU-sponsored CWD research.

2. Develop joint studies with other RWUs and SRS Forest Inventory to identify the species, size, and location of tree species that have the potential to contribute CWD in riparian areas across the southern Appalachians.

3. Determine the response by fish and macroinvertebrate communities to liming of acid-sensitive streams.

Liming to counteract the effects of acid precipitation is becoming more widely used. We need to understand how fish and macroinvertebrates react to the short- and long-term influence of limestone added in various forms (rock, gravel, powder, etc.) to acid sensitive streams. These studies will assess changes in reproductive success, population age and size structure, survival, and growth in trout populations and changes in the structure and composition of macroinvertebrate communities.

4. Determine the response of brook trout and blacknose dace populations to liming of an acidified wilderness stream: St. Marys River, Virginia.

   Research by this RWU and others over the last several years has documented the decline of brook trout and near extirpation of blacknose dace because of acidification. Macroinvertebrate communities also have been dramatically altered over the same time. The George Washington National Forest has proposed to lime the headwater portions of the stream to restore water quality and possibly reverse the population trends. In cooperation with the National Forest and the Virginia Department of Game and Inland Fisheries, this study will continue the previous research to evaluate response by trout and macroinvertebrates to the liming.

5. Determine the genetic status of brook trout in experimental and candidate restoration streams.

   Efforts to reestablish brook trout populations are more likely to succeed if the donor stock is genetically similar to indigenous stocks. This research will examine the genetic characteristics of potential donor stocks of brook trout from selected watersheds.

6. Develop and test strategies to restore native southern brook trout to streams having otherwise suitable habitat, fish assemblages, and water quality.

   For a variety of reasons, including: elimination of recolonization corridors; potential competition with other species; and recurrence of episodic events such as acid rain and floods, brook trout have been extirpated from many streams that could support them. This research will lead to development of techniques to rapidly identify probable limiting factors, strategies for establishing fish populations, and methods for monitoring viability of transplanted fish.

7. Ecosystem Management research: restoration of native southern brook trout and trout response to rhododendron removal from stream banks in Wine Spring Creek and tributaries, North Carolina.

   During the planning phase for the Wine Spring Creek Ecosystem Management project, restoration of native southern brook trout populations and experimental removal of rhododendron from the streambanks were identified as desired future conditions. If these activities are scheduled to occur in the next five years, this RWU will lead the experimental efforts for brook trout reintroduction, including identification of a suitable source population (with cooperators from Virginia Tech), construction of a suitable barrier to immigration (with cooperation of the Wayah Ranger District), removal of non-native salmonids (with multiple cooperators), and reintroduction of brook trout. This RWU also will evaluate trout responses to rhododendron removal.

Environmental consideration: Most of the studies in this Problem Area are expected to have little potential for soil movement, water quality degradation, or impact on sensitive resource values and are therefore covered under FSH 1909.15, Chapter 30, "Categorical Exclusion from Documentation in an EIS or EA." Where specific environmental concerns exist, these will be evaluated within individual study plans or by Environmental Assessments or Impact Statements prepared with and approved by cooperating District or Forest staffs.

11. STAFFING

| Problem No. | Scientist years/year |
|---|---|
| 1 | 1.0 |
| 2 | 1.0 |
| 3 | 1.0 |

Current unit staffing is three scientists, one permanent Biologist, and one term Biologist. The Unit shares a Business Manager with the Integrated Life Cycle of Wood: Tree Quality, Processing, and Recycling RWU (SRS-4702) also housed at Virginia Tech. Seasonal personnel needs are met by hiring students and other temporary employees. Many of the studies outlined require the input and participation of scientists in other SRS-RWUs, university cooperators, and other research partners such as State wildlife and fisheries agencies. Total costs for the 5-year

duration of this RWUD, with no adjustment for inflation, are anticipated to be $875,000 for each problem or $525,000 per year for all three Problems. Because this exceeds the FY 98 appropriation of $483,000 per year, we will seek the balance of funding through outside sources. If funds are insufficient to complete all parts of this research program, research designed to: evaluate impacts of prescribed burning on stream insects, estimate and monitor benthic and non-conspicuous fish, and test specific habitat restoration and monitoring techniques for native southern brook trout will be delayed.

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