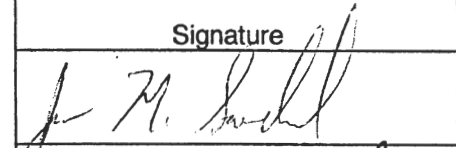

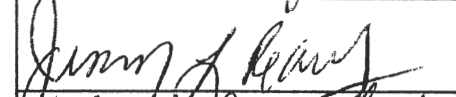
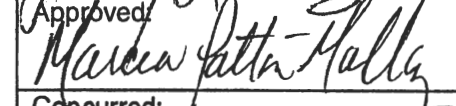



RESEARCH WORK UNIT DESCRIPTION Ref: FSM 4070	1. Number RMRS-4552	2. Station Rocky Mountain Research Station
	3. Unit Location Moscow	
4. Research Work Unit Title Microbial Processes that Affect Ecosystem Function		
5. Project Leader (Name and address) Deborah S. Page-Dumroese; 1221 S. Main; Forestry Sciences Laboratory, Moscow, ID		
6. Area of Research Applicability Primary responsibility is the Inland Northwest, but research will have broad application throughout the western USA and northern, temperate, conifer forests.		7. Estimated Duration 5 years
8. Mission Conduct research and technology transfer on microbial processes that regulate forest ecosystem function in support of sustaining and enhancing productivity in the western USA. This mission is conducted to provide data and tools necessary for managing and sustaining ecosystem function and productivity for future generations. The significance of this research is regional, national, and international.		
9. Justification and Problem Selection Several major issues face the Forest Service at this time: <ul style="list-style-type: none"> • The deterioration of forest health and sustainability caused by natural and human-induced disturbances, • Overall change in fundamental soil productivity with and without forest management activities and, • The risk of catastrophic fire and subsequent loss of forest productivity in stands that have had active fire suppression and/or fire exclusion. These three issues will be addressed through three research problems: Problem 1: Endemic Armillaria root disease and introduced white pine blister rust can be a major threat to forest health. Problem 2: Important soil physical, chemical, and microbial processes may be altered by management and reduce ecosystem sustainability. Problem 3: Fire suppression and/or fire exclusion have altered the balance of diseases, host species, and carbon sequestration to affect forest sustainability and soil productivity.		

Signature	Title	Date
	Assistant Director for Research	9/3/04
	Assistant to Staff Director	10/22/04
	Staff Director	10/22/04
Approved: 	Station Director	11/2/04
Concurred: 	Deputy Chief for Research	11/9/04

9. Justification and Problem Selection (Overview)

The Rocky Mountain Research Station (RMRS) implements its mission with four strategic goals: (1) Ecosystem Health, (2) Multiple Benefits to People, (3) Scientific and Technical Assistance, and (4) Effective Public Service. Six strategic focus areas: (1. Changing Ecosystems – productivity, risks, and uncertainties, 2. Conflicting Values – effects on natural resource use and management, 3. Wildland Fire – responsibilities, risks, and benefits, 4. Healthy Environments – water quantity, water quality, and clean air, 5. Wildlife and Fish Habitats – restoration and maintenance, and 6. Communicating with our Stakeholders) represent priority research and technology transfer needs within the Station. Of these six focus areas, RMRS-RWU-4552 will primarily contribute to areas 1, 2 3, and 6.

The focus for RWU-4552 is to generate, synthesize, and present knowledge on: (1) endemic (e.g., *Armillaria* spp.) and introduced (e.g. white pine blister rust) pathogens, (2) changes in soil productivity and nutrient cycling associated with harvesting, site preparation, and (3) the impact of fire or fire suppression on structure and function of microbial communities.

Forests of the Inland Northwest and Northern Rocky Mountains generally occupy a patchwork of highly variable environments. The region is characterized by rugged, mountainous terrain. Due to diverse, and often young or unconsolidated parent materials, soils are variable. Climate in this region is similarly variable with a dry summer climate (moisture limiting). Most precipitation arrives as snow in October-March. Volcanic- ash depositions (e.g. Mt. Mazama 6,600 BP) and remnant geological effects of the most recent continental glacier 14,000 BP significantly affect ecosystem productivity.

Low-elevation forests are often dominated by Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) ecosystems. Mid-elevation forests are comprised of productive grand fir (*Abies grandis*), western redcedar (*Thuja plicata*), and western hemlock (*Tsuga heterophylla*). These mid-elevation forests also contain the western white pine (*Pinus monticola*) type ecosystems. Subalpine fir (*Abies lasiocarpa*), Englemann spruce (*Picea engelmannii*), and whitebark pine (*Pinus albicaulis*) characterize high-elevation and cold sites. In total, there are 12 major conifer species, several deciduous trees and shrubs, and a multitude of forbs and grasses. There are more than 2.8 million ha of highly productive forestlands that can produce significant timber volumes. Additional values found in these ecosystems of the Inland Northwest are wildlife and fish habitat, water quality, and recreational opportunities.

Fire suppression policies, harvest management, introduction of exotic disease, and climate change have altered the composition and structure of western forests. Until recently, our perceptions of healthy forest ecosystems depended on our experience in present-day forests, rather than historic forest community types. Advanced forest succession, large build-ups of surface organic material, and widespread disease-susceptible host-plants promote forest health problems with devastating consequences. Therefore, the focus of this unit will be to assist land managers in sustaining and enhancing healthy forest ecosystems. Accomplishing these objectives requires close cooperation and coordination of common problem areas with Rocky Mountain Research Station (RMRS) RWU-4155 (D. Ferguson) and RMRS-RWU-4702 (W. Elliot). Collaborative efforts with these projects provide a broad base of expertise. Collaborations with other USFS researchers, Universities, States, Tribal Forestry, BLM, USGS, NPS, and industrial forestry operations provide a cooperative base to make significant scientific advancements.

To address the overriding issues of **forest health, soil productivity, and fire suppression** within the framework of the three focus areas of the RMRS Strategic Framework, we will seek solutions in the following three problem areas:

1. The endemic *Armillaria* root disease and introduced white pine blister rust can be a major threat to forest health.
2. Important soil physical, chemical, and microbial processes may be altered by management and reduce ecosystem sustainability.
3. Fire suppression has altered the balance of diseases, host species, and carbon sequestration to affect forest sustainability and soil productivity.

In addition to our research problems, which can be measured through the RMRS Strategic Framework under Focus Areas 1,2, and 3, we will communicate our scientific information to stakeholders through publications (Appendix 1 – Recent publications), workshops, summaries and syntheses. Use of a variety of media (publications, websites, etc.) will help us communicate research results to land managers.

Problem 1: The endemic *Armillaria* root disease and introduced white pine blister rust can be a major threat to forest health.

There are numerous gaps in our knowledge of how environment or host species affect communities and populations of beneficial and pathogenic microbes. In addition, we know very little about how environmental characteristics, altered by climate change, may affect pathogen and host diversity and their pathogenic interactions at various spatial and temporal scales. These information gaps limit our ability to manage sustainable forest ecosystems and moderate the impact of natural and human disturbance.

Armillaria root rot and white pine blister rust diseases have had serious and synergistic impacts on western forest ecosystems. *Armillaria* root disease is the most widespread soil-inhabiting organism causing mortality throughout the Rocky Mountains and Inland Northwest. It damages conifers throughout the western USA, but host range, aggressiveness, and other ecological behaviors vary locally. This disease is thought to cause up to 40% of all tree mortality in USFS Region 1 and in some cases, highly impacted forests may have greater than 50% mortality. Douglas-fir and grand fir are the two of the most susceptible tree species. Severe disease damage from *Armillaria* root rot is seldom found in dry, seral ponderosa pine stands because of pathogen scarcity. Western white pine and western larch (*Larix occidentalis*) growing in moist forests are also not damaged significantly. However, susceptibility to this disease varies with site conditions, physiological status of the tree, and pathogen isolate. Some *Armillaria* species (e.g., NABS X, *A. sinapina*, and *A. gallica*) are predominately saprophytic, and may act to sustain forest productivity by improving nutrient cycling through decomposition of downed woody material and surface organic matter. These interactions are occurring in many forests of the Inland Northwest. The most pressing issue regarding *Armillaria* spp. is the lack of effective management tools. There are many questions about how pathogenic and saprophytic *Armillaria* species are distributed across the landscape in relation to host trees, soil properties, and topographic characteristics. In addition, factors such as stand history, fire suppression and silvicultural practices may alter the long-term persistence of pathogenic *Armillaria*, and may select against beneficial *Armillaria* species.

Another disease, white pine blister rust (caused by the introduced pathogen, *Cronartium ribicola*), has nearly eliminated western white pine from much of its range and most replacement species are susceptible to *Armillaria* rot disease. Rust-killed western white pine tree roots provide a food source for *Armillaria* species. In addition to western white pine, affected species include whitebark pine (*Pinus albicaulis*) and limber pine (*Pinus flexilis*)—all three species are considered keystone species. On affected sites, species conversion from western white pine to trees less tolerant of pathogens, especially *Armillaria*, has taken place. The massive losses of western white pine that occurred earlier are now seen in high-elevation five-needled pine species. These high-elevation tree species are critical as a windbreak for establishing less

tolerant woody and forb species for watershed health, as food for wildlife (e.g., grizzly bear, birds) and for enhancing wilderness experiences. To understand the ongoing and future impacts of this introduced rust, we must understand the interactions among hosts (both pine and the alternate host *Ribes*), pathogen, environment, fire, and forest management. The genetic structure of *C. ribicola* is likely to change over time to reflect environmental adaptation or changes in host populations. Changing blister rust populations can have widely differing effects. In many stands with serious blister rust, regeneration can be much less affected by the rust. This might be caused by natural selection in both resistance in the host and pathogen. Alternatively, strong selection pressure could cause the development of new rust races that overcome certain host-resistance factors. The potential for pathogen adaptation to new environments and sites, and the constant threat of new rust races makes it essential to acquire knowledge about epidemiology, genetic diversity (host and pest), climate, and the nature of resistance. (Problem 1 – shared with RMRS-RWU-4155)

Problem 2: Important soil physical, chemical, and microbial processes may be altered by management and reduce ecosystem sustainability.

Soil productivity -- the ability of the soil to support plant growth – is a key factor in maintaining ecosystem function and value. Long-term effects of forest management are poorly understood and often do not address process-level functions. However, protection of soil productivity will ensure the capacity of the land to maintain ecosystems. In stands that are in advanced successional stages, forest management often alters nutrient cycling processes--in particular carbon sequestration, the integrity and function of the forest floor, plant diversity, mineral soil productivity, watershed function, and overall forest sustainability.

An excellent foundation for investigating changes in soil properties after management activities is through use of the North American Long-Term Soil Productivity sites and their affiliated satellite sites. Through these research sites (3 sites are managed by RMRS-RWU-4552 personnel) we can validate soil quality standards and investigate a host of questions related to changes in forest productivity associated with management or fire impacts on the soil. Sustainable management is dependent on soil productivity to maintain ecological integrity that will yield both goods and services to the public. As demand for healthy forests rises, reliable information will be needed to gauge soil productivity changes. These gauges must have practical, scientifically defensible data to validate monitoring or predict soil productivity declines or increases. (Problem 2 – shared with RMRS-RWU-4702 as opportunities arise).

Problem 3: Fire suppression and/or fire exclusion have altered the balance of diseases, plant species, and carbon sequestration to affect forest sustainability and soil productivity.

Large-scale catastrophic fires have become the norm in overstocked, non-seral, fire suppressed and fire excluded stands. Forests have become dominated by shade-tolerant Douglas-fir and grand fir in drier western forests. This shift leads to an increased accumulation of aboveground biomass that leads to an increased abundance of large downed wood. These large accumulations make it increasingly difficult to suppress wildfires and, as a result, fires are larger and more extreme. In addition, large wood accumulations may increase the risk. In more mesic forests that were historically dominated by seldom-occurring ground fires and a stand replacing fire every 200 years, a different set of problems exist. In the northern Rocky Mountains at middle elevations, the seral stage was dominated by western white pine. Meanwhile, the seral stage in moister forests at higher elevations was dominated by whitebark pine. The introduction of white pine blister rust and management activities of the introduced threat has also introduced significant shifts in the relative abundance of conifer species. Typical replacement tree species

for five-needled pines show significant damage by root rot and other pests thereby increasing stand damage and altering soil productivity after fire.

Use of forest management techniques to either sequester carbon in the form of large woody material or accelerate decomposition into stable organic matter that can persist in the mineral soil for centuries can lead to healthier forests. Accumulations of organic matter in living trees and as downed stems on the soil surface may be accelerated if carbon sequestration is the main objective for forest management. However, accelerated decay may be a management goal if fire suppression, fire exclusion, or other management has resulted in organic matter accumulation. Both of these goals need considerably more information about the inherent risks to soil productivity, processes, and subsequent forest growth. The different relationships between downed log size class and decomposition rates likely arise from climate, moisture, and log position on the landscape. However, the relationships between downed wood, its decay rate, and biomass production is unclear. Climate change scenarios have predicted an increase in temperature and a decrease in moisture for western forests. These predictions require baseline information about climate and management effects on soil properties, disease incidence, and decay rates with linkages to biomass production or declines. (Problem 3 – part of the National Fire Plan funded proposal in Moscow, ID)

Solutions for the ubiquitous forest health problems in the western US are not simple or straightforward. Scientists in this unit will work independently and cooperatively to solve all 3 problems. Information resulting for this unit's research will provide data needed by the Healthy Forest Initiative, National Forest Management Act, Rangeland Renewable Resource Planning Act, National Fire Plan, and the strategic planning efforts of the Rocky Mountain Research Station. RWU-4552 will implement a science-based, ecosystem function approach to providing management with data. We have strong working relationships with many University, Tribal, Industry, and National Forest System scientists who will help disseminate our results.

10. Approach to Problem Solution

Problem 1. The endemic *Armillaria* root disease and introduced white pine blister rust can be a major threat to forest health

Solution of this problem will come through:

This research will develop tools to predict and manage *Armillaria* root rot disease and white pine blister rust. Scientists will characterize fungal and rust species by developing a system for examining inheritance and genome organization and examine factors responsible for distribution of clones or variants, species and hybrids that occur in their ecological and geographic ranges. We will use both classical and molecular tools. We will assess ecosystems and management treatments affected by species and clone. This approach will address critical knowledge gaps in soil interactions, plant community dynamics, species conservation/restoration, and disease impacts on long-term forest health and sustainability.

RMRS-RWU-4552 has sampled over 400 plots that represent the diverse forests of the western USA to determine the incidence of *Armillaria* spp. and identify their behavior (activity) in relation to soil, habitat type, and microclimate. In the period from 1983-2003, this RWU has archived over 2000 genetically distinct *Armillaria* cultures from over 10,000 collections to assess its ecological function (host range and pathogenicity) related to biotic (host species, habitat type, etc.), and abiotic (topographic characteristics, silvicultural practice – fertilization, species selection, thinning, etc.) factors. These archived cultures are critical for determination of whether species are genetically distinct in western forests, or occur, as appears from recent tests, as hybrid swarms.

In addition, past investigations on the epidemiology of western white pine blister rust have provided an extremely important basis for actively testing theories on rust incidence and behavior. This is a complex problem requiring collaboration from other Forest Service Units, Universities, Private Industry, Tribes, and other government agencies. An interdisciplinary, collaborative approach will be used to achieve the following planned accomplishments.

A. Accomplishments planned for the next 5 yrs.

1. Tools to predict and manage *Armillaria* root and butt rot:

1. Use genetic markers to identify/characterize *Armillaria* spp., populations, genetic diversity, and the genetic basis for interactions among clones. Accumulate critical genetic and environmental data to allow analysis of the forces shaping population structure at the landscape level. Establish critical groundwork toward developing predictive models for sustainable forest management that minimizes risk of *Armillaria* damage
2. Determine short- (5 year) and long-term (rotation) impacts of burning and fertilization on incidence of *Armillaria* spp.
3. Examine specific factors (e.g., pH, temperature, moisture, oxygen tension) that may be affecting competitive advantage or persistence of *Armillaria* spp. and hybrids in soils and forests
4. Develop a genetic map of *Armillaria* spp. and clarify the isolate, clone, and NABS pathogenicity
5. Develop or improve methods of fruiting and long-term culture storage as necessary to accomplish these goals

2. Tools to predict and manage white pine blister rust (working cooperatively with RMRS-RWU-4155):

1. Facilitate restoration of western white pine to its historical ecological roles through integrated rust management (RMRS-RWU-4155 will lead)
2. Determine the genetic diversity of five-needled pine species (e.g., western white and whitebark pine) (both RMRS-RWU-4552 and RMRS-RWU-4155 will lead)
3. Determine the genetic diversity and structure of *Cronartium ribicola* (both RMRS-RWU-4552 and RMRS-RWU-4155 will lead)
4. Calibrate and validate white pine blister rust models (RMRS-RWU-4552 and RMRS-RWU-4155 will share lead roles)
5. Assess *Ribes* spp. impact on rust genetic structure and on blister rust epidemiology (RMRS-RWU-4552 will lead)
6. Cooperate with Region 1 genetics programs in their breeding program (RMRS-RWU-4552 and RMRS-RWU-4155 will cooperate)

Problem 2. Important soil physical, chemical, and microbial processes may be altered by management and reduce ecosystem sustainability.

A. Solution of this problem will come through:

Research in this problem area will address the role of soil and soil productivity indicators for maintaining forest health in ecosystems that are characteristic of or unique to the Inland Northwest. First, we will use the existing North American Long-Term Soil Productivity sites (in the Rocky Mountain Station and elsewhere) to determine the relationship between soil physical, chemical, and microbial changes and forest growth and productivity early in stand development

(stand age: 5-10 years) until the end of the natural rotation of the stand (stand age: 10-100 years). Second, from this information we will work to validate soil quality standards and assist in the development of other, more appropriate standards and guidelines. Third, determine how forest management (fire, harvesting, site preparation) affects belowground processes. These processes can result in altering decomposition rate, disease infestation or spread, or microbial community structure.

This research has been ongoing for the past 10 years and scientists have developed collaborative research studies with other researchers within and outside of the Forest Service. The sites within the Rocky Mountain Research Station (in northern Idaho at the Priest River Experimental Forest, in central Idaho on the Payette National Forest, and in southern Oregon on the Umpqua National Forest) continue to provide many opportunities. Two components of this research not previously fully explored are: (1) the impact of forest management on nutrient cycling changes and loss of nutrients in sediment produced through erosion or fire and (2) linkage of belowground processes (decay) with climate, organic matter, and soil with ties to overstory biomass. A larger focus in this problem area will provide critical information on movement or reallocation of nutrients and the importance of decomposition to site sustainability as associated with small-diameter wood removal, fire, or timber harvesting. Working cooperatively with RWU-4702 or others (nutrient fluxes in water) and RWU-4155 (nutrient fluxes and vegetation) we have the following planned accomplishments:

B. Accomplishments planned in the next 5 yrs.

1. Maintain the RMRS network of North American Long-Term Soil Productivity sites in Regions 1, 4, and 6
2. Determine the relationship of timber management in fire-suppressed stands to soil nutrient cycling changes after management is introduced
3. Determine the effectiveness and appropriateness of soil quality standards and guidelines in the western regions
4. Determine microbial diversity (e.g., fungi) associated with wood decomposition in managed forests
5. Begin development of appropriate indicators of change in below-ground soil productivity

Problem 3. Fire suppression and or fire exclusion have altered the balance of diseases, plant species, and carbon sequestration to affect forest sustainability and soil productivity.

Frequent, low-intensity fires that occur in drier, fire-dependent ecosystems, especially in the western USA, limit the amount of organic matter accumulation in the forest floor and have little impact on overall soil productivity. Long fire-return intervals, little ground fire, and ca 200-year stand replacement fires dominate moist forests of the northern Rocky Mountains. Early seral stages after catastrophic stand replacement fires had been mostly dominated by western white pine at middle elevations and whitebark pine at high elevations, both of whose roles have been altered by blister rust disease. However, less obviously, fire management policies (i.e. fire suppression) and climate change have altered the balance of belowground processes and overstory composition that regulate carbon, nitrogen, organic matter accumulation, and disease incidence. The balance of these processes regulates long-term forest sustainability and productivity. Compounding the possible impacts of current management, fire suppression, and global climate change on woody material accumulations is the widespread interest in using fire to restore perceived and real changes in forest productivity. Active fire suppression or fire exclusion in forests and shrublands that historically supported a regular fire-return interval has led to substantial C increases in the western USA. Consequently, information is needed on the effect of fire suppression on C pools, ecosystem recovery after fire, and changes in decomposition rates.

A. Solution of this problem will come through:

Research in this problem area will address the role of microorganisms in the process of decay, the impact of disease in fire-prone and stand replacement fire-dominated ecosystems, and how carbon may be sequestered or released via management. If biological activity is tightly constrained by temperature and moisture, altering these parameters through prescribed fire, small-diameter wood removal or other management techniques will change the rate at which activity will occur. Little information exists on belowground and soil surface biological changes associated with stand development, the succession of microbes during decomposition of woody debris, or the extent to which decay rates can be altered. These aspects may be most significant in stands dominated by stand replacement fire. Significant opportunities exist to place decomposition and microbial succession studies within burned areas and rehabilitated burn areas (BAER sites), in different aged burns, and harvested stands (e.g., use of the North American Long-Term Productivity sites). International cooperators have begun using our methods (developed at the Priest River Experimental Forest) for developing a surrogate for belowground decomposition. Therefore, a significant portion of this work is already underway to meet our requirements of the National Fire Plan.

B. Accomplishments planned for the next 5 yrs:

1. Determine how fire, forest management (e.g. thinning, salvage) and post-fire soil rehabilitation impacts soil surface and below-ground decomposition rates
2. Describe changes in microbial decomposition and communities as related to fire severity
3. Quantify soil surface and below-ground carbon pools in various ecosystems and the affect of fire and post-fire rehabilitation on forest sustainability and soil productivity
4. Develop plausible decay rates in burned and unburned ecosystems for soil surface and belowground wood. This data will be used in the FVS model and other models describing decay rates
5. Determine the importance of post-fire recruitment of large, downed wood on the soil surface to re-burning (double burns), soil productivity, and forest sustainability

This work unit will address issues the Forest Service must deal with in the future (i.e. non-native pests, degraded soils, catastrophic fires, climate change, nutrient cycling, fire management policies, and fertilization). Efforts by 3.5 research scientists and a post-doctoral researcher will be directed to solution of these 3 problems over the next 5 years. Total cost of this program is estimated between 5 and 6 million dollars over the next 5 years, with returns estimated to be 5 times that amount. As significant, the non-monetary values associated with this research include knowledge critical for restoring native conifer species and grizzly bear habitat, maintaining biodiversity, enhancing wilderness experiences, improving forest health, and improving our knowledge of climate change impacts and other large-scale perturbations on below-ground processes. Completion of our planned accomplishments is contingent upon receiving funding indicated.

11. Cooperation

This Research Unit is staffed to lead research within the 3 problem areas described. However, the research questions often require expertise, capabilities, or staffing levels that are beyond those available within the Unit. Those limitations may be alleviated through joint venture agreements with other FS units, universities, industry, and other federal, state, or tribal agencies. Table 1 presents our current collaborators.

Table 1. Cooperators with RMRS-RWU-4552, Moscow, ID. Effective June 2003

Cooperators	Location
USDA Forest Service	
RMRS-RWU- 4155	Moscow, ID
RMRS-RWU-4702	Moscow, ID
Forest Products Laboratory	Madison, WI
RMRS-RWU-4301	Logan, UT
RMRS-RWU-4451	Fort Collins, CO
RMRS-RWU-4152	Flagstaff, AZ
National Forest Systems in Region 1	Missoula, MT; Coeur d'Alene, ID; Moscow, ID
National Forest Systems in Region 4	Ogden, UT
National Forest Systems in Region 6	Portland, OR
Pacific Southwest Station	Davis, CA; Redding, CA
North Central Station	Grand Rapids, MN; Jefferson City, MO
Southern Research Station	Pineville, LA
Universities	
Michigan Technological University	Houghton, MI
University of Idaho	Moscow, ID
Washington State University	Pullman, WA
Tennessee State University	Nashville, TN
Clemson University	Clemson, SC
Industry	
Boise Corporation	Boise, ID
Weyerhaeuser	Centralia, WA
Tribal	
Nez Perce Tribal Forestry	Lapwai, ID
Other	
Swiss Federal Research Institute	Zurich, Switzerland
Finnish Forestry	Joensuu, Finland
B.C. Ministry of Forests	Nelson, British Columbia, Canada
Natural Resources Canada, Canadian FS	Quebec City, Quebec, Canada
Morton Arboretum	Lisle, IL
Laurentian Forestry Centre	Sainte-Foy, Quebec, Canada

12. Staffing

This research requires 3.5 permanent scientists per year and 1 post-doctoral scientist. These scientists are supported by permanent technicians, support staff, graduate students and collaborators. Distribution of scientist PFTE's through the next 5 years is presented in Table 2.

Table 2. Approximate projected permanent scientist FTE.

Problem Area	Primary scientist	Scientists year/year				
		FY04	FY05	FY06	FY07	FY08
1- Endemic and introduced diseases	N. Klopfenstein P. Zambino	2.0	2.0	2.0	2.0	2.0
2 – Soil productivity	D. Page-Dumroese	0.5	0.5	0.5	0.5	0.5
3 – Fire and sustainability	T. Jain D. Page-Dumroese	1.0	1.0	1.0	1.0	1.0

13. Economic Analysis

At present, 3 permanent scientists are funded through appropriated research dollars at a fairly stable rate of approximately \$600K per year. The 0.5 scientist is funded through National Fire Plan dollars and shared with RMRS-RWU-4155. Using the 'norm' of \$300K per scientist year, estimated budget needs exceeded our appropriated funding during the previous five year period. Currently, we are supported by outside grants (National Fire Plan – 01 RMRS C.3, Agenda 20/20, National Fire Plan – adaptive management, and National Forest Systems Regional support) to fully fund the difference. Loss of NFP funding will result in the loss of 0.5 scientist plus loss of research in fire effects on forest health and productivity. Loss of Region 1 and 4 support will result in termination of data collection on the North American Long-Term Productivity Study plots.

Appendix 1 –Past Accomplishments: Publications – RMRS- RWU- 4552 2000 through 2002

Problem 1- Risk evaluation and management of *Armillaria* and other endemic root pathogens

Kim, Mee-Sook; Klopfenstein, Ned B; McDonald, GERAL I; Arumuganathan, Kathiravetpillai; Vidaver, Anne K. 2000. Characterization of North American *Armillaria* species by nuclear DNA content and RFLP analysis. *Mycologia*. 92: 874-883

Kim, Mee-Sook; Klopfenstein Ned, B; McDonald, GERAL I; Arumuganathan, Kathiravetpillai; Vidaver, Anne K. 2001. Use of flow cytometry, fluorescence microscopy, and PCR- based techniques to assess interspecific and interspecific matings of *Armillaria* species. *Mycological Research* 105: 153-163.

Klopfenstein, Ned B; Kuhlman, E. G.; Schumann, Carol M.; Dix, Mary Ellen. 2000. Biological control of forest pathogens: forest diseases. In: Coulson, J.; Vail, P.; Dix, M.E.; Nordlund, D. A.; Kaufmann, W. C. (eds). 110 yrs. Of Biological Control Research and Development in the USDA: 1883-1993. Beltsville, MD. ARS. 455-458.

Hoff, J. A. 2002. Fungal diversity in woody roots of east-slope Cascade ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*). Washington State Univ. MS Thesis. 76 p.

Lundquist, J. E.; Klopfenstein, N. B. 2001. Integrating concepts of landscape ecology with molecular biology in forest pathogens. *For. Ecol. and Manage.* 150: 213-222.

Problem 2 – Information on host-pest interactions of white pine blister rust

Neuenschwander, Leon F; Byler, James W.; Harvey, Alan E.; McDonald, GERAL I, et al. 1999. White pine in the American west: A vanishing species—can we save it? Gen. Tech. Rep. RMRS-GTR 35. Fort Collins, CO. USDA Forest Service. 20 p.

Tabor, G. M., Kubisiak, T. L., Klopfenstein, N. B., Hall, R. B., and McNabb, H. S., Jr. 2000. Bulked segregant analysis identifies molecular markers linked to *Melampsora medusae* resistance in *Populus deltoides*. *Phytopath.* 90 (9): 1039-1042.

Hoff, Jill A. 2000. Assessing physiological and genetic variation in blister rust. *Women in Natural Resources*. 21: 46-47.

Klopfenstein, Ned B; Dix, Mary Ellen. 200. Biological control of weeds: Dwarf mistletoes. In: Coulson, J.; Vail, P.; Dix, M.E.; Nordlund, D. A.; Kaufmann, W. C. (eds). 110 yrs. Of Biological Control Research and Development in the USDA: 1883-1993. Beltsville, MD. ARS. 465-466.

Mmbaga, Margaret; Klopfenstein, Ned; Kim, Mee-Sook. 2000. Molecular genetic analysis of powdery mildew pathogens of dogwood. In: James, B. L. (comp. Ed.). Proceedings of Southern Nursery Association Research Conference: 45th annual report 2000; Atlanta, GA. 45: 237-243.

Richardson, Bryce A. 2001. Gene flow and genetic structure of whitebark pine (*Pinus albicaulis*): Inferences into bird-dispersed seed movement and biogeography. University of Idaho. MS. Thesis. 55 p.

McDonald, GERAL I.; Hoff, Raymond J. 2001. Blister rust: an introduced plague. In: Tomback, D. F.; Arno, S. F.; Keane, R. E. (eds). Part III. Whitebark pine communities: Threats and consequences. Washington, DC: Island Press. 193-220.

Hoff, Raymond; Ferguson, Dennis; McDonald, GERAL; Keane, Robert. 2001. Strategies for managing whitebark pine in the presence of white pine blister rust. In: Tomback, D. F.; Arno, S. F.; Keane, R. E. (eds). Part III. Whitebark pine communities: Threats and consequences. Washington, DC: Island Press. 17-29.

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