California, Hawaiʻi, and the U.S.-affiliated Pacific Islands have high native biodiversity, and there are few places more unique and diverse anywhere around the globe. This geographic area includes thousands of oceanic islands, elevational clines from coastal to alpine ecosystems in temperate and tropical ecosystems, species and communities that occur nowhere else in the world. The challenge facing this geographic area is the limited time available to stem the tide of species extirpations and extinctions. California, Hawaiʻi, and the U.S.-affiliated Pacific Islands have already lost significant proportions of their native biodiversity and remaining natural areas are threatened with continued loss without sufficient information and tools to respond effectively. Research in the Conservation of Biodiversity program area will fill information gaps for high-quality, relevant information across the spectrum of the conservation continuum: status, threats, vulnerable components, response of organisms and ecosystems to threats, tradeoffs in desired management outcomes, efficacy of management approaches through adaptive management, restoration and recovery techniques and tools, and effectiveness monitoring and evaluation techniques.

Through the Conservation of Biodiversity Program, the Pacific Southwest Research Station (PSW) will conduct research to enhance the conservation of plant and animal species and the restoration and maintenance of native ecosystems. Four problem areas address elements of biodiversity that have pressing needs for new information to inform conservation and restoration efforts, and each of these problem areas includes activities directed at generating new information to address high priority management needs, and effectively delivering that information to management.

- **Problem Area 1:** Determine environmental conditions needed for terrestrial species persistence. Forest, shrubland, and grassland biodiversity is declining as a function of the impact of land use and environmental changes that reduce the diversity and geographic range of populations of native plant and animal species with cascading effects, such as increased risks to species viability, impacts to recreational uses, and reductions in ecosystem services.

- **Problem Area 2:** Identify conditions that can support aquatic biodiversity and ecosystem services. Freshwater ecosystems are in peril because of losses of native biodiversity resulting from a wide-range of environmental threats, which in turn pose risks to a wide range of ecosystem services such as energy generation, water availability, and recreation.

- **Problem Area 3:** Determine the genetic origins of traits that can enhance tree adaptability and utility. Native tree species play important ecological, economic, and cultural roles in ecosystems, yet many species are vulnerable to environmental change as evidenced by reductions of geographic range, genetic diversity, adaptability, forest productivity, resilience, and associated forest products and ecosystem services.

- **Problem Area 4:** Develop innovative approaches to reduce ecological impacts of non-native species. Ecosystem restoration faces challenges created by a lack of historical analogs, knowledge gaps about how to effectively restore ecosystems, and extreme environmental conditions, which require innovative approaches to reduce impacts of non-native species and enhance the resilience of native species assemblages.
R&D PROGRAM NUMBER
TBD

STATION
Pacific Southwest Research Station

R&D PROGRAM LOCATIONS
Albany, Arcata, Davis, Fresno, Placerville, Redding, and Riverside, California
Hilo, Hawai`i

R&D PROGRAM TITLE
Conservation of Biodiversity

PROGRAM MANAGER
Dr. Patricia N. Manley, Supervisory Biological Scientist, 60 Nowelo St., Hilo, HI 96720

AREA OF APPLICABILITY
California, Hawai`i, and the U.S.-affiliated Pacific Islands. Work of the program will contribute substantially to understanding the environmental factors and ecological processes that affect biodiversity. Research performed in this Program is supportive of the USDA “all lands” vision of collaborative efforts across all land designations and ownerships to accomplish landscape-wide stewardship, conservation, and restoration objectives. Collaborations and products of the Program will be applied globally to contribute to the conservation and restoration of global biodiversity.

ESTIMATED DURATION
The Conservation of Biodiversity Program is chartered for 10 years (2011–2021) with a mid-term review and potential charter revision after 5 years (2016). Amendments will be made as needed to address emerging issues.

MISSION
Develop knowledge and tools that support conservation and restoration of biological diversity across all lands, including the identification of current and future conservation challenges and climate adaptation approaches.

OUTCOMES
Our goal for research in this program is to generate needed information and develop tools that support conservation and restoration of biological diversity at genetic, species and community levels that play key roles in conserving and restoring ecosystem function and structure. Our expected outcomes include:
- Increased capacity to create landscape conditions that support the full host of resilient native species and communities through improved knowledge of the primary ecological processes that support biodiversity from genes to landscapes.
- Enhanced understanding of past, present, and predicted future responses of plant and animal species to environmental changes and disturbances to inform management of sites and landscapes to conserve and restore biodiversity.
- Increased number and effectiveness of biocontrol agents and ecological restoration approaches to conserve and restore native ecosystems.
• Increased breadth and effectiveness of tools that put scientific information in a format directly applicable to the needs of managers, policy makers, and practitioners seeking to conserve and restore biodiversity.
• Enhanced capacity of managers, policy makers, and practitioners to apply scientific information to management decisions and actions that conserve and restore biodiversity.

JUSTIFICATION AND PROBLEM ANALYSIS

California, Hawai`i, and the U.S.-affiliated Pacific Islands have high native biodiversity, largely as a function of a diversity of ecosystems and high levels of endemism. Biological diversity encompasses every level of biological organization, including genes, species, populations, communities, ecosystems, and landscapes. The diversity of functions performed by individual species and the redundancy among species in performing these roles is the key to ecosystem resilience and associated ecosystem services, such as recreation, wood products, clean water, pollination, and carbon storage. Ecosystem resilience and services are essential to the long-term sustainability of ecological, cultural, social, and economic systems upon which all species depend.

There are few places more unique and diverse than California, Hawai`i, and the U.S.-affiliated Pacific Islands. In California, National Forest System lands occupy 20% of the land base, represent all major forest ecosystem types, and support the majority of terrestrial and freshwater biodiversity in the state, including many endemic species. As the most isolated archipelago on earth, 90% of Hawai`i’s 10,000 native species are endemic. This geographic area includes thousands of oceanic islands, elevational clines from coastal to alpine ecosystems in temperate and tropical ecosystems, species and communities that occur nowhere else in the world, among the tallest mountains in the world, and a broad range of governments and cultures.

Environmental change from both natural disturbances (wildfire, flood, hurricane, typhoon, drought) and anthropogenic disturbances (invasive species, forest management, deforestation, pollution, urbanization, climate change) affects biological diversity across all biological scales in terrestrial and aquatic ecosystems. The challenge faced around the globe, but particularly acute in California, Hawai`i, and the U.S.-affiliated Pacific Islands, is the pressing need to stem the tide of species extirpations and extinctions. Over the past 200 years in Hawai`i, an estimated 270 plant and animal species have gone extinct, with an additional 440 species being threatened or endangered. In California, extinct species are estimated at approximately 40 plant and animal species, with over 400 species being threatened or endangered. Success in re-establishing species in areas where they have been extirpated is rare, and once an endemic species becomes extinct, it is lost forever. The large number of threatened and endangered species in California and Hawai`i suggests one of two situations: either the availability of suitable environmental conditions remains sufficient to support self-sustaining populations, and the challenge ahead is simply to maintain or restore suitable conditions; or alternatively, environmental conditions are no longer adequate to support many species, and we are observing a lag effect in the reduction in ecological potential to support native species. In either case, the challenge to conserve and restore biodiversity is great, and success will require our best science.

In the U.S.-affiliated Pacific Islands, the status of biodiversity and overall ecosystem conditions range widely. Many of the Pacific Islands have large proportions of their landscapes occupied by intact native ecosystems; however, others are in declining or highly degraded states. In Hawai`i, the rate and
magnitude of species losses, concomitant with the growing extent and dominance of exotic species, now threatens to drive entire native ecosystems to extinction. Similarly in Guam, terrestrial and aquatic ecosystems have been significantly altered over much of the land base. Exceptionally strong effects on native animal and plant species and their habitats are expected from changing climate across the entire western Pacific Islands geographic area.

The Nation’s most significant environmental threats – climate change, altered fire regimes, invasive species, loss and fragmentation of wildlands through urbanization, compromised air quality, drinking water shortages, and sea level rise – have prominent impacts in California, Hawai`i, and the U.S.-affiliated Pacific Islands. Most, if not all, of the 2010 state-wide assessment of forest conditions and resource strategies (SWARS) produced by California, Hawai`i, Guam, and the U.S.-affiliated Pacific Islands in response to the 2008 Farm Bill identified these environmental threats. These same threats are identified as primary concerns in the 2008 Micronesian Challenge, which is an agreement among five U.S.-affiliated island nations in the Pacific to conserve at least 30% of near-shore marine and 20% of the terrestrial resources across Micronesia by 2020. The USDA Forest Service is one of the primary government agencies identified as key to success of California, Hawai`i, and U.S.-affiliated Pacific Islands in addressing local and regional conservation needs and challenges.

Conservation and restoration of biological diversity in California, Hawai`i, and the U.S.-affiliated Pacific Islands requires the availability of high-quality, relevant information across the spectrum of the conservation continuum: status, threats, vulnerable components, response of organisms and ecosystems to threats, tradeoffs in desired management outcomes, efficacy of management approaches through adaptive management, restoration and recovery techniques and tools, and effective monitoring and evaluation techniques. PSW research has a central role in meeting many of these information needs through research, development, and technical transfer of information with and for a wide array of conservation and management partners.

**Focus and Scope**

Basic biological (behavioral, genetic, physiological, or ecological) processes relevant to adaptation and survival of plant and animal species must be sufficiently understood to ultimately conserve and restore biodiversity. A thorough understanding of the interactions among plants and animals is vital to sustaining populations of native species and overall biological diversity, and it is lacking at present. The information provided by this program will be focused on building the capacity to predict and project biological responses to environmental change to 1) improve our understanding of how natural and human-induced environmental change affects biological diversity and how biological diversity contributes to ecosystem resilience, and 2) support resource managers and policy makers in assessing how to conserve and restore biodiversity. The net benefit to society is also an important focus of the research, with emphasis on the wide range of ecosystem services provided by species and communities, such as water quality and quantity, timber, energy generation, pollination, wildlife viewing, fishing, hunting, gathering, recreation, cultural practices, nutrient cycling, seed dispersal, and regulating insect infestations.

Given the ecological and socioeconomic complexity of our area, the scope of this program is broad; approaches and methods used to solve the problems are potentially national and international in scope. Applying cutting edge methods to address natural resource issues under the demanding circumstances in
California, Hawai‘i, and the U.S.-affiliated Pacific Islands will lead to solutions that can be applied across the nation and internationally. The Pacific Southwest Research Station’s network of Experimental Forests and Ranges will provide one important platform from which to conduct focused research, develop technology transfer products, and provide demonstrations of how management can sustain, enhance, or restore species and habitat biodiversity.

There is a pressing need to guide management toward comprehensive regional strategies for preserving and restoring large landscapes. Conservation that is focused only on small geographic units or singular ecological problems may, over time, result in widespread and rapid declines in local and regional biodiversity. Informational and practical tools and techniques are needed to help managers understand and assess management tradeoffs across landscapes, over time, and among competing priorities. Tools to aid regional conservation planning are a critical need for conservation science. Our research will use approaches such as modeling, remote sensing, and geographic information systems (GIS) to expand the geographic scope of site-specific information to support management decisions across landscapes, multiple disciplines, and time (decades to centuries) into the future. Efficient and effective methods of monitoring plant and animal populations and communities and their physical environment, will be needed to validate and adjust management approaches over time.

Research in the Conservation of Biodiversity program encompasses a diverse set of disciplines and scientific approaches and will address key information needs pertaining to plant and animal conservation. The primary users of new scientific information and tools for biodiversity conservation and restoration are similarly targeted. National and State governments and agencies with responsibilities for natural resource management and non-governmental organizations with a conservation focus are the principle users, and in-turn they are a principle source of funding for research activities. Governments use information and tools to set management and conservation policy for public and private lands, and conservation organizations use them to influence management and policy, as well as inform direct conservation actions such as land purchases.

The National and State governments and agencies served by the Program differ across the geographic areas encompassed by the Station. The primary customer and partner in California is the National Forest System, where our partnership results in focused research directed at high priority information needs associated with current land management challenges. Primary research collaborators in California are scientists at academic institutions, including multiple University of California campuses, Humboldt State University, Fresno State University, University of Nevada, and Oregon State University. Primary customers in Hawai‘i and the U.S.-affiliated Pacific Islands are local governments and the U.S. Department of Defense, since they are the primary public land stewards. Research in Hawai‘i and the U.S.-affiliated Pacific Islands is directed at a combination of site-specific and region-wide biodiversity conservation and restoration challenges. Primary research collaborators in Hawai‘i are scientists across a diversity of research institutions, including University of Hawaii at Manoa and Hilo, Stanford University, Yale University, University of Guam, U.S. Geological Survey, and U.S. Fish and Wildlife Service Cooperative Research Units. Most of these organizations have distinct branches and personnel associated with each of the problem areas, with particular distinctions between terrestrial and aquatic resources. Additional groups interested in species and communities of concern include non-governmental conservation organizations operating at local, national and international scales, such as The Nature Conservancy, Trout Unlimited, and the National Fish and Wildlife Foundation.
PROBLEM AREA SELECTION AND TIMELINE

We selected four problem areas:

- **Problem Area 1: Determine environmental conditions needed for terrestrial species persistence.** Forest, shrubland, and grassland biodiversity is declining as a function of the impact of land use and environmental changes that reduce the diversity and geographic range of populations of native plant and animal species with cascading effects, such as increased risks to species viability, impacts to recreational uses, and reductions in ecosystem services.

- **Problem Area 2: Identify conditions that can support aquatic biodiversity and ecosystem services.** Freshwater ecosystems are in peril because of losses of native biodiversity resulting from a wide range of environmental threats, which in turn pose risks to a wide range of ecosystem services such as energy generation, water availability, and recreation.

- **Problem Area 3: Determine the genetic origins of traits that can enhance tree adaptability and utility.** Native tree species play important ecological, economic, and cultural roles in ecosystems, yet many species are vulnerable to environmental change as evidenced by reductions of geographic range, genetic diversity, adaptability, forest productivity, resilience, and associated forest products and ecosystem services.

- **Problem Area 4: Develop innovative approaches to reduce ecological impacts of non-native species.** Ecosystem restoration faces challenges created by a lack of historical analogs, knowledge gaps about how to effectively restore ecosystems, and extreme environmental conditions, which require innovative approaches to reduce impacts of non-native species and enhance the resilience of native species assemblages.

The breadth of roles that research is expanding with the complexity of the conservation challenge. As the Committee of Scientists, convened by U.S. Department of Agriculture in the 1997, outlined 15 years ago and still relevant today that Forest Service research needs to span key tasks in support of conservation planning for land management: 1) creating knowledge of relevance to collaborative planning; 2) developing the integrative science for bioregional assessments; 3) helping managers understand the application of scientific and technical knowledge; 4) helping to design effectiveness-monitoring procedures and adaptive management experiments; and 5) evaluating the use of scientific information in planning and implementation. These five tasks identify points of engagement throughout planning processes from beginning to end, and illustrate the diversity of roles that Forest Service research plays in supporting management. The outcome of these tasks is a portfolio of research contributions required by managers to have the capacity to successfully navigate the complexities of planning for a sustainable future (Fig. 1).
Useful research products can take many forms. Traditional products are written materials in the form of peer-reviewed scientific journal articles, workshop and symposia proceedings, scientific syntheses, and commissioned white papers. Products less commonly considered the primary realm of research, but which more directly meet the needs of resource managers may be in the form of databases, assessments, measurement techniques, monitoring designs, decision support systems, and workshops on these products. Further, advances in web technology and availability have broadened options for making science more accessible to users, such as instructional videos, interactive web sites, and webinars.

Research conducted under the problem areas will generate new capacity in multiple arenas:

- knowledge of life histories, behaviors, genetics, and requirements of species of concern will inform species-specific and landscape-based management and conservation strategies for species;
- knowledge of community dynamics and trophic interdependencies will assist in developing management strategies (e.g., vegetation, fire, recreation) for effective biodiversity conservation and restoration;
- improved knowledge of effective actions and mechanisms to conserve and restore biological diversity across multiple spatial scales and to improve management outcomes;
- development of cutting edge tools in the field of genomics (e.g., the use of next generation sequencing technologies) will improve our understanding of genetic diversity;
- ability to mitigate effects of introduced exotic organisms on native populations and communities will maintain resilient ecosystems;
- new approaches for restoring species, degraded environments, and ecological processes and function will improve the efficiency of restoration efforts;
- improved knowledge-based tools that provide information on the effects of disturbance and management on various facets of biodiversity will enable management and policy decisions to be based on more accurate projections;
- availability of database management systems that make data on past, present, and potential future measures of biological diversity available for research, development, and application;
- improved monitoring techniques and designs for species and communities across landscapes; and
• diversified forms of information dissemination (e.g., publications, reports, webinars, training, workshops, symposia, videos) will meet the needs of managers and practitioners in a timely manner allowing research to inform decisions in a timely manner.

Problem Area 1 - Determine environmental conditions needed for terrestrial species persistence

Forest, shrubland, and grassland biodiversity is declining as a function of the impact of land use and environmental changes that reduce the diversity and geographic range of populations of native plant and animal species with cascading effects, such as increased risks to species viability, impacts to recreational uses, and reductions in ecosystem services.

This problem area involves identifying and understanding interrelationships among the key components of biological diversity in terrestrial ecosystems of California, Hawai`i, the Pacific, and ecological correlates around the world. Research conducted under this Problem area will inform resource managers how to protect, conserve, and restore terrestrial biological diversity, and in turn how to reap the benefits of terrestrial biological diversity as a mitigating factor in the face of increasing environmental change from natural and human disturbances. Societal benefits of this research will include improved scientific basis for impact assessments, preventative management practices, increased accuracy of disturbance impact predictions, and preservation of resilient ecosystems that provide economic and recreational value.

In California, PSW is the primary source of expertise and data on the effects of forest management on native animal species, particularly vertebrates. Our scientists offer animal and habitat expertise in oak woodlands, Sierran conifer forests, Douglas fir (*Pseudotsuga menziesii*) forests, redwood forests, and Great Basin forests. We also are one of the primary sources of expertise on a number of terrestrial species of concern, such as American marten (*Martes americana*), Pacific fisher (*Martes pennanti*), California spotted owl (*Strix occidentalis occidentalis*), Northern goshawk (*Accipiter gentilis*), Great gray owl (*Strix nebulosa*), mountain beaver (*Aplodontia rufa*), and marbled murrelet (*Brachyramphus marmoratus*), among others. We also are leaders in vertebrate community ecology in managed forests in California, specifically bird and small mammal communities in a range of forested ecosystems including redwood forests, Douglas fir forests, Sierran conifer forests, oak woodlands, and chaparral. Expertise in terrestrial animal species in the Pacific Islands is a recognized need, and building this research capacity for native vertebrate species (e.g., native birds, Hawaiian hoary bat [*Lasiurus cinereus semotus*]) would be complementary to the key role that PSW plays in ecosystem conservation and restoration in the Pacific Islands.

**Approach to Problem Solution**

Original research will include laboratory and field experimental studies; field observational and retrospective studies; and both empirical and process-based simulation modeling. The scope of studies will range from gene to ecosystem level of biological organization, from site-specific to global spatial scales, and from breeding season to decadal-and-longer temporal scales.

Research will describe patterns of geographic distributions, environmental associations and sensitivities, ecological thresholds, population dynamics, genetic diversity, and behaviors of key native species of concern and interest (e.g., landbirds, raptors, bats, marten, fisher), as well as associated non-native
species (e.g., plant species, pathogens, insects) that threaten conservation goals. Research will also be directed at species assemblages and communities to determine species interdependencies and the role of species composition on ecosystem resilience. This knowledge will lead to a better understanding of the processes driving biodiversity.

The breadth and complexities of this problem area require a variety of approaches and techniques, including the development of new technologies. New approaches will likely include improved field sampling methods (e.g., scat-detector dogs), innovative genetics techniques that replace some field data needs (e.g., development of genetic markers, DNA from hair or scat used to estimate population sizes), improved statistical methods (e.g., occupancy modeling enhances value of presence data), new spatial analysis methods enabling the ability to create maps of population and community traits, and informatics. Newly developed analytical tools for dealing with the informatics of data sets that are both very large and widely distributed geographically will be developed and applied to gain new insights.

Research outputs will provide tangible new information and tools, such as population parameters that are indicative of species health and adaptive potential, descriptions of habitat requirements, descriptions of species distributions, new tools for measuring landscape and species-level variation in biodiversity, expanded understandings of biotic interactions that threaten native ecosystems, and new tools to manage threats to biodiversity. These data can then serve as input to modeling tools that predict and project the status and response of species across landscapes and over time under various management scenarios and environmental conditions.

A greater understanding of the ecological factors that influence biological diversity will allow managers to implement effective and targeted management strategies. Examples include studies: to determine if landbirds can rapidly shift in response to climate; to identify trade-offs in forest management to reduce the risk of wildfire and to optimize native biodiversity; and to determine the adaptive potential of mid- and high elevation plants to environmental change.

**Planned Topics for Study**

**Temperate Ecosystems**
- Conduct and analyze data from long-term monitoring of California spotted owl demographics to assess the status and population trends of this focal species. FY21.
- Develop predictive habitat modeling tools for individual species (e.g., California spotted owl, Northern goshawk, Pacific fisher) and community diversity that can be used by managers to project changes in habitat suitability and biodiversity under comparative forest management scenarios to assist in project and Forest-level planning. FY16.
- Conduct a meta-analysis workshop to assess the utility of existing, long-term demographic studies of California spotted owls to meet management objectives for determining the response of owls to forest management treatments. FY13.
- Evaluate current survey protocols, develop bioacoustical and genetic field methods, and assess sampling designs for monitoring the genetically unique population of Great gray owls in the Sierra Nevada. FY12.
- Identify the effects of invasive, exotic bird species on native cavity-nesting birds in oak woodland ecosystems. FY15.
Develop recommendations for grazing and mowing practices that will reduce the numbers of European starlings and their impacts on native bird species in California’s oak woodlands. FY13.

Study the habitat associations of black-backed woodpeckers (Picoides arcticus) over a gradient of forest conditions to address an emerging management issue regarding the degree of dependence of this species on moderate to high-intensity burns. FY14.

Determine the seasonal occurrence of the silver-haired bat (Lasionycteris noctivagans), a species threatened by wind energy developments, in forests of northwest California. FY16.

Estimate range-wide population status of the Point Arena mountain beaver (Aplodontia rufa nigra), and establish a statistically sound plan for monitoring trends in status over time. FY16.

Determine the effects of wildfire and forest fuels reduction management treatments and associated biomass production on vertebrate biodiversity and community structure in the Sierra Nevada conifer forests. FY17.

Determine changes in vertebrate biodiversity in the Redwood Experimental Forest over the past 30 years, with emphasis on marbled murrelets and terrestrial salamanders. FY14.

Provide synthesis and consultation on conservation strategies for terrestrial amphibians, mammals, raptors, and native plants at a landscape scale in support of the revision of the 18 Land and Resource Management plans in Region 5. FY20.

Tropical Ecosystems

Develop updated vegetation and carbon maps for the Pacific Islands that will inform current conservation efforts such as the Micronesian Challenge. FY15.

Develop a web-based tool to monitor real time fire risk in selected tropical ecosystems, derived from satellite imagery and analysis of photosynthetic (low fire risk) vs. non-photosynthetic (high fire risk) material, to evaluate risk to valued plant and animal habitat conditions. FY13.

Determine the population dynamics of coqui frog (Eleutherodactylus coqui) in response to climate change in lowland wet tropical forests in Hawai`i. FY13.

Develop monitoring techniques and designs for populations and habitats of native and non-native vertebrate species in the Pacific Islands, with specific emphasis on coqui frog, Hawaiian hoary bat, and native birds. FY17.

Design and test methods for assessing and quantifying impacts of non-native terrestrial vertebrates (amphibians, reptiles, birds, mammals) on island ecosystems. FY21.

Problem Area 2 - Identify conditions that can support aquatic biodiversity and ecosystem services

Freshwater ecosystems are in peril because of losses of native biodiversity resulting from a wide range of environmental threats, which in turn pose risks to a wide range of ecosystem services such as energy generation, water availability, and recreation.

This problem area involves identifying and understanding interrelationships among the key components of biological diversity in aquatic ecosystems of California, Hawai`i, the Pacific, and ecological correlates around the world. Societal benefits of this research will include an improved scientific basis for impact assessments, preventative management practices, increased effectiveness of disturbance impact predictions, and preservation of resilient ecosystems that provide economic and recreational value. Research conducted under this problem area will inform resource managers how to protect, conserve, and restore aquatic biological diversity as well as how to use aquatic biological diversity as a
PSW is a primary source of expertise and data on the effects of forest and water management on native aquatic species and nonnative invasive aquatic species in California and Hawai`i. Our scientists offer expertise in riverine, riparian, meadow, and lake and pond ecosystems in a diversity of biomes, such as the Sierra conifer forests, Douglas fir forests, redwood forests, lowland wet tropical forests, and mangrove forests. We also are one of the primary sources of expertise on a number of aquatic and riparian species of concern, such as coastal tailed frog (*Ascaphus truei*), southern torrent salamander (*Rhyacotriton variegates*), Yosemite toad (*Anaxyrus canorus*), Sierra yellow-legged frog (*Rana sierrae*), western pond turtle (*Actinemys marmorata*), California golden trout (*Oncorhynchus aguabonita aguabonita*), coho salmon (*Oncorhynchus kisutch*), coastal cutthroat trout (*Oncorhynchus clarkii clarkia*), gobie (Gobiidae, “o’opu”), and freshwater shrimp (*Atyoida bisulcata* and *Macrobrachium grandimanus*, “opae”), among others. PSW applies their expertise in aquatic biota to developing predictive models and assessment tools with direct utility to managing populations, habitat, aquatic ecosystems, watersheds, and landscapes. Expertise in aquatic animal species in the Pacific Islands is a recognized gap, and this expertise is needed to address the pressing demands on aquatic ecosystems in the Pacific Islands.

**Approach to Problem Solution**

Original research will include laboratory and field experimental studies; field observational and retrospective studies; and both empirical and process-based simulation modeling. The scope of studies will range from studies at the gene to ecosystem level of biological organization, from site-specific to global spatial scales, and from daily to decadal-and-longer temporal scales. Research will describe patterns of and in some cases reveal the processes driving the geographic distributions, environmental associations and sensitivities, ecological thresholds, population dynamics, genetic diversity, and behaviors of key native species of concern and interest (e.g., salmonids, gobids, shrimp, frogs, toads, salamanders) and aquatic ecosystems (e.g., mangroves, wet meadows, river systems, lakes and ponds). These research results then serve as input to modeling efforts to predict and project the status and response of species across landscapes and over time under various management scenarios and environmental conditions.

The breadth and complexities of this problem area require a variety of approaches and techniques, including the development of new technologies. New approaches are likely to include more effective field sampling methods (e.g., satellite tracking), new genetics techniques (e.g., DNA from tissue used to estimate population sizes), statistical methods (e.g., occupancy modeling enhances value of presence data), spatial analysis methods to create maps of population and community traits, and individual-based, spatially explicit models of populations of species of concern. Examples of needed tools and technology include distribution and abundance surveys of species and communities, probability models of species occurrence, abundance, and movement, and genetic markers. Analytical tools for dealing with the informatics of data sets that are both very large and widely distributed geographically, will be developed and applied to gain new insights.
A greater understanding of the ecological factors that influence biological diversity will allow managers to implement effective and targeted management strategies. For example, studies will examine linkages between mangrove forests and freshwater swamps; inform conservation of high elevation native aquatic fish and amphibians; and inform river management to support native species while generating needed electricity.

**Planned Topics for Study**

**Temperate Ecosystems**
- Quantify local, regional and seasonal variation in predation risk for stream fish, so that variation in this key process can be included in population models for highly valued trout and salmon. FY16.
- Complete and validate a generally applicable individual-based model for stream trout that can be used to predict the consequences of multiple stressors (e.g. invasive species and water diversions) on trout survival and improve restoration efforts. FY20.
- Quantify the fine-scale, high-resolution effects of water diversions on stream salmonid populations and foothill yellow-legged frog (*Rana boylii*) populations using a combination of field measurements and spatially explicit models. FY14.
- Identify amphibian and reptile (e.g., western pond turtle, Shasta salamander [*Hydromantes shastae]*) habitat needs within the context of climate-related variables, such as air and water temperature and precipitation. FY18.
- Study extant populations of Cascades frogs (*Rana cascadae*) in the southern Cascades of California to estimate their size and viability, and determine causes for their declines. FY12.
- Develop and evaluate habitat suitability criteria for the foothill yellow-legged frog. FY13.
- Provide consultation on the development of all-lands conservation strategies for aquatic vertebrates and plants. FY20.
- Determine how to restore native amphibians to high elevation aquatic ecosystems where they have been extirpated by invasive nonnative trout. FY15.
- Conduct a comprehensive assessment of meadow restoration projects effects in meadow ecosystems in California to evaluate the effectiveness of restoration techniques as a tool to mitigate climate change, define the characteristics of success, and highlight the factors contributing to risk of failure so managers can more accurately weigh the potential risks and benefits of future projects and determine appropriate restoration techniques. FY15.

**Tropical Ecosystems**
- Quantify production, reproduction, and recruitment as well as habitat requirements of native shrimp or opae (*Atyoida bisulcata*) in Hawaiian streams. FY18.
- Quantify how increased nutrient loading alters the habitat value of anchiaine ponds for native shrimp or opae (*Halocaradina rubra*). FY19.
- Quantify how decreased precipitation from climate change could alter native fish (e.g., *Sicyopterus stimpson*) and invertebrate habitat in Hawaiian streams. FY20.
- Develop monitoring techniques to identify mangrove forests that may be more resilient to sea level rise. FY21.
Problem Area 3 – Determine the genetic origins of traits that can enhance tree adaptability and utility

Native tree species play important ecological, economic, and cultural roles in ecosystems, yet many species are vulnerable to environmental change as evidenced by reductions of geographic range, genetic diversity, adaptability, forest productivity, resilience, and associated forest products and ecosystem services.

Trees play a dominant role in maintaining many aspects of global ecosystems (e.g., carbon, atmospheric conditions, climate). Forest trees are under increasing pressure from loss of habitat, forest fragmentation, invasive species, pollutants, changing climates, fire suppression, and forest management. These stressors result in reductions in geographic range, abundance, and genetic diversity, and these losses are predicted to increase in future. All contribute to reduce population sizes, genetic diversity within populations, and gene flow among populations, and thus adaptability and resilience. Invasive plant diseases, whether of long standing (e.g., white pine blister rust), or newly-arrived (e.g., sudden oak death and pine pitch canker), pose growing threats to our forests. Invasive microorganisms, typically introduced accidentally and cryptically, go undetected until the disease organism is well-established. Managers can address these threats by manipulating the growing environment (silviculture) or the genetic composition of trees (directly or indirectly). This problem area focuses on the development of genetic solutions to these pressing problems.

The term genetics covers a broad range of biological phenomena, from the molecular level (understanding what specific genes control a trait) to the landscape level (understanding the spatial partitioning of traits across landscapes and the implications). Likewise, one must also understand how the genetics of one species interacts with the environment (the inheritance of adaptive traits) and the surrounding biota (host-pathogen interactions). Today, the foremost use of population genetics in trees is to maintain forest health in the face of external threats. Knowledge of how genetic diversity, adaptive traits, and molecular mechanisms buffer species response to adverse conditions is essential to forecasting the fates of species and to providing opportunities for mitigation.

This problem area stresses resistance genetics that addresses modes and inheritance to avoid, tolerate, or counteract the attacks of pathogens and parasites, and conservation genetics that explores genetic contributions to survival, reproduction, and the continuing evolution of species and populations. The goal of both is to prevent extinction and foster forest health by maintaining or manipulating genetic diversity. Development of genomic tools that can be applied to problems in forest biology is strategically advantageous; genomic tools can be applied to problems ranging from the distributions of disease resistance to the frequency of desirable adaptive traits. Ecosystem genomics provides an opportunity to broadly characterize plant populations based upon their innate genetic potentials to survive and thrive despite adverse environmental conditions.

Forest productivity and resilience, including robust populations of individual tree species, are important to a diversity of users, including Federal, State, and private forest managers, State and Federal policy makers, forest industry, energy industry, conservation organizations, and the public. Forest managers need to understand how individual tree species will respond to changing environmental conditions, particularly climate change and its cascading impacts (e.g., changing disease dynamics), in order to inform short- and long-term management plans. Forest industry has a keen interest in opportunities for
improving the quality and quantity of trees and associated forest products. The energy industry is interested in the quantity and characteristics of trees that could fuel various sectors of the energy industry (e.g., poplars [Populus sp.]). Conservation organizations are interested in the conservation and restoration of individual tree species (e.g., koa [Acacia koa], western white pine [Pinus monticola]), as well as native forest ecosystems.

In California, PSW is a primary source of expertise in tree genetics, including managing genetic resources and working to understand and conserve mechanisms for the adaptation of plants to environmental changes. PSW has been a leader in conifer genetics research, and is uniquely positioned to make significant new contributions. A thorough understanding of the genes regulating adaptive traits is central to determining how genotypes will affect restoration success. Similarly, individual genes that regulate wood formation and disease resistance are of both economic importance and ecological relevance in conservation and restoration efforts.

In Hawai`i and the U.S.-affiliated Pacific Islands there is need for expanded capacity in tropical hardwood tree improvement and regeneration. Climate change and new diseases threaten native species across all Pacific Islands, with potentially large impacts for both dry and wet forest species. By understanding genetic diversity and genes associated with adaptive traits, silvicultural techniques can be employed to enhance disease resistance and restore species distributions to enhance long-term species and community viability. Overall, tropical tree improvement lags behind that of temperate regions, despite the global importance of tropical biodiversity, tropical timber production, and a need for large-scale approaches to restoration.

**Approach to Problem Solution**

PSW uses both traditional host-pathogen inoculation techniques to identify plant responses to infection to characterize potential resistance mechanisms, and laboratory tools to identify potential resistance genes at the molecular level. Coordination between the observed host/pathogen interaction and locating the host genes that underlie such responses is essential to identifying disease resistant populations and individuals. Other studies will compare the similarities and differences between resistance genes of different species to aid in understanding gene function and their value in conserving biodiversity.

PSW has pioneered the use of rapid, high-throughput methods that allow for identifying genes in large numbers of trees and associating specific gene alleles with biological traits. These techniques must be developed for each gene in a species and optimized so that the approach can be applied on a large scale. This will be undertaken in populations of Douglas fir to identify genes involved in the interaction and adaptation of trees with their environment. The techniques and approaches established for Douglas fir can serve to guide similar studies in other populations or species, or to screen for additional traits.

Wood formation is the biological basis of the forest products industry. It is a fundamental process underlying perennial incremental growth in trees. It influences carbon cycling, provides habitat for wildlife, and can be a component of disease progression. Trees provide a significant ecological foundation to local and global ecosystems, and as such, to the conservation of biodiversity. Despite the importance of wood formation, we still do not understand the basic genetic regulation of the vascular cambium or the differentiation of cell types within wood. The use of molecular and genomic tools in poplar presents an opportunity to understand genes regulating wood formation. For example, the
Department of Energy has recently completed sequencing of the poplar genome, representing the first fully sequenced forest tree genome. This resource is anticipated to promote a paradigm shift in forest genetics research, but genetic tools must be established to make use of the sequence information.

**Planned Topics for Study**

**Temperate Ecosystems**
- Identify disease resistance traits and their inheritance in high-elevation white pines to support improved breeding strategies, identify populations at risk, and develop more accurate assessments of species and habitat vulnerabilities. FY14.
- Identify genes in tanoak associated with the infection process by the pathogen that causes Sudden Oak Death. FY15.
- Establish effective strategies for identifying hybrid poplars with superior feedstock characters and biomass production for bioenergy production using genomic tools. FY15.
- Identify the biological and genetic factors that regulate wood properties pertinent to forest industry, carbon sequestration, and bioenergy production. FY15.
- Describe the variation in gene expression in response to rust inoculation through a common garden of Sugar Pines from across the species range to enhance the long-term survival of the species. FY15.
- Determine the impacts of climate on growth and survival in ecologically and economically important pine species using historical provenance test resources established by the Forest Service over the last 90 years to help guide species restoration efforts. FY18.
- Determine the evolutionarily conserved regulatory pathways that control tree growth and development, which can be used to enhance the long-term survivorship of species, associations, and communities. FY18.
- Provide new guidelines for genetic management and conservation that result in the collection and planting of appropriately adapted conifer germplasm. FY17.
- Conduct an evaluation of conservation and restoration projects directed at native conifer populations in California to serve as a tool for adaptive management. FY20.

**Tropical Ecosystems**
- Develop lineages of *Acacia koa* that express different desirable traits, including resistance to disease, so that populations can begin to reoccupy their former elevational range in Hawai‘i. FY21.

**Problem Area 4 – Develop innovative approaches to reduce ecological impacts of non-native species**

Ecosystem restoration faces challenges created by a lack of historical analogs, knowledge gaps about how to effectively restore ecosystems, and extreme environmental conditions, which require innovative approaches to reduce impacts of non-native species and enhance the resilience of native species assemblages.

Invasive species have long been a predominant threat to agricultural economies and certain native ecosystems worldwide. Particularly for small but highly diverse natural areas typical of tropical islands and California’s endemic landscapes, the impacts of invasion by ecosystem-transforming exotic plants can be devastating. Fast-growing tree species like strawberry guava (*Psidium littorale*), Miconia (*Miconia calvescens*) and *Albizia* sp., and fire-promoting alien grasses are leading examples of threats to
native forests and rangelands. For individual native species, disease and other exotic pests can decimate large populations, with sudden oak death and goldspotted oak borer (*Agrilus auroguttatus*) as recent cases. For our rarest native species, exotic invasions can tilt the balance toward swift extinction, such as we have seen with mosquito-borne avian malaria in native Hawaiian birds. In spite of intensive efforts to manage invasions, the severity of their threat to native biodiversity remains extremely high, and the frequency of new invasions has escalated dramatically with global trade.

Managers of public and private lands need new information and tools to counter effects of the most destructive and pervasive invaders. Conventional methods for land preservation are inadequate, given that the worst invaders are able to penetrate and degrade even our most pristine and carefully protected natural areas. The challenge in managed forests and agricultural lands also remains high, since each invasive species may require a tailored response that takes into account its particular impacts and vulnerabilities. Many natural communities have been irreversibly altered by invasion and other transforming forces, so that complete restoration of native biodiversity is frequently not attainable. For such severely altered landscapes, management may require innovative use of surrogate species and novel community structures to reach the goal of sustaining biodiversity.

Conservation focused only on small geographic units rich in biodiversity over time may allow widespread regional erosion of biodiversity to a point where unique species and ecosystems will only be found in scattered, increasingly threatened fragments. Instead, there is a need to guide management toward comprehensive regional strategies for preserving and restoring large landscapes. Developing methods for and demonstrating the utility of regional conservation planning is a critical challenge for conservation science.

Natural ecosystems composed of native species provide ecological stability, tangible services like fresh water, as well as invaluable future services even beyond our predictions. The future costs of mitigating or recovering from degradation will be orders of magnitude greater than the cost of investing now in prevention and control of invasions, and design of restored communities that are resilient to impacts of invasion and other disturbance. Technologies such as weed risk assessment and biological control have demonstrated benefits at a tiny fraction of their costs for development. Successful restoration of ecosystems at any scale depends on knowledge and tools developed through ecological research.

PSW is a leader in biocontrol and the investigation of novel ecosystems, particularly in tropical ecosystems. Our scientists offer the primary source of expertise on the development of effective biocontrol agents for weedy invasive plant species in Hawai`i. In partnership with the USDI National Park Service at Hawaii Volcanos National Park, PSW operates a state-of-the-art APHIS certified insect quarantine facility, one of only two in the State of Hawai`i. In addition, PSW has the primary expertise to address comprehensive risk assessment needs for invasive species, including understanding the ecology of invasive plant species in Hawai`i and across the Pacific Islands, and understanding their potential impacts on native forests and freshwater aquatic ecosystems. PSW is also a lead research institution in the Pacific in investigating the processes that limit the restoration of native forests and options for establishing stable, sustainable ecosystems that include non-native species. Our scientists are conducting ground-breaking research in dry tropical and lowland wet tropical forests to investigate patterns and processes driving ecosystem disintegration so as to inform restoration. In California, similar expertise is growing in the arena of whole-ecosystem wet meadow restoration following decades of grazing, and the restoration of fire-adapted montane forest ecosystems.
**Approach to Problem Solution**

One of the biggest challenges in ecology is developing successful restoration strategies in light of rapid global change including changing climate patterns, impacts of invasive species, and altered disturbance regimes. Our approach will focus on utilizing ecological assembly rules and species-level genetic and ecological information to identify ecosystem-specific combinations of species and restored habitats that can serve as self-sustaining ecosystems. These novel communities are likely to respond differently to disturbances than native species assemblages and our research will examine these responses. Identification of specific communities and more general principles will have the goal of increasing resiliency of these new communities to future disturbances, especially climate change.

Management of key invasive species that can penetrate and overwhelm native ecosystems, such as strawberry guava, African bunchgrass (*Pennisetum setaceum*), or non-native trout, depends on combined strategies for preventing initial invasions, rapid response to alien species, and sustainable methods of control for established populations. Ecological assessments of invasive species and biological control are examples of tools which PSW research can provide managers. To address the global breadth of current threats to biological diversity, our research will use approaches such as modeling, remote sensing, and GIS to expand the geographic scope of information available for conservation management.

Research will consist of a combination of laboratory testing, field trials, predictive modeling, and localized implementation with monitoring. Research within this problem area will provide clearly understood options for managers to consider when planning conservation and restoration efforts. As these new approaches are implemented on public lands both in the U.S. and abroad, recovery of species and degraded ecosystems may increase and risk of extinctions may decrease. Ultimately, our research will contribute to designing landscapes that minimize threats to biodiversity and maximize the benefits that we receive from natural systems.

**Planned Topics for Study**

**Temperate**
- Develop prescriptions for restoring biodiversity in specific ecosystems such as meadow lands, montane forests, and freshwater aquatic systems.

**Tropical**
- Design integrated methods for long-term management of strawberry guava invasions in tropical forests. Complete FY16.
- Improve predictive evaluation of biocontrol effectiveness through case studies of key tropical ecosystems. Complete FY20.
- Develop prescriptions for restoring biodiversity in specific ecosystems such as wet tropical forests, dry tropical forests, mangrove forests, and freshwater aquatic systems.
- Determine how environmental change affects competitive interactions between native and non-native species in lowland wet and dry tropical ecosystems. Complete in FY21.
- Develop new invertebrate biocontrol agents for *Miconia calvescens*, *Tibouchina herbacea*, *Clidemia hirta* and other invasive melastomes. Complete in FY18.
• Develop species distribution maps for non-native terrestrial vertebrate species (amphibians, reptiles, birds, mammals) on Pacific Islands in order to inform managers and to direct research efforts. Complete in FY16.

ENVIRONMENTAL CONSIDERATIONS

Proposed activities in this research area are not expected to have adverse effects on the environment. The effects of specific actions on the environment will be considered during the development of study plans. Cooperators will perform the environmental analyses associated with their activities when we perform work done in conjunction with operational management activities such as prescribed burning and forest management treatments. For research having the potential to affect a plant or animal species that is federally listed as endangered or threatened or proposed for such listing, the Program will consult with the U.S. Fish and Wildlife Service as per Section 7 of the Endangered Species Act of 1973, as amended. Animal handling and care protocols (e.g., tagging and tissue removal from organisms) will comply with all applicable regulations and permitting processes.

STAFFING PLAN AND COST ESTIMATES

Initially, the Conservation of Biodiversity Program consists of 43 permanent employees: 15 research-grade scientists, 17 professionals (three with Ph.D.s), 9 technicians, a Program Manager, and a Program Manager assistant. The 15 scientists are partitioned among the four subject-based problem areas in the following manner: four wildlife biologists/ecologists and one professional with a Ph.D. work primarily in Problem Area 1; three wildlife biologists and three geneticists work primarily in Problem Area 2; one wildlife biologist, two fisheries biologists, and two professionals with Ph.D.s work primarily in Problem Area 3; and one plant community ecologist, one entomologist, and one wildlife biologist work primarily in Problem Area 4.

Program members are organized into three teams: Wildlife Team, Fish and Aquatic Ecology Team, and Biodiversity Protection and Management Team. Research conducted by individual scientists typically spans multiple problem areas, including problem areas in other Programs, and conversely, scientists and professionals from other Programs will contribute to research needs in one or more problem areas in this program. Most scientists work in an interdisciplinary manner, addressing biodiversity in the context of problem areas in other Programs, such as the effects of forest thinning to reduce the risk of fire on individual species, habitat, or communities. We anticipate using creative methods to expand and contract our workforce as necessary - meaning that we do not anticipate being able to fill new permanent positions, but rather we will meet new needs and opportunities through shared positions (i.e., students, post-doctoral positions) in partnership with other research institutions (primarily Universities).

Anticipated funding for the program is in the range of $3 to 4 million dollars per year for 15 scientists per year for 10 years (150 scientist years 2011-2021). At this level of funding, investments in each problem area will be a function of funding from outside sources, since there will be little or no funding within PSW beyond salaries. This will make it difficult to control the direction of research and to make strategic investments as opportunities arise. The anticipated level of activity in each problem area, based on historical funding opportunities from external funding sources (i.e., availability of external funding to conduct research) is roughly: Problem Area 1 = 35%, Problem Area 2 = 20%, Problem Area 3 = 25%, and Problem Area 4 = 20%.
APPENDIX A: RELATIONSHIP TO STRATEGIES, OTHER PROGRAMS, OTHER STATIONS, AND REGION 5

Relationships to National Strategies and Goals

The Conservation of Biodiversity’s program of research is consistent with and critical to the success of the strategic direction outlined in the USDA Strategic Plan (2010-1015), the Forest Service Strategic Plan (2007-2012) and the Forest Service Research and Development Strategic Plan (2008-2012).

USDA Strategic Plan Linkages
The USDA Strategic Goal 2, “Ensure our national forests and private working lands are conserved, restored, and made more resilient to climate change, while enhancing our water resources”, is particularly pertinent to the conservation of biodiversity in California, Hawai`i, and the U.S.-affiliated Pacific Islands. The primary objective within USDA Strategic Goal 2 that is pertinent to the conservation of biodiversity is objective 2.1: help to restore and conserve the Nation’s forests, farms, ranches, and grasslands. Objective 2.1 directs USDA agencies to work towards restoring declining ecosystems and protecting healthy ones to ensure the Nation’s lands will be resilient to threats.

Forest Service Strategic Plan Linkages
This research program also contributes to six of the Agency goals as defined in the USDA Forest Service Strategic Plan 2007-2012:

• Goal 1: Restore, Sustain and Enhance the Nation’s Forests and Grasslands - Research will focus on restoring and maintaining diverse habitats and reducing adverse impacts from invasive and native species, pests, and diseases.
• Goal 2: Provide, Sustain, and Enhance Benefits to the American People - Research will enhance species and ecosystems that people value as resources.
• Goal 3: Conserve Open Space - Research will develop tools to assess ecosystem fragmentation and its impacts on biodiversity at the landscape level.
• Goal 4: Sustain and Enhance Outdoor Recreation Opportunities - Research will quantify the relationship between levels of biodiversity and quality of the environment to optimize recreational opportunities.
• Goal 6: Engage Urban America with Forest Service Programs - Research outputs will promote conservation education to increase environmental literacy and understanding.
• Goal 7: Provide Science-Based Applications and Tools for Sustainable Natural Resources Management - Research will develop more cost-effective methods for biodiversity inventory and monitoring activities, prescriptions for restoring specific ecosystems, tools for conservation and restoration, and methods for evaluating conservation and restoration success.

Forest Service Research and Development Strategic Plan Linkages
The Conservation of Biodiversity Program fully supports the national mission of USFS Research and Development as stated in its Strategic Plan for research for 2008-2012 (February 2008), to “develop and deliver knowledge and innovative technology to improve the health and use of the Nation’s forests and rangelands – both public and private”, with the associated vision of being “recognized as a world leader in providing innovative science for sustaining global forest resources for future generations.” The related objectives within the USDA Forest Service Research & Development Strategic Plan are Objectives 1.A, 1.C, and 7.B-D.
• Objective 1.A: Develop prevention, mitigation, treatment, and short- and long-term restoration methods and strategies for disturbances (e.g., fire, air, and water pollution; invasive species; extreme events);
• Objective 1.C: Advance understanding of ecosystem structure, function, processes, and their interaction with social processes at multiple scales to effectively manage dynamic landscapes.
• Objective 7.B: Develop and deploy more effective methods for transferring scientific information, technologies, and applications to public and private sectors.
• Objective 7.C: Develop and deploy a risk-based approach to choosing management interventions related to invasive species, fire management activities, and extreme events.
• Objective 7.D: Develop and deploy analysis and decision-support systems to minimize costs of land management and protecting lives and property.

Strategic Program Area (SPA) Linkages
The Conservation of Biodiversity Program aligns with the Wildlife and Fish SPA by providing tools for monitoring, conserving, and improving ecosystems to benefit at-risk and declining terrestrial and aquatic species; evaluating the effects of changes in fish and wildlife populations (including invasions, extirpations, and restorations) on the productivity and health of forests and grasslands; and developing management strategies, systems and options to assess and mitigate habitat loss and fragmentation impacts on plant and animal communities at the landscape level.
• Links to the Invasive Species SPA by providing the knowledge and tools for use across landscapes and ecosystems to reduce, minimize, or eliminate invasive species and restore affected ecosystems.
• Links to the Resource Management and Use SPA by developing management strategies and tools to ensure a flow of goods and services from forest ecosystems through the conservation of biodiversity.
• Links to the Inventory and Monitoring SPA by providing resource monitoring and assessment tools that can make inventory and monitoring more effective and efficient so as to identify risks, trends, and emerging issues.
• Links to the Outdoor Recreation SPA by conducting research on the effects of recreation and human development and disturbance on species and ecological communities, as well as impacts to recreational uses from declines in biodiversity.

Links to Other Research Stations
The Conservation of Biodiversity Program has strong linkages with FS R&D Station program charters in every Research Station; however only two other Stations have programs that target species, populations, or biodiversity: RMRS Wildlife and Terrestrial Ecosystems, and the NRS Sustaining Forests Program. Direct linkages also exist with the International Institute for Tropical Forestry’s wildlife research and ecosystems research emphasis areas.

Links to other PSW Station Strategies and Programs
The Conservation of Biodiversity research program intentionally overlaps with the other three PSW research programs:
• Urban Ecosystems and Social Dynamics Program
  Human influences on biodiversity. Collaborative research will be aimed at understanding the economic forces leading to biodiversity loss, understanding the social-ecological interactions that
affect ecosystem services (water, food and fiber, ecosystem processes, and recreation), and developing social mechanisms to slow biodiversity loss. 

Cultural influences on biodiversity. Collaborative research will be aimed at understanding the social and cultural processes that affect biodiversity, including indigenous land use practices and knowledge, as well as the coupling of natural and human systems.

- Fire and Fuels Program
  *Fuels management impacts on biodiversity.* Collaborative research will be aimed at understanding the relationships between fire, fuel, plants and animals; understanding response to fire for species of concern; and understanding the effect of hazardous fuels reduction and other fire management practices on biodiversity.
  *Impacts of fire and fuels on habitat restoration.* Collaborative research will be aimed at strategies to maintain and restore populations, habitat, and communities occurring in fire-adapted landscapes, while maintaining ecosystem function and conserving biodiversity.

- Ecosystem Function and Health Program
  *Restoration and adaptation.* Collaborative research will be aimed at understanding species evolution in response to changing environments, understanding the ecology and management of wildlife, fish, and tree species in the context of improving forest health, and understanding how watershed function contributes to native biological diversity.
  *Invasive species impacts on forest function.* Collaborative research will be aimed at understanding the effects on native and non-native invasive plant and animal species on forest function, and how restoration of forests through removal of invaders impacts overall biodiversity and resiliency.

- The Conservation of Biodiversity Program supports National and PSW Climate Change strategies by conducting research that increases understanding of the responses of plants and animals to projected effects of climatic change and its effects on habitat; improving the ability to evaluate the efficacy of adaptation and mitigation measures; and informing the design and implementation of plant and animal monitoring programs to increase their effectiveness.

**Links to Region 5 of the National Forest System**

Our program also aligns with identified Regional priorities:
- Ecological restoration: advance options for the conservation and management of species of concern (particularly threatened and endangered species) and biological diversity.
- Climate change adaptation and mitigation: advance options for the management of populations, species, communities, and habitats under changing climates (predict biotic responses and interactions including the impact of invasive species on native systems).
- Management indicators: advance tools for the selection and evaluation of the effectiveness of management indicators
- Forest Plan revision: serve on teams or as reviewers as appropriate to ensure the incorporation of the best science into the Forest Planning process.