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New Publications

July–September 2016

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The Rocky Mountain Research Station

We maintain 14 research locations throughout a 12-state territory encompassing the Great Basin, Southwest, Rocky Mountains, and parts of the Great Plains. The station employs more than 400 permanent full-time employees, including about 100 research scientists.

Scientists conduct research that spans an area containing 52% of the nation's National Forest System lands (54 national forests and grasslands). In the lower 48 states, our territory also includes 55% of the nation's Bureau of Land Management lands; 48% of the designated wildernesses; 37% of National Park Service lands; numerous other public and tribal lands; and 41% of the non-urban/rural private lands.

We administer and conduct ecological research on 14 experimental forests, ranges, and watersheds over the long term, even centuries, enabling us to learn how forests change as climate and other factors change over time.

We also oversee activities on several hundred research natural areas, a network of ecosystems set aside to conserve biological diversity. These areas represent a wide variety of habitats and ecosystems from alpine ecosystems to lowlands and from coniferous forests of the Northern Rockies to semiarid deserts of the Southwest and prairie ecosystems of the Great Plains.

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New RMRS Publication Series

Classification and description of world formation types

Contact David Tart, dtart@fs.fed.us, for a printed copy

Classification and description of world formation types. Faber-Langendoen, D.; Keeler-Wolf, T.; Meidinger, D.; Josse, C.; Weakley, A.; Tart, D.; Navarro, G.; Hoagland, B.; Ponomarenko, S.; Fults, G.; Helmer, E. 2016. Gen. Tech. Rep. RMRS-GTR-346. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 222 p.

An ecological vegetation classification approach has been developed in which a combination of vegetation attributes (physiognomy, structure, and floristics) and their response to ecological and biogeographic factors are used as the basis for classifying vegetation types. This document summarizes the development of the upper formation levels. We first describe the history of the Hierarchy Revisions Working Group and discuss the three main parameters that guide the classification - it focuses on vegetated parts of the globe, on existing vegetation, and includes (but distinguishes) both cultural and natural vegetation for which parallel hierarchies are provided. Part I of the report provides an introduction to the overall classification, focusing on the upper formation levels. Part II provides a description for each type, following a standardized template format.

http://www.fs.fed.us/rm/pubs/rmrs_gtr346.html.

Ecohydrologic impacts of rangeland fire on runoff and erosion: A literature synthesis

Limited number of paper copies are available through RMRS Distribution

Ecohydrologic impacts of rangeland fire on runoff and erosion: A literature synthesis. Pierson, Frederick B.; Williams, C. Jason. 2016. Gen. Tech. Rep. RMRS-GTR-351. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 110 p.

Fire can dramatically influence rangeland hydrology and erosion by altering ecohydrologic relationships. This synthesis presents an ecohydrologic perspective on the effects of fire on rangeland runoff and erosion through a review of scientific literature spanning many decades. The objectives are: (1) to introduce rangeland hydrology and erosion concepts necessary for understanding hydrologic impacts of fire; (2) to describe how climate, vegetation, and soils affect rangeland hydrology and erosion; and (3) to use examples from literature to illustrate how fire interacts with key ecohydrologic relationships. The synthesis is intended to provide a useful reference and conceptual framework for understanding and evaluating impacts of fire on rangeland runoff and erosion.

http://www.fs.fed.us/rm/pubs/rmrs_gtr351.html.

New RMRS Publication Series

Riparian fuel treatments in the western USA: Challenges and considerations

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Riparian fuel treatments in the western USA: Challenges and considerations. Dwire, Kathleen A.; Meyer, Kristen E.; Riegel, Gregg; Burton, Timothy. 2016. Gen. Tech. Rep. RMRS-GTR-352. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 156 p.

This report is a synthesis of current knowledge on the effects of wildfire and fuels treatments in riparian areas of the interior western United States, and includes the following: (1) a literature review of fire effects on riparian and aquatic characteristics and functions; (2) a review of the potential effects of prescribed fire and mechanical treatments on riparian and aquatic resources and biota; (3) results of an online survey of resource managers, summarizing information about proposed and completed fuel reduction projects in riparian areas and wetlands in the interior west; (4) suggestions for pre- and post project-level monitoring for riparian fuels projects; and (5) a presentation of case studies, describing riparian fuel treatments with different objectives and methods. The integration of riparian fuel treatments with other aspects of fire and watershed management could potentially improve riparian condition in multiple stream and vegetation types.

http://www.fs.fged.us/rm/pubs/rmrs_gtr352.html.

Mountain pine beetles: A century of knowledge, control attempts, and impacts central to the Black Hills

Contact Russ Graham, rtgraham@fs.fed.us, for printed copies.

Mountain pine beetles: A century of knowledge, control attempts, and impacts central to the Black Hills. Graham, Russell T.; Asherin, Lance A.; Battaglia, Michael A.; Jain, Theresa B.; Mata, Stephen A. 2016. Gen. Tech. Rep. RMRS-GTR-353. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 193 p.

This publication chronicles the understanding, controlling, and impacts of mountain pine beetles (MPB) central to the Black Hills of South Dakota and Wyoming from the time they were described by Hopkins in 1902, through the presentation of data from work started by Schmid and Mata in 1985. The differentiation of western bark beetle species is discussed and how the final species designations of MPBs and western pine beetles (WPB) came about. The life cycle of MPBs is described and how it was used to develop direct control strategies. This publication strives to synthesize a large portion of the information produced in the last 115 years on MPBs and provide this context for informing, planning, and executing forest treatments to produce MPB resilient forests. In addition, it tells an intriguing and fascinating story about bark beetles and the people who tried to understand and control them.

http://www.fs.fed.us/rm/pubs/rmrs_gtr353.html.

New RMRS Publication Series

Development and use of a commercial-scale biochar spreader

Online only

Development and use of a commercial-scale biochar spreader. Page-Dumroese, Deborah S.; Anderson, Nathaniel M.; Windell, Keith N.; Englund, Karl; Jump, Kevin. 2016. Tech. Rep. RMRS-GTR-354. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 10 p.

The Missoula Technology and Development Center of the U.S. Forest Service, working with Rocky Mountain Research Station scientists, developed and tested a high-capacity biochar spreader that can be mounted on a log forwarder and used on skid trails and log landings to distribute either pelleted or bulk biochar. This spreader can be modified to carry a variety of payloads and adjusted to apply biochar at many different spread rates. In our field trials, we detected no change in soil bulk density when using the spreader on sites with an intact forest floor, but found that compaction increased by 11 percent from forwarder ground pressure when using the spreader on a flat area with no forest floor. However, biochar applied to forest sites adds organic matter and helps to retain water, thereby potentially resulting in a decrease in soil bulk density over time. Field trials also demonstrated that biochar can be effectively and efficiently applied to forest sites at commercial scales by using existing and modified logging equipment.

http://www.fs.fed.us/rm/pubs/rmrs_gtr354.html.

A protocol for collecting environmental DNA samples from streams

Online only

A protocol for collecting environmental DNA samples from streams. Carim, Kellie J.; McKelvey, Kevin S.; Young, Michael K.; Wilcox, Taylor M.; Schwartz, Michael K. 2016. Gen. Tech. Rep. RMRS-GTR-355. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 18 p.

Environmental DNA (eDNA) is DNA that has been released by an organism into its environment, such that the DNA can be found in air, water, or soil. In aquatic systems, eDNA has been shown to provide a sampling approach that is more sensitive for detecting target organisms faster, and less expensively than previous approaches. However, eDNA needs to be sampled in a manner that has been tested and found effective and, because single copies of target DNA are detected reliably, rigorous procedures must be designed to avoid sample contamination. Here we provide the details of a sampling protocol designed for detecting fish. This protocol, or very similar prototypes, has been used to collect data reported in multiple peer-reviewed journal articles and from more than 5,000 additional samples at the time of publication. This process has been shown to be exceedingly sensitive and no case of field contamination has been detected. Over time, we have refined the process to make it more convenient.

http://www.fs.fed.us/rm/pubs/rmrs_gtr355.html.

New RMRS Publication Series

A 20-year reassessment of the health and status of whitebark pine forests in the Bob Marshall Wilderness Complex, Montana

Contact Molly Retzlaff, mollylretzlaff@fs.fed.us, for printed copies.

A 20-year reassessment of the health and status of whitebark pine forests in the Bob Marshall Wilderness Complex, Montana. Retzlaff, Molly L.; Leirfallom, Signe B.; Keane, Robert E. 2016. Res. Note RMRS-RN-73. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 10 p.

Whitebark pine plays a prominent role in high elevation ecosystems of the northern Rocky Mountains and is an important food source for many birds and mammals as well as an essential component of watershed stabilization. However, it is vanishing from the landscape. In the summers of 2013 and 2014, we assisted "citizen scientists" from the Bob Marshall Wilderness Foundation in remeasuring 25 plots to assess changes in the health and status of whitebark pine over the past 20 years. Results of this remeasurement effort show that mortality of mature whitebark pine trees in the Bob Marshall Wilderness Complex has more than doubled in the last two decades. Most tree deaths were from white pine blister rust (>60 percent), but a large increase in mountain pine beetle attacks was also noted. As blister rust kills more stands dominated by whitebark pine, the trees will be replaced with the more shade-tolerant subalpine fir and Engelmann spruce, further inhibiting regeneration of the shade-intolerant species.

http://www.fs.fed.us/rm/pubs/rmrs_rn073.html.

Bayesian techniques for surface fuel loading estimation

Limited number of paper copies are available through RMRS Distribution

Bayesian techniques for surface fuel loading estimation. Gray, Kathy; Keane, Robert; Karpisz, Ryan; Pedersen,m Alyssa; Brown, Rick; Russell, Taylor. 2016. Res. Note. RMRS-RN-74. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 9 p.

A study by Kean and Gray (2013) compared three sampling techniques for estimating surface fine woody fuels. Known amounts of fine woody fuel were distributed on a parking lot, and researchers estimated the loadings using different sampling techniques. An important result was that precise estimates of biomass required intensive sampling for both the planar intercept and fixed-area plot methods. This study explores Bayesian statistical methods as a means to reduce the sampling efort needed to obtain a desired precision. We found that Bayesian techniques dramatically increased the precisionn compared to using no prior information from the site.

http://www.fs.fed.us/rm/pubs/rmrs_rn074.html.

Forest Service Publications Still Available

A field guide for selecting the most appropriate treatment in sagebrush and piñon-juniper ecosystems in the Great Basin

Limited number of paper copies are available through RMRS Distribution

A field guide for selecting the most appropriate treatment in sagebrush and piñon-juniper ecosystems in the Great Basin: Evaluating resilience to disturbance and resistance to invasive annual grasses, and predicting vegetation response. Miller, Richard F.; Chambers, Jeanne C.; Pellant, Mike. 2014. Gen. Tech. Rep. RMRS-GTR-322-rev. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 68 p.

This field guide identifies seven primary components that largely determine resilience to disturbance, as well as resistance to invasive grasses and plant succession following treatment of areas of concern. The primary components are (1) characteristics of the ecological site, (2) current vegetation prior to treatment, (3) disturbance history, (4) type, timing, and severity of the treatment, (5) post-treatment weather, (6) post-treatment management, especially grazing, and (7) monitoring and adaptive management. A series of key questions and a set of tools are provided to assess these primary components.

http://www.fs.fed.us/rm/pubs/rmrs_gtr354.html.

Using resistance and resilience concepts to reduce impacts of invasive annual grasses and altered fire regimes on the sagebrush ecosystem and Greater Sage-Grouse

Limited number of paper copies are available through RMRS Distribution

Using resistance and resilience concepts to reduce impacts of invasive annual grasses and altered fire regimes on the sagebrush ecosystem and Greater Sage-Grouse: A strategic multi-scale approach. Chambers, Jeanne C.; Pyke, David A.; Maestas, Jeremy D.; Pellant, Mike; Boyd, Chad S.; Campbell, Steven B.; Espinosa, Shawn; Havlina, Douglas W.; Mayer, Kenneth E.; Wuenschel, Amarina. 2014. Gen. Tech. Rep. RMRS-GTR-326. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 73 p.

This Report provides a strategic approach for conservation of sagebrush ecosystems and Greater Sage-Grouse (sage-grouse) that focuses specifically on habitat threats caused by invasive annual grasses and altered fire regimes. It uses information on factors that influence (1) sagebrush ecosystem resilience to disturbance and resistance to invasive annual grasses and (2) distribution, relative abundance, and persistence of sage-grouse populations to develop management strategies at both landscape and site scales. A sage-grouse habitat matrix links relative resilience and resistance of sagebrush ecosystems with sage-grouse habitat requirements for landscape cover of sagebrush to help decision makers assess risks and determine appropriate management strategies at landscape scales.

http://www.fs.fed.us/rm/pubs/rmrs_gtr326.html

Journals and Other Publications

Air, water, and aquatic environments

Beyond the single species climate envelope: A multifaceted approach to mapping climate change vulnerability. Balzotti, Christopher S.; Kitchen, Stanley G.; McCarthy, Clinton. 2016. Ecosphere. 7(9): e01444. 10.1002/ecs2.1444. http://www.treesearch.fs.fed.us/pubs/52883.

A bridge over troubled water: A contextual analysis of social vulnerability to climate change in a riverine landscape in south-east Norway. Gundersen, Vegard; Kaltenborn, Bjørn Petter; Williams, Daniel R. 2016. Norwegian Journal of Geography. doi: 10.1080/00291951.2016.1194317. http://www.treesearch.fs.fed.us/pubs/52968.

Changing times, changing stories: Generational differences in climate change perspectives from four remote indigenous communities in Subarctic Alaska. Herman-Mercer, N.M.; Matkin, E.; . . . Elder, K.; [et al.]. 2016. Ecology and Society. 21(3): 28. http://dx.doi.org/10.5751/ES-08463-210328. http://www.treesearch.fs.fed.us/pubs/52884.

Climate change velocity underestimates climate change exposure in mountainous regions. Dobrowski, Solomon Z.; Parks, Sean A. 2016. Nature Communications. 7: 12349. http://www.treesearch.fs.fed.us/pubs/52246.

Development of high-resolution (250 m) historical daily gridded air temperature data using reanalysis and distributed sensor networks for the US northern Rocky Mountains. Holden, Zachary A.; Swanson, Alan; Klene, Anna E.; [et al.]. 2016. International Journal of Climatology. doi: 10.1002/joc.4580. http://www.treesearch.fs.fed.us/pubs/50800.

Effects of habitat quality and ambient hyporheic flows on salmon spawning site selection. Benjankar, Rohan; Tonina, Daniele; Marzadri, Alessandra; [et al.]. 2016. Journal of Geophysical Research Biogeosciences. 121: 1222–1235. doi. 10.1002/2015JG003079. http://www.treesearch.fs.fed.us/pubs/52521.

An environmental DNA marker for detecting Arctic grayling in the upper Missouri River basin, North America. Carim, J.K.; Dysthe, J.C.S.; Young, M.K.; [et al.]. 2016. Conservation Genetics Resources. 8: 197–199. doi: 10.1007/s12686-016-0531-1. http://www.treesearch.fs.fed.us/pubs/52517.

Environmental DNA marker development with sparse biological information: A case study on opossum shrimp (*Mysis diluviana*). Carim, K. J.; Christianson, K. R.; McKelvey, Kevin; [et al.]. 2016. PLoS ONE. 11: e0161664. http://www.treesearch.fs.fed.us/pubs/52518.

Habitat connectivity as a metric for aquatic microhabitat quality: Application to Chinook salmon spawning habitat. Carnie, Ryan; Tonina, Daniele; McKean, James A.; Isaak, Daniel. 2016. Ecohydrology. 9: 982–994. http://www.treesearch.fs.fed.us/pubs/50139.

Numerical modeling of coupled water flow and heat transport in soil and snow. Kelleners, Thijs J.; Koonce, Jeremy; Shillito, Rose; [et al.]. 2016. Soil Science Society of America. 80: 247–263. http://www.treesearch.fs.fed.us/pubs/52331

Quantitative PCR assays for detecting loach minnow (*Rhinichthys cobitis*) and spikedace (*Meda fulgida*) in the southwestern United States. Dysthe, Joseph C.; Carim, Kellie J.; Paroz, Yvette M.; [et al.]. 2016. PLoS One. 11: e0162200. http://www.treesearch.fs.fed.us/52519.

Riparian trees and aridland streams of the southwestern United States: An assessment of the past, present, and future. Smith, D. Max; Finch, Deborah M. 2016. Journal of Arid Environments. 135: 120–131. http://www.treesearch.fs.fed.us/pubs/52769.

Fire, fuel, and smoke

Burning rates of wood cribs with implications for wildland fires. McAllister, Sara; Finney, Mark. 2016. Fire Technology. doi: 10.1007/s10694-015-0543-5. http://www.treesearch.fs.fed.us/pubs/52989.

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The effect of wind on burning rate of wood cribs. McAllister, Sara; Finney, Mark. 2016. Fire Technology. 52: 1035–1050. http://www.treesearch.fs.fed.us/pubs/52987.

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Forest fuels and potential fire behaviour 12 years after variable-retention harvest in lodgepole pine. Crotteau, Justin S.; Keyes, Christopher R.; Sutherland, Elaine K.; [et al.]. 2016. International Journal of Wildland Fire. 25: 633–645. http://www.treesearch.fs.fed.us/pubs/52086.

Forest biomass diversion in the Sierra Nevada: Energy, economics and emissions. Springsteen, Bruce; Christofk, Thomas; York, Robert A.; [et al.]. 2015. California Agriculture. 69(3): 142–149. http://www.treesearch.fs.fed.us/pubs/52990.

Getting ahead of the wildfire problem: Quantifying and mapping management challenges and opportunities. O'Connor, Christopher D.; Thompson, Matthew P.; Rodriguez y Silva, Francisco. 2016. Geosciences. 6(3): 35. http://www.treesearch.fs.fed.us/pubs/52280.

Potential postwildfire debris-flow hazards—A prewildfire evaluation for the Jemez Mountains, north-central New Mexico. Tillery, Anne C.; Haas, Jessica R. 2016. Scientific-Investigations Report 2016-5101. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey. 27 p. http://www.treesearch.fs.fed.us/pubs/52316.

Spatiotemporal variability of wildland fuels in US northern Rocky Mountain forests. Keane, Robert E. 2016. Forests. 7(129). 16 p. doi.10.3390/f7070129. http://www.treesearch.fs.fed.us/pubs/52516.

Wildfires in northern Eurasia affect the budget of black carbon in the Arctic—A 12-year retrospective synopsis (2002–2013). Evangeliou, N.; Balkanski, Y.; Hao, W.M.; [et al.]. 2016. Atmospheric Chemistry and Physics. 16: 7587–7604 plus 7-page supplement. http://www.treesearch.fs.fed.us/pubs/52514.

Forest and woodland ecosystems

Assessing the potential for maladaptation during active management of limber pine populations: A common garden study detects genetic differentiation in response to soil moisture in the Southern Rocky Mountains. Borgman, Erin M.; Schoettle, Anna W.; Angert, Amy L. 2015. Canadian Journal of Forest Research. 45: 496–505. http://www.treesearch.fs.fed.us/pubs/52551.

Defense traits in the long-lived Great Basin bristlecone pine and resistance to the native herbivore mountain pine beetle. Bentz, Barbara J.; Hood, Sharon A.; Hansen, Matt; Vandygriff, Jim; Mock, Karen E. 2016. New Phytologist. doi: 10.1111/nph.14191. http://www.treesearch.fs.fed.us/pubs/52768.

Effects of air pollution and climatic factors on Norway spruce forests in the Orlické hory Mts. (Czech Republic), 1979–2014. Vacek, Stanislav; Hunova, Iva; Vacek, Zdenek; [et al.]. 2015. European Journal of Forest Research. 134: 1127–1142. http://www.treesearch.fs.fed.us/pubs/52333.

The effects of seed source health on whitebark pine (*Pinus albicaulis*) regeneration density after wildfire. Leirfallom, Signe B.; Keane, Robert E.; Tomback, Diana F.; Dobrowski, Solomon Z. 2015. Canadian Journal of Forest Research. 45: 1597–1606. http://www.treesearch.fs.fed.us/pubs/52985.

Forest insect and fungal pathogen responses to drought [Chapter 6]. Kolb, Thomas E.; Fettig, Christopher J.; Bentz, Barbara J.; [et al.]. 2016. In: Vose, James M.; Clark, James S.; Luce, Charles H.; Patel-Weynard, Toral, eds. Effects of drought on forests and rangelands in the United States: A comprehensive science synthesis. Gen. Tech. Rep. WO-93b.

Journals and Other Publications

Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office: 113–133. http://www.treesearch.fs.fed.us/pubs/52328

Gambel oak ecology and management in the southern Rockies: The state of our knowledge. Kaufmann, M.R.; Huisjen, D.W.; Kitchen, S.; [et al.]. 2016. SRFSN Publ. 2016-1. Fort Collins, CO: Southen Rockies Fire Science Network.

Genetic mapping of *Pinus flexilis* major gene (Cr4) for resistance to white pine blister rust using transcriptome-based SNP genotyping. Liu, Jun-Jun; Schoettle, Anna W.; Sniezko, Richard A.; et al. 2016. BMC Genomics. 17: 753. 12 p. doi: 10.1186/s12864-016-3079-2. http://www.treesearch.fs.fed.us/pubs/52886.

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Have we been successful? Monitoring horizontal forest complexity for forest restoration projects. Dickinson, Yvette L.; Pelz, Kristen A.; Giles, Emma; Howie, Josh. 2016. Restoration Ecology. 24(1): 8–17. http://www.treesearch.fs.fed.us/pubs/52354.

Lethal trap trees and semiochemical repellents as area host protection strategies for spruce beetle (Coleoptera: Curculionidae, Scolytinae) in Utah. Hansen, E. Matthew; Munson, A. Steven; Blackford, Darren C.; Wakarchuk, David; Baggett, L. Scott. 2016. Journal of Economic Entomology. doi: 10.1093/jee/tow172. http://www.treesearch.fs.fed.us/pubs/52314.

Limber pine conservation strategy: Recommendations for Rocky Mountain National Park. Cleaver, Christy M.; Schoettle, Anna W.; Burns, Kelly S.; Connor, J. Jeff. 2015. In: Ramsey, A.; Palacios, P., comps. Proceedings of the 63rd annual western international forest disease work conference; 2015 September 21–25; Newport, OR. Olympia, WA: Washington Department of Natural Resources; Logan, UT: Utah State University: 81–82. http://www.treesearch.fs.fed.us/pubs/52448.

Macroanatomy and compartmentalization of recent fire scars in three North American conifers. Smith, Kevin T.; Arbellay, Estelle; Falk, Donald A.; Sutherland, Elaine Kennedy. 2016. Canadian Journal of Forest Research. 46: 535–542. http://www.treesearch.fs.fed.us/pubs/50477.

Mountain pine beetle host selection between lodgepole and ponderosa pines in the southern Rocky Moutains. West, Daniel R.; Briggs, Jennifer S.; Jacobi, William R.; Negrón, José F. 2016. Environmental Entomology. 45(1): 127–141. http://www.treesearch.fs.fed.us/pubs/52969.

National report on sustainable forests—2015: Conservation of biological diversity. Nelson, Mark D.; Flather, Curtis; Riitters, Kurt H.; Sieg, Carolyn; Garner, James D. 2015. In: Stanton, Sharon M.; Christensen, Glenn A., comps. 2015. Pushing boundaries: New directions in inventory techniques and applications: Forest Inventory and Analysis (FIA) symposium; 2015 December 8–10; Portland, OR. Gen. Tech. Rep. PNW-GTR-931. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. p. 375.

Patterns of conifer regeneration following high severity wildfire in ponderosa pine-dominated forests of the Colorado Front Range. Chambers, Marin E.; Fornwalt, Paula J.; Malone, Sparkle L.; Battaglia, Mike A. 2016. Forest Ecology and Management. 378: 57–67. http://www.treesearch.fs.fed.us/pubs/52277.

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Prioritization of forest restoration projects: Tradeoffs between wildfire protection, ecological restoration and economic objectives. Vogler, Kevin C.; Ager, Alan A.; Day, Michelle A.; [et al.]. 2015. Forests. 6: 4403–4420. http://www.treesearch.fs.fed.us/pubs/52992.

Psst . . .pass the algae: Succession in lichen soil crusts. Root, Heather T.; Dodson, Erich Kyle. 2016. Frontiers in Ecology and the Environment. 14(8): 451–452.

Restoration planting options for limber pine (*Pinus flexilis* James) in the Southern Rocky Mountains. Casper, A.M.A.; Jacobi, W.R.; Schoettle, A.W.; Burns, K.S. 2016. Journal of the Torrey Botanical Society. 143(1): 21–37. http://www.treesearch.fs.fed.us/pubs/52449.

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Volatile and within-needle terpene changes to Douglas-fir trees associated with Douglas-fir beetle (Coleoptera: Curculionidae) attack. Giunta, A.D.; Runyon, J.B.; Jenkins, M.J.; Teich, M. 2016. Environmental Entomology. 45(4): 920–929. http://www.treesearch.fs.fed.us/pubs/52776.

Grasslands, shrublands, and desert ecosystems

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Science Program Areas

Air, Water, and Aquatic Environments

Air quality, water availability, water quality, and aquatic habitats are critical issues within the rapidly changing Western United States. The Air, Water and Aquatic Environments program is committed to the development of knowledge and science applications related to air and water quality, as well as the habitat quality, distribution, diversity, and persistence of fish and other aquatic species. Website: http://www.fs.fed.us/rm/boise/awae_home.shtml. Contact Frank McCormick, Program Manager, for more information: 208-373-4351.

Aldo Leopold Wilderness Research Institute

The Aldo Leopold Wilderness Research Institute aims to provide scientific leadership by bringing diverse groups of scientists and managers together to develop and use the knowledge needed to assure wilderness ecosystems and values endure for generations to come. Website: http://leopold.wilderness.net. Contact Susan Fox, Program Director, for more information: 406-542-4193.

Fire, Fuel, and Smoke

The Fire, Fuel and Smoke program works to improve the safety and effectiveness of fire management through the creation and dissemination of basic fire science knowledge. The program investigates the impacts of fires on the environment by means of fundamental and applied research for understanding and predicting fire behavior, its effects on ecosystems, and its emissions into the atmosphere. Website: http://www.firelab.org. Contact Bret Butler, Acting Program Manager, for more information: 406-329-4801.

Forest and Woodland Ecosystems

Forests and woodlands are increasingly being impacted by large scale urbanization and human developments, uncharacteristically large and severe wildfires, insect and disease outbreaks, exotic species invasions, and drought, and interactions of multiple stressors at local, landscape, and regional scales. The Forest and Woodland Ecosystems program acquires, develops, and delivers the scientific knowledge for sustaining and restoring forests and woodlands landscape health, biodiversity, productivity, and ecosystem processes. Website: http://www.fs.fed.us/rmrs/research/programs/forest-woodlands-ecosystem/. Contact Alison Hill, Program Manager, for more information: 928-556-2105.

Grassland, Shrubland, and Desert Ecosystems

Disruptions by large-scale clearing for agriculture, water diversions, extensive grazing, changes in the native fauna, the advent of alien weeds, altered fire regimes, and increases in human-caused insect and disease epidemics have contributed to produce areas that are in unsuitable condition. The Grassland, Shrubland and Desert Ecosystems program addresses the biology, use, management, and restoration of these grass and shrublands. Website: http://www.fs.fed.us/rmrs/research/programs/grassland-shrubland-desert/. Contact Debbie Finch, Program Manager, for more information: 505-724-3671.

Human Dimensions

The Human Dimensions program provides social and economic science based innovation to human societies as they develop a sustainable relationship with their environment. Major issues confronting societies across the globe such as global climate change, energy, fire, water, and ecosystem services all have important social-economic dimensions that will be explored and addressed by this program. Website: http://www.fs.fed.us/rmrs/research/programs/social-economics-decision/. Contact David Chapman, Program Manager, for more information: 970-498-1378.

Inventory, Monitoring, and Analysis

The Inventory, Monitoring and Analysis program provides the resource data, analysis, and tools needed to effectively identify current status and trends, management options and impacts, and threats and impacts of fire, insects, disease, and other natural processes. Website: http://www.fs.fed.us/rm/ogden/. Contact Michael Wilson, Program Manager, for more information: 801-625-5407.

Science Application and Integration

The Science Application and Integration program is a knowledge transfer unit that provides leadership for the integration and use of scientific information in natural resource planning and management across the Interior West. Website: http://www.fs.fed.us/rm/science-application-integration/. Contact Jan Engert, Assistant Station Director, for more information: 970-498-1377.

Wildlife and Terrestrial Ecosystems

The Wildlife and Terrestrial Ecosystems program is engaged in sustaining species and ecosystems of concern through studies of ecological interactions within and between plant, aquatic, and terrestrial animal communities; understanding public use effects through studies elucidating social and economic values associated with consumptive and non-consumptive uses of fish and wildlife; managing terrestrial and aquatic habitats; and evaluating outcomes of land and water uses and natural disturbances. Website: http://www.rmrs.nau.edu/wildlife/. Contact William Block, Program Manager, for more information: 928-556-2161.

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