FINAL REPORT, JFSP Project 05-2-1-101

Project Title: Predicting Burn Severity in the Gila Wilderness, New Mexico: Meeting Local Need for Potential Impact of Fire on Fish and Streams

JFSP Project No.: 05-2-1-101

Project Locations: We collected data on the Gila National Forest in New Mexico. The data analysis and interpretation and writing activities were conducted at the University of Idaho campus in Moscow, ID and at the Rocky Mountain Research Station in Boise, ID.

Principal Investigators: Penelope Morgan, Matt Rollins and Zack Holden were the principal investigators. Charlie Luce and Matt Dare were instrumental to the success of this project, as was Jerry Monzingo of the Gila National Forest.

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SUMMARY OF PROJECT OBJECTIVES

In this research, we investigated the broad-scale factors associated with burn severity in the Gila Wilderness, NM. This is an important local need identified by the Gila National Forest and the Nature Conservancy. Changes in vegetation structure and fuel loading have increased the risks associated with burning. A key question in fire science remains where and under what conditions fires are likely to burn severely**.** Concerns about the potential impacts of recent, large (49,000 ha) Wildland Fire Use fires in the Gila Wilderness on critical threatened and endangered Gila trout and Gila chub populations, which are now restricted to small, geographically isolated streams in the wilderness, have raised questions about the long-term future of one of the most active and long-term Wildland Fire Use programs in the US. Successful management of Wildland Fire Use programs while protecting critical resources in the Gila Wilderness and elsewhere requires a better understanding of the landscape and vegetation characteristics that are associated with burn severity.

We had two research tasks:

- **Task 1:** Using pre and post-fire high-resolution satellite imagery and ground measures of burn severity, we will address the following questions: 1) how do factors like pre-fire vegetation structure, landscape and topographic position influence the occurrence of high burn severity? 2) How well can comparison of pre- and post-fire high-resolution images map burn severity, compared to dNBR and ground measures of severity? 3) How do post-fire effects such as vegetation damage and tree mortality vary with prior treatments?
- **Task 2:** Using Landsat satellite imagery, we built an historical burn severity atlas with which we will assess relationships between landscape factors (slope, aspect, elevation, vegetation type, prior fire history) and burn severity. Using Landsat imagery, we analyzed burn severity data and produce risk assessment maps for the areas of the Gila NF encompassing fish populations and streams of concern

This three-year project was completed on-time and within budget. We met or exceeded the proposed objectives and list of deliverables. The Joint Fire Science Program granted a one-year no-cost extension to 31 May 2008 for Project 05-2-1-101.

SUMMARY OF OUR FINDINGS

Twenty-Year (1984-2004) Severe Fire Occurrence Across Vegetation and Topographic Gradients in a Large Southwestern US Wilderness Area

- Using a burn severity atlas derived from multi-temporal Landsat TM satellite imagery and differenced Relative Normalized Burn Ratio (RdNBR) images, we describe patterns of severe fire occurrence for 20 years (1984-2004) with respect to Potential Vegetation Type (PVT) and topography (elevation, aspect, slope, solar radiation, heat load index and wetness).
- In 20 years, 11% (152,874 ha) of the 1.4 million-ha Gila National Forest burned, and 10% of that burned severely (>75% of tree canopy removed), mainly in upper elevation mixed-conifer and spruce-fir forest PVTs. When all PVTs were analyzed together, severe fire occurred more frequently at higher elevations and on north-facing, steep slopes.
- Regression Tree Analyses within drier pinyon-juniper, ponderosa pine and Douglas-fir PVTs show that severe fire occurrence was associated with north-facing slopes, higher wetness index and lower heat load index values.
- Using the Random Forest algorithm with 14 topographic predictor variables, we predict the occurrence of severely burned pixels with a classification error rate of 17.3% and 38.3% for RdNBR grids classified as severe vs. not severe (two classes) or as low, moderate and high severity (three classes), respectively.
- Our results support the idea of hierarchical top down (climate-driven) and bottom up (topographic) controls on severe fire occurrence. The strong predictability of burn severity based on topographic variables demonstrates the strength of vegetation-climate coupling in this semi-arid wilderness area.
- Our analysis approach shows strong potential as a tool for identifying potential fuels treatment areas.

Beyond Landsat: Multi-scale Assessment of Four Satellite Sensors for Detecting Burn Severity in Ponderosa Pine Forests of the Gila Wilderness, NM, USA.

- Methods of remotely measuring burn severity are needed to evaluate the ecological and environmental impacts of large, remote wildland fires. The uncertain future of the Landsat program highlights the need to evaluate alternative sensors for characterizing post-fire effects.
- We compared pre- and post-burn imagery from four satellite sensors with varying spatial-resolutions, Quickbird Multi-spectral, the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Landsat Thematic Mapper (TM), and the Moderate Resolution Imaging Spectroradiometer (MODIS), using a subset of the 2003 Dry Lakes Fire in the Gila Wilderness, NM. Where spectrally feasible, burn severity was evaluated using the differenced Enhanced Vegetation Index (dEVI), differenced Normalized Difference Vegetation Index (dNDVI) and the differenced Normalized Burn Ratio (dNBR).
- We use 55 Composite Burn Index (CBI) plots to assess burn severity on the ground.
- Both the EVI derived from Quickbird and the ASTER-derived dNBR showed similar or slightly improved correlations over the dNBR derived from Landsat TM data (r^2 = 0.82, 0.84, and 0.78, respectively). The relatively coarse resolution MODIS-derived NDVI image was weakly correlated with ground data (r^2 = 0.38).
- Our results suggest that moderately high-resolution satellite sensors like Quickbird and ASTER have potential for providing accurate information about burn severity.
- Future research should further develop stronger links between higher resolution satellite data and burn severity across a range of environments.

Risk assessment maps for burn severity and fish for the areas of the Gila NF encompassing fish populations and streams of concern

- Fire management on the Gila National Forest (GNF) is an example of progressive integration of naturally occurring wildland fire in order to maintain forest health and minimize the chance of large-scale, catastrophic fire. Gila trout (*Oncorhynchus gilae*) management on the GNF reflects the precarious situation in which many populations exist due to habitat loss, isolation, and competition and genetic introgression with non-native species. Whereas historical fires and post-fire disturbances are believed to have had positive effects on large, inter-connected populations; the effects of fire are characterized currently as threats to extant patches of Gila trout habitat and resident populations. Translocation is the primary management tool for imperiled populations: fish residing in streams likely to be affected by wildland fire are moved to adjacent streams or hatcheries. This approach assumes every fire will realize a "worst-case scenario" where fire and post-fire effects, such as debris flows and ash flows, will result in complete mortality of the affected population.
- Our goal was to provide resource managers with information on the potential for fire and post-fire threats to affect Gila trout populations in 21 occupied and recovery patches within the Gila National Forest.

- This exercise involved GIS-based mapping of potential debris flow initiation sites and travel paths and the use of a Bayesian model of patch persistence to evaluate the long-term suitability of individual patches for translocation and restoration.
- The ability of a resident fish population to survive disturbance is dependent upon patch size, connectivity to external habitats, and life-history diversity.
- Model results suggest the greatest benefit to Gila trout will be derived from expanding the size of existing patches in the WF Gila River and Mogollon Creek drainages. Recovery work in these areas will result in larger patches and inter-patch connectivity. Conversely, there are several patches where debris-flow potential and isolation contribute to very low persistence probabilities, for example McKnight and Sheep Corral Creeks.
- Assuming the result of wildland fire use would involve fire sizes and severities akin to historical probability distributions, then wildland fire use could have positive effects on the long-term persistence of Gila trout in the Big Dry Creek Recovery Area, Iron Creek, McKnight Creek, and South Diamond Creek
- These results define a need for monitoring and evaluation of Gila trout population response to wildland fire use in the four watersheds where proactive fire management could positively influence Gila trout persistence.

Springtime Precipitation Variability Influences Fire Extent and Severity in a Large Southwestern Wilderness Area, USA

- A twenty-year series of Landsat TM satellite imagery for all forest fires on the 1.4 million ha Gila National Forest suggests that increasing trend in area burned and area burned severely from 1984-2004 are well correlated with spring dryness (total and consecutive number of days without rain from April 1st-July 15th; $r^2 = 0.63$, $p < 0.01$).
- Winter precipitation was marginally correlated with burn severity in but only in high-elevation forest types.
- These results suggest the importance of within-season precipitation rather than snow pack in modulating recent wildfire size and severity in lower to mid-elevation southwestern forests.

DELIVERABLES

This three-year project was completed on-time and within budget. We met or exceeded the proposed objectives and list of deliverables. The Joint Fire Science Program granted a one-year no-cost extension to 31 May 2008 for Project 05-2-1-101.

We have included copies of most of these on the enclosed CD.

Proposed	Delivered	Status	File Name on CD
Submit 3 manuscripts to refereed journals We completed 5 and will complete a 6th manuscript synthesizing our work in 2009.	1. Holden, Z.A., P. Morgan, M. Crimmins, R. Steinhorst and A. Smith (2007). Fire season precipitation variability influences fire extent and severity in a large southwestern wilderness area, USA. Geophysical Research letters (34): 1-5.	1. Published	1. Holdenetal_GRL_2007.pdf
	2. Lentile, L.B., Holden, Z.A., Smith, A.M.S., Falkowski, M.J., Hudak, A.T., Morgan, P., Gessler, P.E. and Benson, N.C. (2006) Remote sensing techniques to assess active fire and post-fire effects, International Journal of Wildland Fire 15:319-345	2. Published Featured Paper in Issue 3 (2006) of the International Journal of Wildland Fire, and one of the most often downloaded	2. Lentile_2006-RSreview.pdf
	3. Holden, Z.A., Smith, A., Morgan, P. and Vierling, L. (accepted). Beyond Landsat: A multi-sensor assessment of burn severity on the Gila Wilderness, NM. Submitted to International Journal of Wildland Fire.	3. Accepted	3. Holden_etal_multisensor_severity.pdf
	4. Holden, Z.A. and Penelope Morgan (in review). Patterns of Fire Season Precipitation Variability and Green Up inferred from 1 km AVHRR data Across a Vegetation Gradient in the Gila Wilderness, NM. Submitted to Remote Sensing of Environment.	4. Submitted to Rem. Sens. Envt.	4. Holden_etal_AVHRR_precip_abstract.pdf

	5. Holden, Z. A., P. Morgan and J. S. Evans. Twenty-Year (1984-2004) Severe Fire Occurrence Across Vegetation and Topographic Gradients in a Large Southwestern US Wilderness Area	5. Submitted to Ecol. Applications	5. Holden_etal_topo.severity_abstract.pdf
Collaborate with Gila National Forest staff to develop a burn severity risk assessment map identifying areas of highest potential for severe fires and vulnerability of streams and fish	Map is complete and was delivered in May 2008. Matt Dare will travel to the Gila National Forest to lead a workshop with local personnel to help them as they learn to use the map and tool	Completed in May 2008, workshop to follow	GilaFigure01Dare.ppt (This map figure is described in the overview document, see below)
The Gila National Forest staff will receive an ARCinfo database containing a digital burn severity and fire perimeter atlas for the last 25 years of wildland fires in the GALWC	Completed and delivered in 2008	Completed in 2008	-----
The Gila National Forest staff will receive the decision support system tool for assessment of areas of potential fire impacts to fish populations. This GIS-based model will be specifically calibrated for fish populations in the Gila Wilderness.	Decision support tool is complete and was delivered in May 2008. Matt Dare will travel to the Gila National Forest to lead a workshop with local personnel to help them as they learn to use the map and tool	Completed in May 2008, workshop to follow	GilaFinalMapOverview.doc (This is the document describing the map and tool)

We will present our research progress and results at two national professional conferences	1. Holden, Z.A., P. Morgan and M. Rollins, 2008. Climate and Landscape Drivers of 20-Year Burn Severity Patterns on the Gila NF. Int. Ass. Wild. Fire Southwest Regional Conference. Nov. 11-14, 2008. Tucson, AZ. 2. Morgan, P., E.K. Heyerdahl, and Z. Holden. 2007. Climate drivers of fire extent and severity. Invited. American Geophysical Union. 10 December 2007. San Francisco, CA	Completed	1. Holden_etal_Fire SW2008abstract.pdf 2. AGUAbstract.pdf
We will also submit a short article on the management implications of this research to Fire Management Today. This will emphasize the value and ecological effects of the Wildland Fire Use Program in the Gila Wilderness Area	Not completed. Instead we worked with a JFSP editor on a forthcoming research highlights article. The results of our work will also be included in a forthcoming synthesis project provided directly to fire management decisions makers.	Not completed. Instead we worked with a JFSP editor on a forthcoming research highlights article	----
The field CBI data we collect will be provided to Carl Key, Nate Benson and others to further refine Landsat-derived burn severity indices (NBR and dNBR)	Data were provided to the Monitoring Trends in Burn Severity Project. MTBS is a national effort to map the perimeter and severity of all large fires across the conterminous US. We have worked closely with the MTBS project to ensure that our methods are consistent, and we have provided them with all our CBI data.	Completed in 2006	-----
Mr. Holden will complete his PhD dissertation based in part on this research. (November)	Holden, Z. A. 2008. Twenty year (1984-2004) temporal and spatial burn severity patterns inferred from satellite imagery in the Gila National Forest, New Mexico. Dissertation. University of Idaho, Moscow, ID.	Completed in January 2008	Holden.Dissertation.Final.pdf

	Holden ZA and Morgan P. 2006. Twenty-five year temporal and spatial burn severity patterns in the Gila Wilderness, New Mexico. Symposium, Fire Research. Gila National Forest, Silver City, NM.	Managers on the Gila NF invited this presentation. It was given to local managers and others interested in fire research there in Silver City, NM.	----
	On accompanying CD: 1) final report for JFSP; work plan, 2 and 3) two progress reports to JFSP, 4 and 5) progress and final report for RJVA between USDA Forest Service and University of Idaho, 6) included for original proposal to JFSP, 7) extension request	Completed	1) Morgan_JFSP05-2-1-101_Final Report.doc 2) JFSP Project Accomplishment_05-2-1-101.xls 3) 05-2-1-101_2006 Progress Report.doc 4) Progress_report RJVA_Feb2008.doc 5) Final_report RJVA_May2008.doc 6) Morgan-JFS-2004 localneeds-Final.doc 7) Request_for_ extension_JFSP05-2-1-101 Final.doc