ECOLOGICAL INVENTORY AND ASSESSMENT OF SPRINGS IN THE RIM FIRE PERIMETER, STANISLAUS NATIONAL FOREST, CALIFORNIA: FINAL REPORT

Prepared for:
Stanislaus National Forest, Ms. Tracy Weddle
The Sierra Nevada Conservancy, Mr. Chris Dallas
The Tuolumne River Trust, Mr. Patrick Koepele
The Yosemite Stanislaus Solutions Collaborative

Prepared by:
Lawrence E. Stevens, Jeri D. Ledbetter, and Monica Swihart
Springs Stewardship Institute
Museum of Northern Arizona
3101 N. Fort Valley Road
Flagstaff, AZ 86001
(928) 774-5211 ext 231 office
larry@springstewardship.org
www.springstewardship.org

31 December 2014

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ACKNOWLEDGEMENTS

This project would not have been possible without the administrative and logistical support of the staff of the Stanislaus National Forest. We particularly thank Tracy Weddle, Margaret Willits, David Weixleman, Fernando Perez, and Curtis Kuamme for their interest and assistance with the field work. The Tuolumne River Trust, the Sierra Nevada Conservancy, and the Yosemite Stanislaus Solutions Collaborative provided much-appreciated administrative and financial support for this project, and we particularly thank Patrick Koepele and Chris Dallas for their interest and support of springs inventory and assessment on the Forest. The Museum of Northern Arizona provided administrative and logistical support, and we thank Robert Breunig and his staff for their assistance with this effort. Abraham Springer assisted with geohydrological field work, and Kirsten Olman and Jennifer Chavez (MNA) provided botanical and invertebrate preparation expertise, respectively. Monica Swihart assisted with data entry and logistics planning. We thank these individuals for their assistance with the project.

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INTRODUCTION

Springs are among the most biologically diverse, ecologically interactive, and culturally important terrestrial ecosystems, in both arid and mesic landscapes, and exist in an array of types and settings (Springer and Stevens 2008, Weixelman et al. 2011). Although often small in area, springs serve as hotspots of aquatic, wetland and riparian diversity, and function as keystone (highly interactive) ecosystems that play disproportionally important roles in relation to adjacent uplands (Thomas et al. 1979, Fleishman et al. 2005, Perla and Stevens 2008). In addition, springs are intensively used by humans throughout the world for water and other resources, and consequently springs are often ecologically impaired (Hendrickson and Minckley 1984, Shepard 1993, Sada and Vinyard 2002). Appropriate stewardship of springs is hampered by a lack of knowledge of their distribution, ecology, extent of impairment, and the generally limited scientific attention that has been paid to these remarkable ecosystems (Stevens and Meretsky 2008). Among the many shortcomings of the present state of knowledge about springs has been the role of fire on springs ecosystem function. Springs may serve as regeneration hotspots following fire or other disturbances, points from which population and landscape recovery radiates across landscapes following major disturbances.

For the above reasons and in response to an inquiry by Stanislaus National Forest, the Sierra Nevada Conservancy, the Tuolumne River Trust, and the Yosemite Stanislaus Solutions Collaborative, the Museum of Northern Arizona's Springs Stewardship Institute (SSI) undertook an ecological inventory of the springs within the Rim Fire perimeter on Stanislaus National Forest to improve understanding of springs distribution, typology, and status. This field work was coordinated by Stanislaus National Forest and was conducted in August and September 2014. SSI staff used the U.S. Forest Service Level I Springs Inventory Protocols (U.S. Forest Service 2012) to inventory Forest springs ecosystem distribution and to determine the ecological condition of those springs. This report summarizes our findings and we present detailed reports on each springs ecosystem visited (Appendices A and B), as well as lists of species encountered (Appendix C), the project geodatabase (Appendix D), the USFS GDE database (Appendix E), a web mapping service (Appendix F), and all images (Appendix G).

METHODS

Study Area and Rim Fire Background

Stanislaus National Forest occupies 898,099 ac (3,632 km^2) on the west slope of the Sierra Nevada to the west of Yosemite National Park. The Sierra Nevada range is a granite batholith that has undergone both volcanic and glacial action in the recent geologic past, producing a complex terrain. Ranging in elevation from 1,500 to more than 11,000 ft (460-3,350 m), the Forest supports habitats that vary from oak savannahs to near-treeline mixed conifer forests. Lying two hours from the Great Central Valley and three hours from the San Francisco Bay Area, the Forest is an

important recreation area and destination for visitors. In addition, the Forest protects the water sources and pipeline systems of the greater San Francisco metropolitan area, with several large reservoirs, such as Cherry Lake Reservoir. Yosemite National Park immediately east of the Forest contains Hetch Hetchy Reservoir, another major water source for San Francisco. The Forest occupies portions of Tuolumne and Mariposa counties, and is organized into four Ranger Districts along three highway corridors: the Groveland District is accessed on Route 120 on the south side of the Forest; the Mi-Wok and Summit Districts are accessed from Route 108 along the middle fork of the Stanislaus River; and the Calaveras District is accessed through Route 4 on the north side of the Forest. Several large in-holdings of private land exist on the Forest, with logging as a primary private use.

The Rim Fire occurred from 17 August to 24 October 2013, consuming 257,314 ac (1,041 km^2) of forest and oak woodland habitat on the Mi-Wok and Groveland Ranger Districts, and extended into Yosemite National Park to near Hetch Hetchy Reservoir (U.S. Forest Service 2014). It was the third largest wildfire in California's history and the largest wildfire in the Sierra Nevada Range. Eleven residences, three commercial buildings, and 98 outbuildings were destroyed. Although the fire burned to the edge of the town of Groveland and 10 injuries were reported, the US Forest Service prevented far more serious loss of property and no fatalities occurred. The fire cost more than $127 million to fight, and considerable expense was incurred by the local communities through loss of recreation revenues. Much funding and management attention has been devoted to restoration of the burned landscape.

Data Sources and Logistics Planning

Prior to undertaking field work, we mapped the distribution of all known springs on the Forest (Fig. 1). We imported data from the Springs Stewardship Institute's online Springs Inventory Database (springsdata.org); this was originally imported from the US Geological Survey's NHD database in 2013. We also scanned Digital Raster Graphics maps to locate additional sites. This initial analysis initially indicated that 84 springs had been reported within the burn perimeter across the Forest, only nine of which were named and none of which had been previously inventoried. Upon closer inspection of more accurate ownership layers, we determined that three of the 84 springs were located on private land, leaving 81 springs reported as existing on Stanislaus NF within the Rim Fire burn perimeter. We conducted a general literature review of the springs in and near the study area, and consulted with Forest staff regarding logistics, resources, schedule, and permitting and disposition of collected plant and invertebrate specimens. We also reviewed the Forest plant species list, including wetland, native, sensitive, and invasive species.

We used the initial springs map and a Forest roads layer to develop a logistics plan for efficiently conducting site visits. Prior to field work, we compiled GPS coordinates and written directions to each site. We then identified clusters of springs to reduce redundancy of driving and hiking access.

We developed a USFS GDE Access database using the latest version (5.4, released 12/15/14), which we populated with pre-field data described in the USGS protocols. The bulk of this information was imported from GIS layers, including USGS Quad, 12-digit HUC, county, district, geology, and soils mapping layers. We also obtained the Forest plant list, which was matched with USDA plants database. We printed Level I inventory field sheets for each reported site with pre-

field data that included the GPS coordinates and access directions (SSI 2012). We also printed 50 additional sets of blank field sheets to use at previously unmapped sites that we encountered.

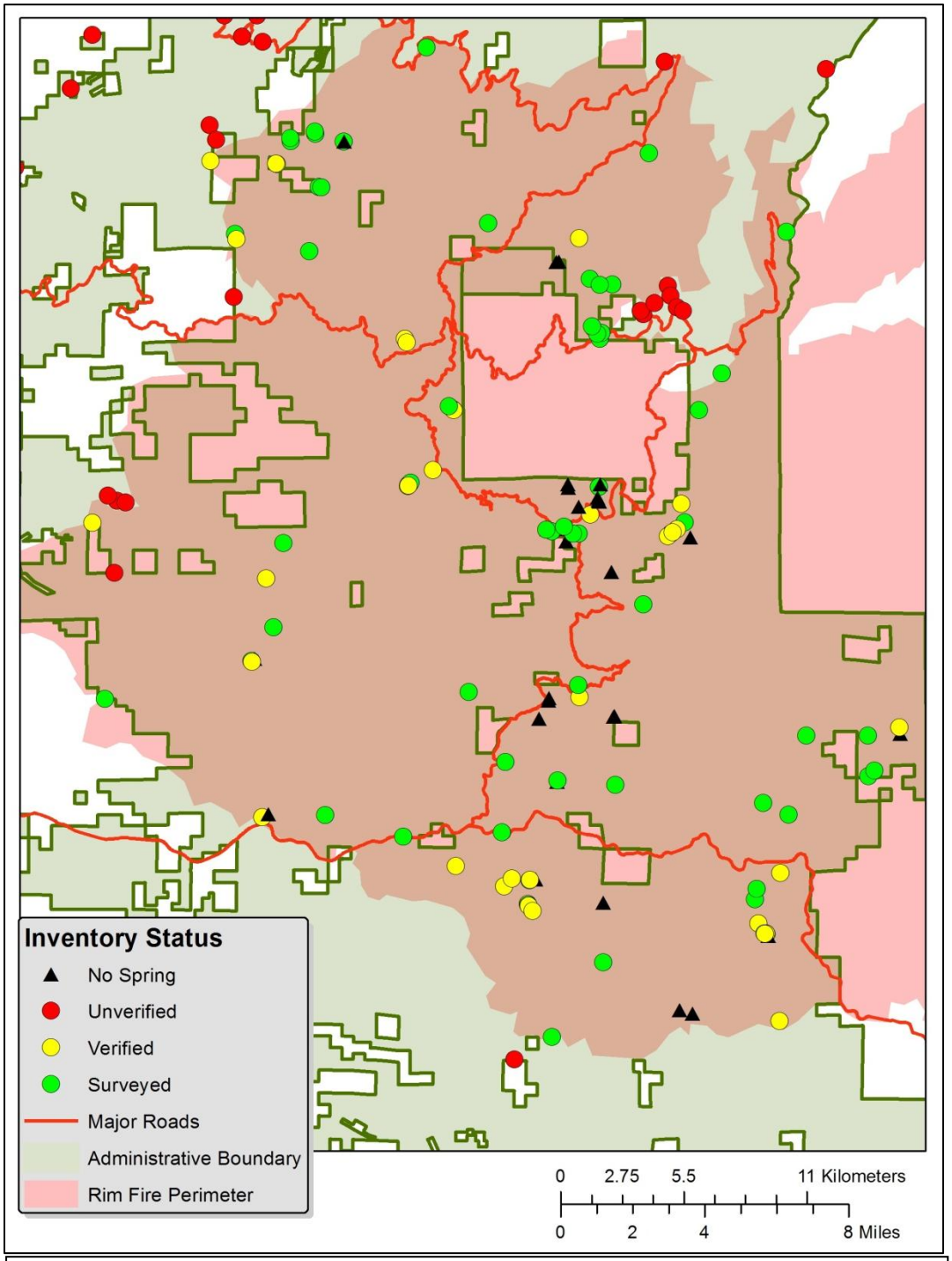

Fig. 1: Map of the survey status of springs within the Rim Fire perimeter on Stanislaus National Forest, California.

Field Logistics and Methods

The intent of this inventory was to provide background information to Stanislaus National Forest regarding the condition of up to 80 springs. Our survey team consisted of Larry Stevens and Jeri Ledbetter, and we were joined by Abraham Springer for several days, all of whom are intimately familiar with USFS Level I and II inventory protocols (U.S. Forest Service 2012). In addition, we were joined by several Forest staff for one or more surveys, including Tracy Weddle, Margaret Willits, David Weixleman, Fernando Perez, and Curtis Kuamme. We established base camps, initially at the Cherry Lake Borrow Campsite, and later at the Groveland District Office. From these sites we traveled to 2-7 springs per day, with an overall average of 4 springs/day.

We completed springs inventories of previously reported sites following USFS Level I GDE protocols, attempting to inventory as many springs as possible given time, funding, and travel constraints, as well as unforeseen conditions. We followed the U.S. Forest Service's Groundwater-Dependent Ecosystems (GDE) Level I inventory of springs (US Forest Service 2012, as provided at: http://www.fs.fed.us/geology/GDE_Level_I_FG_final_March2012_rev1__printing.pdf.

SSI provided all field equipment required to conduct the surveys, including a POV and field survey gear. Due to the rough terrain of the landscape and numerous possible dangers inherent in visiting springs in a severely burned landscape, we communicated twice daily with Ms. Weddle as to our daily plans.

Data Management

The inventory team recorded data onto paper field sheets that were organized into folders with one site/folder. Field data sheets, plant and invertebrate specimens, and observations on the sites were recorded and returned to our laboratory in Flagstaff for data entry, quality control, and reporting. SSI staff entered all data on field sheets, one representational photograph and sketchmap into the GDE database. Senior SSI staff conducted QA/QC using standard methods and edited the final reports on each springs ecosystem that was inventoried. Specimens of unrecognized species of plants and invertebrates were collected and labeled as to site and polygon. Specimens were identified to the lowest taxonomic level possible in the field, and taxonomy of selected specimens is continuing. However, complete species-level identification of all specimens collected during this project was not feasible within the life of this contract, and some identification of plant specimens is still on-going.

Analyses

We refined understanding of Stanislaus National Forest springs distribution by compiling site visit data into the USFS GDE Database, a relational Access database developed by Ms. Ledbetter for Forest Service springs inventory data nationwide. We also updated location information in our online Springs Inventory Database. This is securely password-protected and designed for ease of use by Forest staff. We recommend importing the survey data there as well. We developed an interactive online map at http://bit.ly/1tVn8Nw that provides access to the report on each site visited, and this database can be used to further improve Forest springs mapping, inventory, assessment, and management planning. We provided a draft version of this report and the online map for review by the Forest Service and participating collaborators. We received comments from

Patrick Koepele, Tracy Weddle, and Margaret Willits, and those comments have been integrated into this final report.

RESULTS AND DISCUSSION

Springs Mapping and Site Visits

We began field work on 20 August 2014, and during the project visited a total of 112 sites, including 80 of the 81 springs reported on the Forest from our initial mapping process (Table 1; Fig. 1). We were unable to inventory one springs ecosystem (NHD ID 66762173) due to safety issues related to heavy rains and poor road conditions. In addition to the 80 sites visited, we encountered an additional 32 springs that had not previously been mapped on the Forest.

Among the total number of sites visited, we found no evidence of groundwater or GDE characteristics at 34 (42%) of the 80 originally reported springs that we were able to access. Many of these sites showed no geohydrologic, geomorphologic, soils, or vegetation evidence of the site ever having been a springs ecosystem. In part we attribute this to mapping inaccuracy, as in all of those cases, organized searches within a 100 m radius around the reported point failed to indicate any nearby springs or other GDEs. At those locations, we took a photograph of the site, documented brief survey notes, and entered the site data as a USFS Level 0.5 inventory. Although this level was not described in the Level I protocols, the USFS has since recognized the need for a reduced inventory level for sites that are not, or cannot be fully surveyed (USFS unpublished).

We also report 32 springs (29% of the total, 40% more than previously recognized) as new to the Forest. These sites were noted, georeferenced, and photographed, but were usually not inventoried in more detail due to the project work load. They were documented in the geodatabase as USFS Level 0.5 inventories (Table 1). In Plum Valley, the crew hiked for an entire day to a reported springs that had been mismapped or had dried up, but encountered 6 springs along the way that had not previously been mapped. We inventoried Liverwort Springs, one of the more prominent of those new sites. We photographed, georeferenced, and briefly described the others, completing Page 1 of the US Forest Service Level I field forms.

We observed outflow at 7 locations during the study that likely originate at springs, as there were no upslope water features. Several of these produced significant flows. Although we were not able to locate those sources due to time constraints, we added their approximate locations to the geodatabase.

Table 1: Sites visited in the Stanislaus National Forest Rim Fire springs assessment, August-September 2014, by survey level and site name. Staff initials: AES – Abraham E. Springer (SSI), CK - Curtis Kuamme (USFS), DAW – David A. Weixleman, FP – Fernando Perez (USFS), JDL – Jeri D. Ledbetter (SSI), LES – Lawrence E. Stevens (SSI), MW – Margaret Willits (USFS), TW – Tracy Weddle (USFS).

Site Name	Site ID	Ranger District	Survey Date	Survey Level	Start Time	End Time	Staff
66761601 NHD_ID	159339	Groveland	9/25/2014	0.5	10:00	10:20	LES, JDL, FP, and TW
66761619 NHD_ID	159340	Mi-Wok	9/3/2014	0.5	12:45	13:10	LES, AES, and JDL
66761685 NHD_ID	159348	Mi-Wok	9/4/2014	0.5	16:30	16:45	LES and JDL
66761695 NHD_ID	159350	Groveland	8/25/2014	0.5	10:20	10:30	LES and JDL
66761717 NHD_ID	159352	Groveland	9/1/2014	0.5	16:45	17:00	LES
66761725 NHD_ID	159353	Groveland	8/25/2014	0.5	10:10	10:20	LES and JDL
66761729 NHD_ID	159354	Groveland	9/22/2014	0.5	12:30	12:50	LES and JDL
66761731 NHD_ID	159355	Groveland	9/22/2014	0.5	13:10	13:25	LES and JDL
66761741 NHD_ID	159358	Groveland	9/21/2014	0.5	13:45	14:15	LES and JDL
66761787 NHD_ID	159362	Groveland	8/23/2014	0.5	15:45	16:00	LES and JDL
66761807 NHD_ID	159365	Mi-Wok	9/3/2014	0.5	14:40	14:55	LES, AES, and JDL
66761815 NHD_ID	159366	Groveland	8/23/2014	0.5	15:35	15:45	LES and JDL
66761843 NHD_ID	159367	Groveland	9/21/2014	0.5	10:30	10:45	LES and JDL
66761849 NHD_ID	159368	Groveland	8/23/2014	0.5	16:40	17:00	LES and JDL
66761893 NHD_ID	159372	Groveland	9/21/2014	0.5	10:45	11:00	LES and JDL
66761915 NHD_ID	159374	Groveland	9/21/2014	0.5	13:15	13:30	LES and JDL
66762031 NHD_ID	159381	Groveland	8/22/2014	0.5	16:10	16:25	LES and JDL
66762057 NHD_ID	159383	Groveland	9/19/2014	0.5	16:30	17:00	LES and JDL
66762063 NHD_ID	159385	Groveland	8/23/2014	0.5	15:15	15:30	LES and JDL
66762111 NHD_ID	159390	Groveland	9/19/2014	0.5	18:00	18:15	LES and JDL
66762145 NHD_ID	159393	Groveland	9/6/2014	0.5	16:30	16:50	LES and JDL
66762157 NHD_ID	159394	Groveland	9/24/2014	0.5	17:00	17:15	LES and JDL
66762163 NHD_ID	159395	Groveland	8/31/2014	0.5	11:45	12:00	LES and JDL
66762183 NHD_ID	159398	Groveland	8/25/2014	0.5	10:35	10:55	LES and JDL
66762221 NHD_ID	159403	Groveland	9/20/2014	0.5	10:45	11:05	LES and JDL
66762275 NHD_ID	159414	Groveland	9/21/2014	0.5	13:00	13:15	JDL
66762329 NHD_ID	159425	Groveland	9/23/2014	0.5	17:25	17:40	LES and JDL
66762365 NHD_ID	159431	Groveland	8/23/2014	0.5	15:00	15:30	LES and JDL
66762383 NHD_ID	159435	Groveland	8/25/2014	0.5	11:25	11:45	LES and JDL
66762439 NHD_ID	159441	Groveland	9/2/2014	0.5	12:00	12:15	LES and JDL
Big Life	164159	Groveland	8/31/2014	0.5	15:15	16:00	LES and JDL
Cedar Twin East	164148	Mi-Wok	9/4/2014	0.5	10:00	10:15	LES and JDL
Cedar Twin West	164149	Mi-Wok	9/4/2014	0.5	10:00	10:15	LES and JDL
Claro	164195	Groveland	9/5/2014	0.5	18:40	18:50	LES and JDL

Site Name	Site ID	Ranger District	Survey Date	Survey Level	Start Time	End Time	Staff
Duckweed Dam	164163	Groveland	9/20/2014	0.5	10:30	11:00	LES and JDL
Effusus	164164	Groveland	8/31/2014	0.5	11:30	11:35	LES and JDL
Excavated	164194	Groveland	9/5/2014	0.5	18:30	18:40	LES and JDL
Goldenrod	164165	Groveland	8/31/2014	0.5	11:15	11:20	LES and JDL
Hardhat	164167	Groveland	9/5/2014	0.5	15:00	15:10	LES and JDL
Jawbone Creek Dry	164168	Mi-Wok	9/1/2014	0.5	16:00	16:15	LES and JDL
Lycopus	164169	Groveland	9/21/2014	0.5	11:00	11:20	LES
Monarch	164170	Groveland	9/5/2014	0.5	15:15	15:40	LES and JDL
Parallel Center	164179	Groveland	9/19/2014	0.5	16:40	16:45	LES
Parallel East	164180	Groveland	9/19/2014	0.5	16:45	17:00	LES
Parallel Lower	164181	Groveland	9/19/2014	0.5			JDL
Parallel West	164182	Groveland	9/19/2014	0.5	16:30	16:40	LES
Pilot Peak	159451	Groveland	9/22/2014	0.5	13:25	13:50	LES and JDL
Rackerby Jack Far	164192	Groveland	9/2/2014	0.5	17:10	17:15	LES and JDL
Rackerby Jack Middle	164191	Groveland	9/5/2014	0.5	16:30	16:35	LES and JDL
Rackerby Jack Near	164193	Groveland	9/2/2014	0.5	17:18	17:25	LES and JDL
Second Flow	164183	Groveland	8/31/2014	0.5	11:20	11:25	LES and JDL
Sedge Hillslope	164184	Groveland	9/23/2014	0.5	11:00	11:20	LES and JDL
Third Flow	164185	Groveland	8/31/2014	0.5	11:25	11:30	LES and JDL
Two Boulder Meadow	164187	Groveland	9/1/2014	0.5	17:00	17:10	LES and JDL
Walton Cabin	159459	Mi-Wok	9/27/2014	0.5	9:45	10:00	LES and JDL
55 Gallon	159346	Groveland	9/20/2014	1	12:50	14:00	LES and JDL
66762217 NHD_ID	159402	Groveland	9/20/2014	1	11:10	11:40	LES and JDL
66762247 NHD_ID	159409	Groveland	9/20/2014	1	11:50	12:25	LES and JDL
Aquarius	159357	Groveland	9/20/2014	1	14:35	15:25	LES and JDL
Bathtub	159421	Groveland	9/24/2014	1	9:15	11:05	LES, JDL, FP, and TW
Bedrock Pools	159349	Groveland	9/28/2014	1	13:30	14:45	LES and JDL
Box	159443	Mi-Wok	9/4/2014	1	11:45	12:45	LES, AES, and JDL
Brackenfern H.G.	159384	Groveland	9/23/2014	1	11:20	13:50	LES and JDL
Burnt Log Meadow	159379	Groveland	8/21/2014	1	16:30	17:50	LES and JDL
Camp Twentyone	159446	Mi-Wok	9/3/2014	1	9:25	10:40	LES, AES, and JDL
Cardinal	164146	Mi-Wok	9/3/2014	1	12:05	13:20	LES, AES, and JDL
Chickadee	159388	Groveland	9/19/2014	1	14:15	15:25	LES and JDL
Conyza Seep	159434	Mi-Wok	9/27/2014	1	7:55	8:50	LES and JDL
Cordulegaster	159351	Groveland	8/29/2014	1	16:05	17:50	LES and JDL
Cottonwood Road	159420	Groveland	8/20/2014	1	11:15	12:45	LES, JDL, and MW
Cowbell Meadow	159347	Groveland	8/22/2014	1	8:55	12:35	LES, JDL, and DAW
Damselfly	159426	Groveland	9/21/2014	1	15:00	16:45	LES and JDL

Site Name	Site ID	Ranger District	Survey Date	Survey Level	Start Time	End Time	Staff
Elmeri	159343	Groveland	8/20/2014	1	14:45	16:20	LES, JDL, and MW
Fallen Cedar	159412	Groveland	9/1/2014	1	14:15	15:15	LES and JDL
Granite Ditch	159437	Groveland	8/25/2014	1	12:00	13:15	LES and JDL
Himalaya	159419	Groveland	9/24/2014	1	15:15	16:45	LES and JDL
Hope	159401	Mi-Wok	9/5/2014	1	12:00	13:30	LES and JDL
Hopeful	159373	Groveland	8/29/2014	1	18:00	19:00	LES and JDL
Incense	159418	Groveland	9/29/2014	1	10:00	11:30	LES and JDL
Indian	159449	Mi-Wok	9/27/2014	1	13:40	14:55	LES and JDL
Liverwort	164152	Groveland	8/31/2014	1	12:30	14:50	LES and JDL
Milk Ranch	159450	Mi-Wok	9/4/2014	1	14:45	15:15	LES, AES, and JDL
Mosspool	159376	Groveland	8/23/2014	1	11:30	13:10	LES and JDL
Nettle Ditch	159345	Groveland	8/22/2014	1	16:30	17:45	LES and JDL
Newt	164171	Groveland	9/25/2014	1	10:05	11:00	LES, JDL, FP, and TW
Pedestal	159344	Mi-Wok	9/3/2014	1	15:30	16:15	LES, AES, and JDL
Peltigera Source	164144	Groveland	8/21/2014	1	13:00	15:30	LES, JDL, and MW
Powerline	159407	Groveland	9/28/2014	1	14:00	14:50	LES
Propane Tank	159436	Groveland	9/1/2014	1	11:05	13:10	LES and JDL
Rackerby Jack Big	164153	Groveland	9/2/2014	1	17:15	18:40	LES and JDL
Rackerby Jack	159453	Groveland	9/2/2014	1	18:45	19:05	LES and JDL
Roadcut	159440	Groveland	9/5/2014	1	17:10	18:30	LES and JDL
Rockwall	159361	Groveland	8/20/2014	1	16:25	18:00	LES, JDL, and MW
Salvage Meadow	159427	Groveland	8/23/2014	1	14:00	15:10	LES and JDL
Sawmill Pilot	159377	Groveland	9/25/2014	1	15:50	16:50	LES, JDL, and CK
Scoit	159337	Groveland	9/22/2014	1	14:40	16:40	LES and JDL
Scoulers Willow	159391	Groveland	8/21/2014	1	9:50	11:50	LES, JDL, and MW
Shingle	159457	Groveland	8/24/2014	1	11:15	13:30	LES and JDL
Soldier Sunset	159424	Groveland	9/19/2014	1	11:00	12:50	LES and JDL
Spiranthes Seep	164143	Groveland	8/24/2014	1	16:30	17:30	LES and JDL
Sweetwater	159397	Groveland	9/25/2014	1	13:25	15:00	LES, JDL, FP, and TW
Tecnu	159375	Groveland	9/2/2014	1	10:10	10:50	LES and JDL
Towhee	159380	Groveland	8/24/2014	1	15:00	16:20	LES and JDL
Treed Cubs	164150	Mi-Wok	9/4/2014	1	15:00	15:45	LES, AES, and JDL
Twomile Bridge	164151	Mi-Wok	9/4/2014	1	17:00	17:55	LES, AES, and JDL
Vista Seep	159413	Groveland	9/6/2014	1	17:20	17:45	LES and JDL
Walton Lower	159406	Mi-Wok	9/27/2014	1	10:15	11:50	LES and JDL
Water	159363	Groveland	9/21/2014	1	11:30	12:45	LES and JDL
Wet Meadows	159460	Mi-Wok	9/3/2014	1	16:25	17:30	LES, AES, and JDL
White Lupine	159378	Groveland	9/23/2014	1	14:30	16:45	LES and JDL
Wild Ginger	164147	Mi-Wok	9/4/2014	1	10:45	11:50	LES, AES, and JDL
Winding	159356	Groveland	9/24/2014	1	12:20	13:30	LES, JDL, FP, and TW

We conducted USFS Level I inventories at a total of 57 sites, spending an average of 1:20 hours at each. The inventories included water quality, flow, flora, fauna, geomorphology, georeferencing, disturbance, and management indicator assessment. All data were recorded on field sheets adapted from the USFS (2012). We took 4-8 georeferenced photographs of each inventoried springs ecosystem. All location data were entered into SSI's ArcSDE geodatabase. All survey data were entered in the USFS GDE Database. We collected selected plant and invertebrate specimens from some sites, of which some specimens are noted below. Taxonomic identifications are on-going, and will be reported as identifications are accomplished. Those specimens are presently housed at the Museum of Northern Arizona in

Flagstaff. We completed work on the project on 30 September 2014, as planned, having visited all but one of the 81 reported springs locations.

Overall, we considerably clarified the distribution of springs on the Forest. Our results indicate that there remain many additional unmapped springs both in the Rim Fire perimeter and on the Forest overall. Given that we located 32 new springs within the Rim Fire perimeter, we estimate that at least 100 additional springs may remain unmapped on the entire Forest.

Drought and fire interactively affect springs discharge and ecology, a limitation on understanding fire impacts that can be addressed by simultaneously inventorying unburned springs, by evaluating variation in burn intensity among springs within a burned landscape, or by conducting both analyses. With respect to the timing of site visits, we conducted our inventories in late summer after three years of intense drought. While the drought has harsh consequences on Forest life and regional economics, such conditions were fortuitous for this project because they allowed us to better understand the proportion of ephemeral versus perennial springs. We found that 42% of the springs on the Forest may be ephemeral, reflecting emergence from shallow aquifers with short flowpaths. However, springs that flow after 3 years of drought are likely perennial and should provide persistent flow in the future. Understanding which springs are perennial during prolonged droughts may be useful to Forest stewards seeking to prioritize and ensure the success of management planning and implementation.

Physical Characteristics

Springs Types: Terrestrial springs spheres of discharge (types) were classified by Springer and Stevens (2008), and such information is useful to managers because rare springs types are likely to support rare species, both of which may merit management attention. Among the 57 springs documented in this study, rheocrene (channel), helocrene (marsh-forming) and hillslope springs were the most common types encountered, with hypocrene, limnocrene, and hanging gardens types rarely encountered (Table 2):

Rheocrene > Helocrene > Hillslope >> Hypocrene > Limnocrene = Hanging Garden.

These findings are similar to those in some other western landscapes (e.g., the Spring Mountains of Nevada - Ledbetter et al. 2012, and southern Alberta - Springer et al. in press), but differ in proportional abundance in landscapes with less geologic deformation (e.g., Kaibab National Forest, with horizontally-bedded Colorado Plateau strata- Ledbetter et al. in press).

Table 2: Springs types encountered among 57 springs inventoried on Stanislaus National Forest in August-September 2014.

Type	Number	Percent
Hanging Garden	1	1.8
Helocrene	16	28.1
Hillslope	13	22.9
Hypocrene	2	3.5
Limnocrene	1	1.8
Rheocrene	24	42.1
All	**57**	**100**

Area: Area, aspect, slope angle, and the percent cover of various microhabitat types within the springs varied considerably among the springs inventoried during this study (Table 3). Springs area is the estimated area of land directly influenced by a springs ecosystem. Springs area varied greatly, with an average area of 464.9 (95% confidence interval = 115.3) m^2, among 54 springs for which data were available. Springs variation in area was in part related to springs types, varying from small seepage hillslopes springs, such as Sweetwater Spring (7.8 m^2), to large wet meadow helocrenes like Cowbell Springs (5,200 m^2). These data indicate that the total area of the 77 known springs in the Rim Fire perimeter is approximately 3.6 $\pm$ 1.7 ha (0.0034% of the Rim Fire area), and by extrapolation the area of springs habitat on the entire forest (prior to further inventory) may reach 12.5 ha.

Similarly, aspect and the percent cover of springs, channel, wetland, and open water microhabitats varied considerably among and within springs types. Wetland habitat predominated on helocrenes, such as Box, Conyza, Cowbell, Rackerby Jack, and Spiranthes springs, while channels predominated on rheocrenes (e.g. Newt and Incense Cedar Springs) and anthropogenic roadside ditch springs (e.g., Nettle Ditch and Roadcut Springs).

Table 3: Area, aspect, % slope, and % cover by springs microhabitat types of 57 springs in Stanislaus National Forest, inventoried in August and September 2014.

Site Name	Site ID	HUC 12	Area (m^2)	Aspect (°True North)	%Slope	% Microhabitat Cover				
						%Spring	%Channel	%Wetland	%Open Water	% Other
55 Gallon	159346	180400090602	54	205	9	5	40	29	25	1
66762217 NHD_ID	159402	180400090701	---	175	0	0	0	0	0	0
66762247 NHD_ID	159409	180400090602	---	139	3	0	0	0	0	0
Aquarius	159357	180400090602	49	122	11	5	80	10	5	0
Bathtub	159421	180400090702	25	182	36	5	75	0	20	0

Site Name	Site ID	HUC 12	Area (m^2)	Aspect (°True North)	%Slope	% Microhabitat Cover				
						%Spring	%Channel	%Wetland	%Open Water	% Other
Bedrock Pools	159349	180400091004	157	345	3	5	35	30	30	0
Box Spring	159443	180400090803	283	28	11	0	10	85	5	0
Brackenfern H.G.	159384	180400090702	122	210	170	10	30	0	30	30
Burnt Log Meadow	159379	180400091001	1315	194	14	1	10	77	2	10
Camp Clavey	159401	180400090803	200	49	19	5	20	15	60	0
Camp Twentyone	159446	180400090803	375	20	2	0	0	0	0	100
Cardinal	164146	180400090803	68	135	5	5	60	20	15	0
Chickadee	159388	180400090702	338	307	3	10	0	20	10	60
Conyza Seep	159434	180400090804	70	209	25	0	0	90	0	10
Cordulegaster	159351	180400090405	228	149	21	20	20	10	5	45
Cottonwood Road	159420	180400091001	2300	155	9	0	1	2	0	97
Cowbell Meadow	159347	180400091001	5200	155	5	5	10	50	20	15
Damselfly	159426	180400090602	154	125	27	10	20	60	10	0
Elmeri	159343	180400091001	1230	183	14	0	1	20	0	79
Fallen Cedar	159412	100700071102	158	215	25	15	60	20	5	0
Granite Ditch	159437	180400090405	64	234	9	0	60	10	0	30
Himalaya	159419	180400090602	125	240	27	10	20	30	30	10
Hopeful	159373	180400090405	42	151	29	2	20	10	2	66
Incense	159418	180400091001	100	287	9	5	65	30	10	0
Indian	159449	180400090804	710	97	9	20	10	50	20	0
Liverwort	164152	180400090405	157	210	16	5	60	10	15	10
Milk Ranch	159450	180400090803	315	138	11	0	15	10	0	75
Mosspool	159376	180400090405	18.5	144	16	5	60	20	10	5
Nettle Ditch	159345	180400090405	248	169	9	5	60	5	5	25
Newt	164171	180400090702	200	310	60	10	60	10	20	0
Pedestal	159344	180400090803	1204	151	5	0	20	0	0	80
Peltigera Source	164144	180400091001	296	290	5	10	40	35	15	0
Powerline	159407	180400091004	160	340	29	20	40	30	10	0
Propane Tank	159436	100700071102	266	214	21	10	0	60	10	20
Rackerby Jack Big	164153	180400091001	2224	104	12	20	3	50	10	17
Rackerby Jack	159453	180400091001	1520	141	21	1	0	80	2	17
Roadcut	159440	180400090804	610	188	7	40	0	20	10	30
Rockwall	159361	180400091001	188	183	9	0	5	0	0	95
Salvage Meadow	159427	180400090405	350	130	19	0	0	50	0	50
Sawmill Pilot	159377	180400090602	85	317	5	5	0	10	10	75

Site Name	Site ID	HUC 12	Area (m^2)	Aspect (°True North)	%Slope	% Microhabitat Cover				
						%Spring	%Channel	%Wetland	%Open Water	% Other
Scoit	159337	180400080401	210	200	7	5	40	25	10	20
Scoulers Willow	159391	180400091001	93	84	5	0	80	0	0	20
Shingle	159457	180400090405	292	205	11	5	60	10	5	20
Soldier Sunset	159424	180400090702	175.5	295	19	10	70	10	10	0
Spiranthes Seep	164143	180400090405	344	204	9	0	0	90	0	10
Sweetwater	159397	180400090602	7.8	294	14	10	30	30	20	10
Tecnu	159375	180400090405	47.5	235	23	5	80	15	10	0
Towhee	159380	180400090405	378	235	18	10	30	30	5	25
Treed Cubs	164150	180400090803	500	145	9	5	5	25	0	65
Twomile Bridge	164151	180400090803	287	---	58	1	0	98	1	0
Vista Seep	159413	180400090702	8	25	40	2	98	0	0	0
Walton Lower	159406	180400090804	354	---	5	5	20	60	15	0
Water	159363	180400091001	---	48	12	15	25	25	5	30
Wet Meadows	159460	180400090803	688	201	7	1	40	54	5	0
White Lupine	159378	180400090702	100	318	53	10	50	0	1	39
Wild Ginger	164147	180400090803	37	33	11	5	15	55	25	0
Winding	159356	180400090702	372	145	0	10	50	20	10	10

Flow and Water Quality: Springs discharge varied from diffuse seepage that was measurable only as the wetted area, to focused flow with discharge as high as 0.73 L/sec at Shingle Spring (Table 4). The total measurable flow from all 77 sites identified as springs was 6.26 L/s, with an average discharge from the 38 springs at which flow measurements could be made of 0.17 L/s (± 95% confidence interval = 0.068 L/s). Extrapolating these data to the entire Forest is complicated by lack of information on the extent and magnitude of flow perenniality. However, in a dry year such as 2014, it is unlikely that the total springs discharge from the Forest exceeds 22 L/sec.

Water quality similarly varied among sites (Table 4). Water temperature ranged from 7-21.7°C, with warmer temperatures at sites with more atmospheric exposure. Water pH varied from 5.4 in igneous-dominated and boggy vegetation-filled pond settings, up to 7.8 in springs derived from non-igneous aquifers. Specific conductance varied from 31.4 to 769 and was mirrored by variation in salinity from 0 to 303 ppm. Dissolved oxygen concentration was crudely measured at most sites using a CHEMmets[R] Kit, and varied from near 0 to complete saturation at 9 mg/L, with variation related to water temperature, as well as exposure to aquatic vegetation. Total alkalinity was measured at only a few sites and but similarly showed considerable variation.

Table 4: Flow, field water quality variables, and dominant in-flow and out-flow characteristics of springs inventoried on Stanislaus National Forest, August-September 2014.

Site Name	Date	Flow (L/s)	H_2O Temp (°C)	pH	SC (uS/cm)	DO (mg/L)	Domnt In-Flow Pattern	Domnt Out-Flow Pattern
55 Gallon	9/20/14	0.052	13.6	6.3	330.3	3.5	GW	---
Aquarius	9/20/14	---	17.5	6.54	238.8	1.0	Surf.	Surf.
Bathtub	9/24/14	0.028	13.6	6.01	187.8	2.0	GW	Surf.
Bedrock Pools	9/28/14	0.041	14.4	7.48	769.0	7.0	Surf.	Surf.
Box	9/4/14	0.002	15.6	6.37	178.9	1.7	GW	GW
Brackenfern H.G.	9/23/14	0.170	15.6	5.39	34.5	5.0	GW	GW
Burnt Log Meadow	8/21/14	0.014	8.6	5.43	67.0	6.0	GW	GW
Camp Clavey	9/5/14	0.600	7.8	6.73	209.0	5.0	Surf.	Surf.
Cardinal	9/3/14	---	12.0	5.71	36.8	1.0	Mixed	Surf.
Chickadee	9/19/14	---	19.2	7.05	169.0	4.5	Surf.	Surf.
Cordulegaster	8/29/14	0.084	17.1	6.32	226.8	3.5	Surf.	Surf.
Cowbell Meadow	8/22/14	0.610	9.9	5.49	88.8	3.5	GW	GW
Damselfly	9/21/14	0.036	19.3	7.81	246.1	9.0	Surf.	Surf.
Fallen Cedar	9/1/14	0.031	10.2	6.00	105.1	---	Surf.	Surf.
Himalaya	9/24/14	0.007	15.8	6.78	301.0	3.0	GW	GW
Hopeful	8/29/14	0.002	19.9	5.98	231.6	1.0	Surf.	Surf.
Incense	9/29/14	0.032	14.1	6.51	226.0	1.5	Surf.	Surf.
Indian	9/27/14	0.220	12.5	6.61	188.0	4.0	GW	GW
Liverwort	8/31/14	0.440	16.6	6.31	293.3	3.5	Surf.	Surf.
Mosspool	8/23/14	0.002	19.8	6.20	219.0	4.5	Surf.	Surf.
Nettle Ditch	8/22/14	0.019	16.1	6.65	226.0	5.0	Mixed	Surf.
Newt	9/25/14	0.048	14.1	7.49	90.0	7.0	Surf.	Surf.
Pedestal	9/3/14	---	12.8	5.36	31.4	0.2	GW	Surf.
Peltigera Source	8/21/14	0.250	10.7	5.55	63.0	4.0	Surf.	Surf.
Propane Tank	9/1/14	0.100	10.8	7.14	178.8	7.0	GW	GW
Rackerby Jack Big	9/2/14	0.024	18.8	6.12	170.1	2.5	GW	GW
Rackerby Jack	9/2/14	---	21.7	6.09	137.0	---	Surf.	Surf.
Roadcut	9/5/14	0.028	16.6	6.64	149.0	1.0	GW	GW
Shingle	8/24/14	0.730	11.5	6.11	65.7	6.0	Surf.	Surf.
Soldier Sunset	9/19/14	0.021	11.0	6.23	133.0	2.5	Surf.	Surf.
Sweetwater	9/25/14	0.590	11.9	6.52	294.0	5.0	Mixed	Surf.
Tecnu	9/2/14	0.100	15.1	7.42	178.0	6.5	Surf.	Surf.
Towhee	8/24/14	0.370	12.6	6.11	83.8	5.0	Surf.	Surf.
Twomile Bridge	9/4/14	0.420	7.0	6.10	80.5	7.9	GW	Surf.
Walton Lower	9/27/14	0.065	17.0	6.36	190.5	---	Surf.	Surf.
Water	9/21/14	---	17.0	6.21	262.0	---	Surf.	GW
Wet Meadows	9/3/14	---	20.7	6.00	82.0	0.2	GW	Surf.
White Lupine	9/23/14	0.072	14.6	6.19	53.0	6.0	Surf.	Surf.

Wild Ginger	9/4/14	0.210	8.4	6.24	140.5	5.0	GW	Surf.
Winding	9/24/14	---	17.7	6.63	206.0	4.5	Surf.	Surf.
Minimum	All	0.002	7.0	5.4	31.4	0.2	All	All
Maximum	All	0.730	21.7	7.8	769.0	9.0	All	All
Mean	All	0.17	14.5	6.4	179.0	4.0	All	All
1 sd	All	0.215	3.77	0.58	125.46	2.26	All	All
N	All	32	40	40	40	36	All	All
t	All	2.037	2.021	2.021	2.021	2.028	All	All
95% confidence interval	All	0.078	1.203	0.186	40.090	0.765	All	All

Biota

Plant Species: We documented at least 284 plant taxa at the 57 Forest springs inventoried (Appendix C). The total number of plant taxa encountered at springs amounts to 20.4% of the approximately 1,395 plant taxa reported occurring on and in the immediate vicinity of entire Forest (Jepson Herbarium 2014), with a density of 113.1 plant species/ha of springs habitat. Given that the Forest flora exists at a density of 0.08 plant spp/ha, Stanislaus NF springs support 1,360-fold greater species density than that on the Forest as a whole. These estimates are only slightly lower than plant species packing estimates at springs throughout western North America (e.g., Ledbetter et al. in press, Springer et al. in press), demonstrating that even burned springs support extraordinarily high concentrations of plant species.

Despite the naturally elevated plant species packing at springs, intensive disturbance of springs by wildfire, livestock grazing, and other factors exposes springs to colonization by non-native species (Stevens and Ayers 2002). We found that at least 12.1% of the species we detected at springs were non-native species, and some (e.g., *Cirsium vulgare*) were highly invasive, entirely dominating severely burned sites (e.g., Liverwort Springs). The successional trajectories of springs recovery following fire are poorly known. Early colonization by non-native species is generally believed to give way to subsequent colonization by native species. However, such processes are likely to vary by springs types, with helocrenes (marshy springs) following markedly different trajectories than rheocrenes or hanging gardens (e.g., Graham 2008).

Invertebrates: Springs in the Rim Fire perimeter were generally depauperate with respect to aquatic and wetland invertebrates (Appendix C). We were typically only able to sample invertebrates opportunistically due to the small amount of flow at most sites. However, such sampling provided evidence of at least 84 invertebrate species, and proved interesting at several sites. Several Odonata were detected. Most common were green darners (Aeshnidae: *Anax junius*), but other species detected included the Pacific Spiketail (Cordulegasteridae: *Cordulegaster dorsalis*) at Cordulegaster Springs, *Sympetrum* (Libellulidae), and other aeshnid dragonflies were regularly observed as well. At least one species of tetrigid wetland grasshopper was detected in our survey. Common aquatic Hemiptera included Corixidae, the gerrid *Aquarius remigis*, and *Microvelia* (Microveliidae). Aquatic beetles included gyrinids, *Agabus/Ilybius* and other dytiscid diving beetles, while hydrophilid water scavenger beetles were relatively rarely detected. Semi-aquatic beetles included several staphylinid rove beetles and ground beetles (Carabidae). Aquatic larval and semi-

aquatic adult Diptera included mosquitoes and dolichopodid flies. Sphaeriid finger clams of the genus *Pisidium* were detected relatively frequently in Stanislaus National Forest springs.

We detected a crangonyctid blind amphipod, *Stygobromus* cf. *hara* at Brackenfern Hanging Garden Springs. The single specimen collected was sent to, and identified by Dr. John Holsinger (Old Dominion University, Norfolk, VA). He recognized it as being similar to the specimens described from Pinnacle Point Cave in Tuolumne Co by Wang and Holsinger (2001). That specimen has been accessioned into his collection as H-4718, and will be curated into the U.S. National Museum (Smithsonian Museum of Natural History). Another *Stygobromus* species is known from the region: *S. wengerorum* was reported in Bower Cave and another cave near Coulterville in Mariposa County by Holsinger (1974, 1977, 2003). Dr. Holsinger recommended that additional specimens be sought to conclusively identify this species.

Vertebrates: The list of vertebrates of Stanislaus National Forest is far from complete; however, our brief surveys indicate that at least 61 vertebrate species use Forest springs (Appendix C). We detected only two amphibians during our surveys. Sierra newt (Salamandridae: *Taricha sierrae*) were detected in a relatively large aggregation at Newt Springs. Wikipedia (http://en.wikipedia.org/wiki/California_newt) reports the following regarding the life history of this species:

> "Reproduction occurs generally between December and early May. Typically, the adult newts will return to the pool in which they hatched. After a mating dance, the male mounts the female and rubs his chin on her nose. He then attaches a spermatophore to the substrate, which she will retrieve into her cloaca…The egg mass released by the female contains between seven and 30 eggs, and is roughly the consistency of a thick gelatin dessert. Typically, the egg masses are attached to stream plant roots or to rocky crevices in small pools of slow-moving water, but they have also been known to be attached to underwater rocks or leaf debris. While shallow in a wide sense, these pools are rather deep relative to the average depth of a Southern California stream, varying in depth from about 1–2 metres (3.3–6.6 ft)…Adult newts will stay in the pools throughout the breeding season, and can be occasionally found well into the summer. Larvae hatch sometime in early to midsummer, depending on local water temperature. Larvae are difficult to find in streams, as they blend in well with the sandy bottom, to which they usually stay close."

The occurrence of Sierra newts at this rheocrenic hillslope springs complex is peculiar because the springs emerge in extremely steep, actively eroding terrain, and the site has been much compromised by the construction and now erosion of a dirt roadway there. In addition, it is heavily grazed and browsed by livestock. Newt Springs was the only site at which this T. sierra was detected, and due to the several anthropogenic impacts on it, the site may merit management attention.

We also detected Pacific chorus frogs (Hylidae: *Pseudacris regilla*) at several sites, including sites such as Shingle Spring that had been severely altered by the fire. Due to drought conditions and the late time of year, this species may likely occur at more springs than we detected it.

Of the at least 44 bird species detected during our surveys, the observation of Northern Goshawk near Brackenfern Hanging Gardens was exceptional, and band-tailed pigeons were detected at several springs that had sustained lower intensity fire impacts.

We observed at least three American black bears, and commonly detected sign of bears at springs during our site visits. These observations, and the abundance of deer sign at springs, suggest that the role of springs as ambush sites for large predators is maintained or increases in importance following wildfire and burning of the landscape.

Human Uses

The Forest has a rich and lengthy history of human use of springs. We regularly encountered evidence of anthropogenic alteration or regulation of flow, with old piping, tanks, and more elaborate structures detected. We did not detect archeological evidence at the sites we visited, but have little doubt that prehistoric human use of larger springs also was intensive. More research into prehistoric and historic use of Forest springs is likely warranted.

Use of the Forest Service Level I inventory provides qualitative evidence of the extent of anthropogenic alteration, but unfortunately cannot readily be used to clarify management priorities across the landscape. Such an analysis is more easily accomplished using a quantitative condition and risk analysis, such as that provided by the Springs Stewardship Institute's Springs Ecosystem Assessment Protocol (SEAP, available on-line at the SSI website, http://www.springstewardship.org/PDF/SEAPCulturalApril2012.pdf).

Management Considerations

Overview

Our ecological inventory of springs on the Stanislaus National Forest appears to be the first of its kind in California, and demonstrates that Forest springs are relatively abundant and ecologically important ecosystems. As with most landscapes, springs provide habitat for species of plants and animals that are rare and sometimes are new to science.

We provide the Forest Service with a refined and expanded database of Forest springs, including many that had been neither mapped nor included in other databases. We surveyed several of these new springs, but generally only had time to georeference and photograph the site and fill out page one of the US Forest Service Level I field forms. Also, we observed outflow at 7 locations that we suspect originate at springs, as there were no water features upslope. Although we were not able to locate those sources due to time constraints, we added their approximate locations to the geodatabase. Several of those produce significant flows, and we encourage further investigation of those sources.

Management Indicators and Recommendations

The Forest Service Level I protocols include scoring a list of disturbance factors and management indicators (Appendix C), but do not apply that information towards recommendations on stewardship priorities. We included management suggestions on many of the field inventory sheets we prepared during this project to assist Forest managers with improving springs stewardship. Following completion of our draft report, the Forest selected 10 springs at which site rehabilitation may be considered. These springs lie in the Wilson Meadow and Granite Creek areas

and include: Liverwort Springs, Spiranthes Seep, Towhee Springs, Tecnu Springs, Granite Ditch Springs, Hopeful Springs, Cordulegaster Springs, Nettle Ditch Springs, Mosspool Springs, and Salvage Meadow Springs. In addition to the project data for these sites, we conducted a preliminary assessment of natural resource condition and human impacts risks for the 10 sites selected by the Forest, as well as four other sites of interest, using springs ecosystem assessment protocol (SEAP; http://springstewardship.org/assessment.html; Table 5). Full use of this approach requires more detailed scoring and feedback from management on desired conditions, but this preliminary analysis may provide additional information for managers about potential springs stewardship planning (Springer et al. in press).

Table 5: Preliminary springs ecosystem assessment protocol (SEAP) scores for natural resource conditions and anthropogenic risks at 14 selected sites within the Rim Fire perimeter, Stanislaus National Forest, California in 2014.

							Anthropogenic Risk										
Springs Ecosystem	**Springs Type**	**Aquifer/WQ Condition**	**Geomorphology Condition**	**Habitat Condition**	**Biota Condition**	***Averaged Natural Resouce Condition***	**Surface Water Quality**	**Flow Regulation**	**(Erosion)**	**Roads/trails/railroad**	**Fencing**	**Construction**	**Herbivory**	**Recreation**	**Adjacent Uplands**	**Fire**	***Averaged Anthropogenic Risk***
1. Cordulegaster	Rheocrene	3	3	2	3	***2.8***	3	1	5	3	1	0	2	0	5	5	***2.5***
2. Brackenfern	Hanging garden	3	4	4	4	***3.8***	4	1	4	4	1	1	4	0	5	5	***2.9***
3. Granite Ditch	Rheocrene-Anthropogenic	3	2	2	2	***2.3***	3	2	4	4	1	1	1	0	5	5	***2.6***
4. Hopeful	Rheocrene	3	3	2	3	***2.8***	3	1	4	3	1	0	2	0	5	5	***2.4***
5. Liverwort	Rheocrene	3	2	2	1	***2.0***	4	0	5	0	0	0	2	0	5	5	***2.1***
6. Mosspool	Rheocrene	3	2	2	2	***2.3***	4	1	4	4	1	0	3	0	5	5	***2.7***
7. Nettle Ditch	Rheocrene-Anthropogenic	3	1	2	1	***1.8***	4	5	5	5	1	0	3	0	5	5	***3.3***
8. Newt	Rheocrene	3	3	2	4	***3.0***	4	4	5	5	1	0	5	0	5	5	***3.4***
9. Roadcut	Hillslope	2	1	1	1	***1.3***	5	4	4	5	2	0	5	0	5	5	***3.5***
10. Salvage Meadow	Hillslope	2	3	2	2	***2.3***	4	3	4	5	1	0	2	0	5	5	***2.9***
11. Scoit	Rheocrene	3	4	4	4	***3.8***	3	3	4	5	1	0	2	0	4	4	***2.6***
12. Spiranthes Seep	Helocrene-Anthropogenic	3	2	2	2	***2.3***	4	4	4	5	2	0	1	0	4	5	***2.9***
13. Tecnu	Rheocrene	3	2	2	3	***2.5***	4	1	5	3	0	0	2	0	5	5	***2.5***
14. Towhee	Rheocrene	3	2	2	2	***2.3***	4	2	4	4	0	2	1	0	4	5	***2.6***
Average Scores	**All**	***2.9***	***2.4***	***2.2***	***2.4***	***2.5***	***3.8***	***2.3***	***4.4***	***3.9***	***0.9***	***0.3***	***2.5***	***0.0***	***4.8***	***4.9***	***2.8***

For this preliminary SEAP analysis, natural resource conditions and anthropogenic risks were scored for each site, based on expert opinion of the survey team. A site's natural resource condition score is calculated as the average score of the condition or value of the aquifer, site geomorphology, habitat quality, and population biology of native and non-native species in relation to the inventory team's expert opinion on the natural condition of the site. Natural resource scores range from 0 (wholly degraded natural condition) to 6 (pristine condition). Anthropogenic risk scores similarly range from 0 (no risk) to 6 (site is irretrievably degraded, with no potential for rehabilitation).

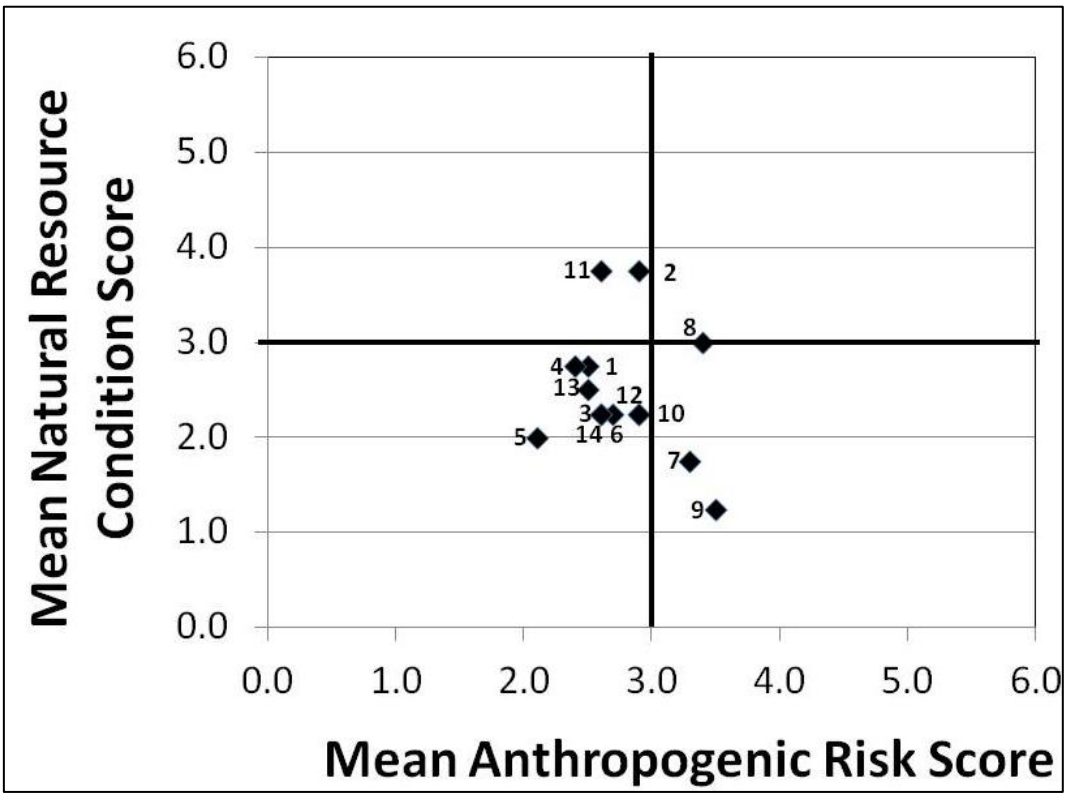

Figure 2: Averaged natural resource condition score in relation to anthropogenic risk at 14 springs in the Rim Fire perimeter, Stanislaus National Forest, California in 2014. Site numbers refer to site names in Table 5.

A plot of natural resource conditions in relation to human risk scores generally produces a cloud of points with a negative slope (Fig. 2). Among that cloud of points, sites with low natural condition scores and high risk scores are likely too degraded to warrant management actions, while sites with high natural condition scores and low anthropogenic risk are in good condition, and many only warrant occasional monitoring. In between those two extremes, sites with moderately good natural conditions and relatively low risks may be sites at which a modest amount of management attention will produce the most resource benefits.

Results of this preliminary SEAP analysis show that overall natural resource condition scores have been reduced by fire, drought, and grazing impacts, with most sites at or below a condition of three - impaired (Table 5; Figure 2). Sites with scores to the upper left quadrant are those with the highest natural resource conditions/values and the least at risk from anthropogenic impacts. If such sites are important to the Forest, a small amount of stewardship attention at those sites is likely to provide the best management benefit : cost ratio. Sites like Brackenfern Hanging Garden (Site 2), Scoit (11), and Newt Springs (8) fall into this category. Springs in good ecological condition also may provide reference sites, against which to measure the success of management treatments in relation to climate or other environmentally-induced ecosystem changes.

In contrast, springs in the lower right quadrant of the graph (Fig. 2) are those with lowest condition and highest risk (lowest rehabilitation potential). For example, Roadcut Springs (Site 9) and Nettle Ditch (Site 7) are the most degraded, and are sites where rehabilitation may be least likely to be successful. For the former, geomorphic recontouring of the road and livestock-altered landscape may be warranted, while the latter site lies along a heavily used road where rehabilitation efforts might not be compatible with desired road use levels. Rheocrene springs, such as Liverwort (Site 5; lying in a shallow gradient channel) and Cordulegaster, Hopeful, and Tecnu Springs (Sites 1, 4, and 13, respectively; lying in steep canyon-bound channels) are likely to be subject to large floods and potentially debris flows, making rehabilitation difficult. This SEAP approach also can be used as an assessment monitoring approach for evaluating project success after treatment.

The natural resource conditions at many springs affected by the Rim Fire involve both local (e.g., excessive erosion and other geomorphololgical impacts, livestock grazing impacts, non-native species control, etc.) as well as regional landscape-generated management challenges (e.g., regional surface erosion, forest tree fall, etc.). While the SEAP is approach may be useful for highlighting conditions and risks, it was primarily developed as a tool to promote discussion and planning among managers about what, if any, springs stewardship actions merit consideration. Our primary management recommendation regarding next steps in Forest springs stewardship is for the collaborating parties to discuss stewardship goals and objectives, before embarking on complex management actions. Consideration of the management indicators, and tools such as SEAP analysis, may help guide this process, but must be founded on agreements as to goals and objectives.

Below we list several general and specific recommendations regarding springs stewardship on the Forest.

General Recommendations

- Conduct a training for Forest managers to clarify springs ecohydrology and stewardship issues
- Conduct a prioritization strategy session for springs based on condition and risk assessment of natural resources, anthropogenic impacts, and the administrative context (e.g., http://www.springstewardship.org/PDF/SEAPCulturalApril2012.pdf)
- Conduct a springs stewardship strategy session with Forest managers to improve long-term management of springs ecosystems on the Forest
- Develop a Forest-wide groundwater model to better predict short and longer-term climate-related risks, to predict where additional springs and rare springs types may exist

- Develop a Forest-wide springs georeferencing program for Forest and potentially volunteer staff to train them in basic geo-documentation of springs. Such information is needed to continue to refine the Forest springs database
- Develop a list of springs-dependent macrospecies of plants, invertebrates and vertebrates for the Forest so that rare springs species can be included in management planning.

Specific Recommendations

- Continue to inventory Forest springs both in the Rim Fire perimeter (including those newly discovered in this study), as well as those throughout the Forest
- Integrate meadows survey data to determine how many meadows are GDE fens
- Conduct a more detailed biological inventory of those springs at which rare species have been reported
- Compare burned with unburned springs to improve understanding of stewardship needs, the vulnerability of springs to environmental change, and the role of springs as regeneration hotspots
- Develop and implement stewardship actions at rare springs types that have been affected by fire, such as the coniferous forest swamp helocrenes (e.g., Indian and the Parallel Springs)
- Determine the distribution of the newly discovered *Stygobromus* cf. *harrai* population and those of other rare invertebrate species among Forest springs.

We appreciate the opportunity to work with the Forest and its collaborating partners on this first in-depth analysis of Stanislaus NF springs. With this final report, we submit the geodatabase to the Forest and the collaborating partners. We hope this report is of use in improving stewardship of Forest springs, and we look forward to continuing to work with the Forest on springs-related issues. Please feel free to contact us if you have any questions or comments about this report.

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APPENDIX A:

Site reports of Forest Service Level I surveys of springs ecosystems inventoried during August-September 2014

(Submitted electronically as a concatenated pdf file)

APPENDIX B:

Site reports of Forest Service Level 0.5 surveys of springs ecosystems inventoried during August-September 2014

(Submitted electronically as a concatenated pdf file)

APPENDIX C:

Stanislaus National Forest springs: Biota detected during site visits in August-September 2014; FS Level 1 disturbance factors; and FS Management Indicators summarized by springs.

(Submitted electronically in Excel format, with separate worksheets in a single workbook)

APPENDIX D:

GEODATABASE OF Stanislaus National Forest springs biota detected during site visits in August-September 2014

(Submitted electronically as a File Geodatabase)

APPENDIX E:

GDE Database of Stanislaus National Forest with data from site visits in August-September 2014

(Submitted electronically as front end and back end Access files)

APPENDIX F:

WEB MAPPING SERVICE

(Available at http://bit.ly/1tVn8Nw)

APPENDIX G:

SURVEY IMAGES - Georeferenced photographs and Sketchmaps from surveys conducted in Stanislaus National Forest August - September 2014

(Submitted electronically as jpg files)