



SUMMARY

Stability returned during the 2016 season for the Grand Canyon National Park (GRCA) Fire Ecology Program. No turnover in permanent staff allowed all scheduled work to be completed while personnel participated in a wide variety of opportunities supporting incidents nationally and locally. Support continued for the Saguaro National Park (SAGU) Fire Ecology Program, incorporating field data collection on multiple plot types as well as database management expertise. With monitoring of 35 Fire Monitoring Handbook (FMH) plots, 22 Rapid Assessment Protocol (RAP) pilot sampling plots, and 38 Composite Burn Index (CBI) burn severity plots at GRCA; 50 RAP plots on the Kaibab National Forest; 26 FMH plots at Chiricahua National Monument (CHIR); and incorporating 12 unplanned plot reads from an early-season wildfire, it was a demanding, diverse, and ultimately successful year.

The tradition of assisting other programs with fire ecology ties continued, with the Assistant and three crewmembers helping the Saguaro Fire Ecology staff accomplish plot work at Chiricahua National Monument in southern Arizona. No mixed conifer plots were read at GRCA in 2016, but relationships were maintained with the Southern Colorado Plateau Inventory and Monitoring Network (I&M) by attending their annual meeting and a crewmember working for both programs. Additionally, further cooperation with the Kaibab National Forest resulted in installation of 50 RAP plots on the North Kaibab Ranger District (NKR) within the Burnt Corral Project Unit to assess baseline conditions and measure the effects of burning and other treatments within the project. The interagency North Zone fire management structure again provided funding to extend the crew into the fall and offer monitoring and other operational support on multiple prescribed burns along with gathering data from plots within the Burnt Corral Unit.

A third full season of 100% tablet-based, electronic field data collection and office data management using FFI (FEAT/FIREMON Integrated) and FFI Lite software again enhanced efficiency. Exclusive use of tablets for data collection again saved enough time compared to traditional data entry that all

seasonal crewmembers learned advanced skills by performing query-based quality assessment-quality control (QAQC), modifying Access-based datasheet replicates, standardized data analysis for this annual report, or specialized analysis for a report on the NKRD Burnt Corral Unit.

Based on Grand Canyon's extensive work in the electronic data collection and management realm, the Lead was supported by GRCA and the Intermountain Region (IMR) in traveling to Rocky Mountain, Grand Teton, and Yellowstone National Parks to help their Fire Ecology Programs successfully incorporate tablet-based data collection and data management. This 3-week, in-person visit in April-May allowed for one-one-one support to help customize software tools to improve efficiency and address protocol issues unique to each program, while training the Leads and Ecologists in best-practice methodologies to productively incorporate and independently problem-solve these new hardware and software tools for the subsequent field season.

Hands-on training in use of tablets for plot and incident fire effects monitoring (FEMO) data collection was similarly provided to the Utah Parks Group Fire Effects crew during separate visits to GRCA while assisting our program with accomplishing plot reads and a prescribed burn. This cross-training between programs occurred while multiple members of GRCA's Fire Effects staff were assisting at CHIR, and would not have been possible without the early-season assistance of a fourth crewmember and permanent staffing at both the Lead and Assistant positions providing dual leadership. Such a demand on our crew's time during the initial part of the season was anticipated and graciously accommodated by multiple GRCA fire managers. To be able to split our crew to simultaneously read plots at two different locations while also providing specialized FEMO support and training individuals in two other Fire Ecology programs is a testament to the employees who perform the work as well as those who generously support our staffing.

Along with the accomplishment of plot-related work, the program supported a busy national fire season, and crewmembers continued to expand both their skill sets and their variety of contributions to fire operations. This balance would not have been possible without sufficient staffing, the experience of existing crewmembers, and hiring our returning Assistant Lead with years of institutional knowledge of the program as a permanent employee. In some capacity, the crew worked on a total of 15 different incidents over 178 operational periods and completed 10 different NWCG or IAT training classes. Highlights of this experience included 4 assignments with the Grand Canyon Helitack Crew in Arizona, Texas, and Montana; intra-Zone cooperation through a severity detail to Nevada on North Kaibab Engine 334; and inter-rim cooperation through another severity detail to Nevada on GRCA S Rim Engine 812. The crew also continued its role as the primary Fire Effects Monitors (FEMO) within Grand Canyon National Park and the neighboring North Kaibab Ranger District on both prescribed and wildfire events, amounting to a total of 146 operational periods of local fire assistance in all capacities. In a unique role during the 14,989 acre Fuller Fire on the North Rim, the Fire Effects crew worked directly for the Type 2 Team Fire Behavior Analyst for multiple weeks, gathering fire and weather observations, collecting fuel samples, setting up remote weather sampling stations, and reading plots burned in the fire. Tablet computer and mobile device use continued to support FEMO duties, with concerted effort to move toward a singular device for all field FEMO photos and data. These opportunities led to the completion of two fire qualifications (ICT5, FEMO) and work on many others (FEMO, FFT1, FAL3, HECM) to further increase the crew's ability to fulfill a variety of roles within fire.

Cross-training Fire Ecology crewmembers with other field disciplines in the fire management program continued to allow the crew to build myriad skills and increase overall staffing flexibility. Personal interest by the crew greatly facilitated this multi-disciplinary learning, be it assisting with saw work on prescribed burn prep or backfilling on the wildland engine. To spread the wealth of knowledge further, two other fire personnel from the North Zone and 10 individuals from both GRCA S Rim and N Rim vegetation management and volunteer crews were cross-trained in fire effects plot protocols.

The new Fire Ecologist completed her first year. While much of her time was spent on getting set up and organized, as well as learning the ropes throughout the year, she was able to pursue professional development that included attending two conferences (IJWF Conference and AFE Conference) and completing various training courses, as well as participating in several fire assignments and networking opportunities with local and regional fire ecologists and researchers. Aside from being heavily involved in fire activities locally, the Fire Ecologist spent the majority of time this year on planning and data management tasks for GRCA and the growing network of collaborations, as well as presentations and education. In addition to the standard GRCA planning and data tasks, the Fire Ecologist performed the following duties:

- Continued work on the NPS-funded research collaboration with researchers from The University of Montana FireCenter and submitted a JFSP proposal to extend this work.
- Performed ecological review of LANDFIRE BpS models, descriptions, and rule sets for the BpS models occurring within the GRCA landscape.
- Served as NPS representative on RX510 (Advanced Fire Effects) steering committee.
- Contributed to GRCA Fire & Aviation's expanding work with volunteer groups by developing a new WUI thinning plot monitoring protocol specifically for use by volunteers, a new photo point geodatabase to qualitatively monitor the landscape through time, and giving presentations on fire ecology and monitoring to five volunteer groups.
- Developed and presented fire ecology/management educational material to ~200 university students in natural resource majors in eight lectures at three East Coast universities (Yale, Suffolk, and University of Southern New Hampshire). This was a direct result of work with volunteer students at GRCA, and included the GRCA Deputy FMO, Fire GIS Specialist, and Volunteer Coordinator.
- Developed and presented a training curriculum on integration of fire science, technology, policy, and management to 20 students at an AFE Conference Workshop with the Deputy FMO.
- Assisted the IMR with NFPORS FY16 closeout.

Both the Fire Ecologist and the Fire Effects crewmembers also helped fire management staff at GRCA with other duties. The Fire Effects Crew participated in Wildland Fire Day on the North Rim, hosting multiple workstations for visitors, and the Assistant Lead Monitor gave an evening interpretive presentation on wildland fire ecology at the North Rim Lodge. Crewmembers also participated in field trips with volunteers and visiting New Zealand-Australian Fire Staff, as well as assisting with BAER field data collection on the Fuller Fire.

We'd be remiss to not make mention of the Fire GIS Specialist, Eric Gdula. Eric accepted a new position in the Forest Service after serving as the Fire GIS Specialist at Grand Canyon National Park since 2001. Eric has been instrumental in connecting Science & Resource Management (SRM) staff and their resource values to the fire ecology side of the aisle. He often helped with validating spatial data that had an impact on fire management, such as performing surveys with the Fire Ecologist across the entire North Rim to confirm presence/absence of northern goshawk nests and birds in order to update a map that both fire and wildlife managers use in decision making. The field-verification of the burn severity map products was largely spearheaded by Eric, and we can say that our severity data is some of the best in the country undoubtedly because of this effort. His departure will leave a void here at Grand Canyon and in the Fire Ecology Program as we move forward without the attention to detail in mapping and the special projects that he was known for undertaking.

STAFF ACCOMPLISHMENTS & AREAS OF FOCUS

TABLE 1. Fire Ecology Staff for 2016 calendar year.

Employee	Starting Date	Ending Date	# Pay Periods	Training	NWGG Taskbooks
Casey Teske, GS-11	1/01/16	12/31/2016	26	RX510 A450 READ/F	LTAN-t RXB2-t
Li Brannfors, GS-7	1/01/16 4/03/16	3/05/16 12/31/16	22 ¹		LTAN-t
Dominic Ali, GS-6 ²	4/04/16	11/12/16	16 ³	S390 L280	FFT1 FEMO EMTF FAL3 SAR3 ICT5 HECM-t
Greg Hamby, GS-5	4/05/16	10/13/16	14 ⁴	S271 S211 READ	FEMO FFT1-t FAL3-t HECM-t
Emma McClure, GS-5	5/09/16	11/18/16	14 ⁴	S212 S290 A110 A116 A200	FEMO-t FAL3-t
Brad Anderson, GS-5	5/02/16	11/03/16	13.5 ⁴	S212 S290 A110 A116 A200 L280	ARCH READ FEMO-t FAL3-t
Meredith Talbert, GS-5	5/09/16	6/22/16	3.5	S212	FEMO-t FAL3-t

¹ Time for Li Brannfors reflects part-time work across 8 different payperiods.

² Through 5/14/16 Dominic Ali was term. After 5/15/16 he was permanent.

³ After Oct. 16, Dominic Ali was funded by GRCA project accounts.

⁴ After Oct. 1, 4 total payperiods of crewmember salary were funded by North Zone project accounts.

TABLE 2. Base-hour Fire Effects Crew activities by percent and category.

Employee	FMH Plots	RAP Plots	CBI Plots	I&M Plots	Data Entry/Mgmt	Plot Office	Other Office	Monitoring (Rx or Wildfire)	Rx Fire Ops	Wildfire/ Incident Ops	Training Courses	Other
Li Brannfors, GS-7	7	6	2	<1	15	11	28	8	1	<1	1	22
Dominic Ali, GS-6	10	10	<1	<1	11	11	15	12	2	6	4	17
Greg Hamby, GS-5	11	8	0	0	4	9	15	12	2	15	9	15
Emma McClure, GS-5	12	10	0	<1	9	10	12	10	2	9	6	20
Brad Anderson, GS-5	16	14	0	<1	7	8	9	5	2	14	8	17
Meredith Talbert, GS-5	28	0	0	0	8	8	16	6	2	4	12	16

"Plot Office" includes miscellaneous plot data preparation and management time, plant ID, photo filing, etc.

"Rx Fire Ops" includes time spent on non-fire fuels projects and fuel sampling.

"Wildfire/Incident Ops" includes in-park details with GRCA Helitack, GRCA and NKR engines, administrative leave associated with fire assignments.

"Other" includes PT, leave taken, official meetings, conferences, webinars, paid holidays off, non-fire duties, etc.

TABLE 3. Base-hour Fire Effects Crew Focus Areas/Accomplishments in 2016.

Focus Area	Percent Time	Accomplishments and Activities
FMH Plots	11%*	24 remeasurements, 11 immediate post-burn reads at GRCA 26 remeasurements at CHIR by Assistant Lead & 3 crewmembers
RAP Plots	9%*	50 installs in Kaibab NF Burnt Corral treatment unit 20 pre-burn re-reads, 1 remeasurement, 1 immediate post-burn read across 3 project units
CBI Plots	1%*	38 plots across 1 fire
I&M Plots	<1%*	Traveled on two separate occasions to unburned I&M plot in the Fuller Fire
Data Entry/ Management	9%*	<i>ALL 2016 plot data collected and checked electronically with tablet computers in the field; data entry and field checking is included in % time under each plot type</i> - QAQC queries completed for 2016 FMH & RAP data by Oct 27 - Includes FFI/FFI Lite electronic data prepping, merging, checking, & hardcopy datasheet creation for all plots at GRCA, CHIR, & Kaibab NF
Data Analysis	1%	- Annual Report analysis on all major variables in program - Seasonal Fire Ecology staff analyzed data for annual report - Seasonal Fire Ecology staff analyzed data for Kaibab NF Burnt Corral report
Plot Office	10%	Includes plot preparation, plant ID, photo filing, tree mapping, hardcopy data filing/organization, and plot-related projects
General Office/ Supervision/ Admin	17%	- Includes paperwork for travel, credit cards, non-plot related projects - Hiring, evaluations, and supervision by Lead & Assistant - Lead & Ecologist hired seasonal crew - Lead supervised 1 permanent Assistant & 4 seasonals
Fire Monitoring (Rx or Wildfire)	9%*	- Lead and Assistant FEMO & FEMO-trainees on 2 Rx fires at GRCA and 5 Rx fires on Kaibab NF - Lead and Assistant FEMO & FEMO-trainees on 1 managed wildfire at GRCA and 1 managed wildfire on Kaibab NF - Trained member of Blue Ridge Hot Shots as FEMO on Kaibab NF Rx fires
Fire Operations/ Assignments (Rx, Wildfire, Engine, Helitack, Non-fire Fuels Projects)	10%*	- Qualified personnel as ICT5 and FEMO - Assistant Lead detailed with GRCA Helitack for 1 week in Texas 1 crewmember detailed with GRCA Helitack for 4 weeks locally & in Montana 1 crewmember detailed for 2 weeks with North Kaibab Engine 334 for severity in Nevada 1 crewmember detailed for 2 weeks with GRCA South Rim Engine 812 for severity in Nevada - ICT5, FFT1, FAL3, & FFT2 support on multiple North Zone fires - Cross-trained crewmembers with GRCA engines, mechanical fuel reduction projects, fuel sampling
Training	5%	- All attended annual fire refresher 3 completed S212 2 completed L280 2 completed S290 online 1 completed S390 1 completed S271 1 completed S211 1 completed READ 2 completed A110, A116 and A200 aviation courses online
Travel Away from Duty Station	—	Total of ~3 months spent on South Rim, camped out on Walla Valley unit, or assisting Saguaro Fire Ecology at Chiricahua National Monument
Other	17%	~5% of crew time spent on PT ~7% of crew time spent on leave

*Approximately 1585 hours of overtime on both fire and plot duties, equaling 19% of total crew work time (base + OT), are not reflected.

TABLE 4. Fire Ecologist Focus Areas/Accomplishments in 2016.

Focus Area	Percent Time	Accomplishments and Activities
Planning	12%	- Managed activities in NFPORS and participated in out-year planning - Gained understanding of GRCA fire monitoring and fire management programs - Create out-year planning tool for FFI with SRM staff - Field-verified (& updated) sensitive resources map (NOGO)
Presentations/ Education	9%	- Developed/Presented training curriculum at fire conference workshop - Developed/Presented training for 5 groups of volunteers at GRCA - Developed/Presented fire ecology educational materials for E Coast University students in Natural Resources (5 lectures; ~200 students) - Presented at Fire Behavior Conference - Created Fire Ecology Story Map with Fire GIS Specialist - NAU Career Fair – NPS Fire Representative
NPS Meetings/ Task Groups	3%	- Leadership & Supervisory meetings; staff & strategy meetings - Fire, Compliance, & Resource Management, and I&M collaboration meetings - Regional fuel and fire ecology conference calls and meeting - NFPORS FY2016 cleanup
Interagency Work	2%	- RX-510 Steering Committee - Participated in Fire Research (FASMEE) field trip with N.Z. KNF
Fire Assignments and Project Work	21%	- RX: Village Rx (FFT1); HS Edge (FIRB) 1 FEMO assignment (Mormon Lake), 4 LTAN-t assignments (Doghead; Fuller; R2 RO Support – 4 fires; Fulton)
Research	2%	- Meetings for IMR Fire funded research project - Field Trip for IMR Fire funded research project - Submitted JFSP proposal for continuation of fire-related projects
Data Collection	2%	- Participated in CBI plot data collection (Mt Emma) - Installed WUI thinning plots with volunteer groups - Tested new technology for mapping fire perimeters - Created new photo database for 'historic' photos volunteer project - LiDAR Field Data collection
Data Entry & Management	1%	- Identified FFI database errors for GRCA, KNF, and SAGU - Created out-year plot planning & reporting tool for FFI
Data Analysis	3%	Analyzed FMH, RAP, and I&M plot data, severity data, and weather and fuel data for burn plans, field trips, and annual report
Supervision/ Admin	7%	- Supervised Lead Monitor - Worked with Lead Monitor to furlough term Assistant Lead Monitor and seasonal crewmembers - Managed fire monitoring, internship, and ecology budgets - Travel, time, and purchasing
Training & Conferences	9%	- Training: Rx-510, READ/REAF, sUAS (A450) - Conferences: IJWF Fire Behavior & AFE Fire Ecology - NPS required annual training; fire and aviation refreshers
Other	29%	- Install software on computer - Leave, holidays, travel, PT (3.5%), etc.

FIRE EFFECTS PLOT WORKLOAD

The 2016 season produced a moderate but very consistent plot load for most of the year at Grand Canyon. Unplanned workload was created with the Fuller Wildfire and Kaibab National Forest Burnt Corral project, adding 12 FMH & RAP immediate post-burn plot reads in July-August, and 50 RAP plot installations in September-October.

TABLE 5. Grand Canyon National Park Fire Effects Plot Workload for 2016.

Rim	Monitoring Unit	Plot Type	Install/ Pre-burn	Immed. Post-burn	Year 1	Year 2	Year 5	Year 10/ 20	Annual Total	Total Plots¹
South	Ponderosa Pine PIPO	FMH - Forest					5	5	10	41
South	Pinyon-Juniper Woodland—PIED²	FMH - Forest							0	17
South	Moqui Rx	RAP ³							0	5
South	Picnic Rx	RAP ³							0	10
South	Quarry Rx	RAP ³							0	10
North	Ponderosa Pine PIPN	FMH - Forest				11	2		13	30
North	Ponderosa Pine with White Fir Encroachment PIAB	FMH - Forest		4					4	27
North	Rocky Mountain Subalpine Conifer PIEN	FMH - Forest	1	7					8	17
North	Grassland Interior GRIN	FMH - Brush							0	10
North	Grassland Edge GRED	FMH - Forest							0	6
North	Emma Fire	CBI			38				38	-
North	Burnt Corral-NKRD	RAP ³	50						50	50
North	Fawn Spring Rx	RAP ³				1			1	20
North	Highway 67 Rx	RAP ³							0	20
North	Range Rx	RAP ³							0	20
North	Spring Canyon Rx	RAP ³	20 ⁴						20 ⁴	20
North	Thompson Rx	RAP ³		1					1	20
North	Tipover Rx-NKRD	RAP ³							0	40
North	Walla Valley Rx	RAP ³							0	6
North	Mixed Conifer	I&M ⁵							0	44
Total			71	12	38	12	7	5	145	413

¹ Total Plots includes all permanent plots (FMH, RAP, or I&M) installed to date within a monitoring unit/type

² PIED monitoring type reads were discontinued in 2000

³ Pilot sampling

⁴ Five plots that burned in the 2014 Slopes Rx project were simultaneously read for Pre-burn and Year 2 data during one visit

⁵ Fuel and tree data collected to add to data collected by I&M crews

During 2015, fire effects monitoring plots within the three Flagstaff Area National Monuments were evaluated to determine their utility in providing feedback for fire management activities in the monuments. As a result of the evaluation, five monitoring types containing 33 total plots were discontinued and archived. The details of the evaluation and decision process are contained in the report “Fire Effects Monitoring for the Flagstaff Area National Monuments: Overview, Status, and Future Direction” (Bunn 2015; National Park Service Integrated Resource Management Applications Data Store Reference Code: 2223756). GRCA worked with the I&M program in 2015 to share data and repeat the pre-burn fuel, pole-sized tree, and overstory tree measurements in eleven FMH-established ponderosa pine (PIPO) plots and two I&M-established PIPO plots in Walnut Canyon National Monument (WACA). Going forward, these 13 plots will comprise the foundation of the active network at WACA. A copy of the FFI database containing the existing plot data, as well as the three archived databases, are available on the NPS IRMA portal (Reference Codes: Walnut Canyon NM current-2194013, Walnut Canyon NM historic-2222935, Sunset Crater NM historic-2221713, Wupatki NM historic-2222001).

TABLE 6. Flagstaff Area National Monuments Fire Effects Plot Workload for 2016.

Park	Monitoring Unit	Plot Type	Install/ Pre-burn	Immed. Post-burn	Year 1 - 20	Annual Total	Total Plots ¹
Walnut Canyon NM	Ponderosa Pine Forest PIPO	FMH – Forest / I&M				0	13
Total						0	13

¹ Total Plots includes all permanent plots (FMH or I&M) installed to date within a monitoring unit/type.

MONITORING OBJECTIVES & RESULTS

Fuel Loading & Tree Density – FMH plots

Grand Canyon National Park's Fire Ecology Program has installed 148 permanent FMH-style plots to date and 119 of these same plots have burned. This large body of data allows us the luxury of being able to report results to our desired level of statistical accuracy for many of our major management objectives. The PIEN and PIED monitoring types are not included in these tables because (1) these areas are thought to be within the natural fire regime and (2) prescribed fires are not the management focus in these areas. Of the 9 restoration objectives listed in Table 7, we can say with statistical confidence we are achieving 5 of them after first entry fire and 3 of them after second entry fire.

Targeted mean fuel loading values were achieved during first entry fires in the PIPO and PIPN monitoring types. In the PIAB monitoring type, mean fuel loading fell within the targeted range, but the confidence limits extend above the targeted range (too much fuel remaining). After second entry fires, mean fuel loading values in all monitoring types were within the targeted range, but the confidence limits extend above the targeted range (too much fuel remaining) in the PIPO and PIAB monitoring types.

In the PIPO and PIPN monitoring types we cannot realistically install and maintain the number of plots needed to overcome the variability in pole-sized tree density. In the PIPO monitoring type, mean pole-sized tree density fell within the targeted range after first entry fire, but the confidence limits extend above the targeted range (too many pole-sized trees). After the second entry in PIPO, the mean pole-sized tree density was above the targeted range, although the lower confidence limits fall within the targeted values. In the PIPN monitoring type, mean pole-sized tree density fell within the targeted range after both first and second entry fire. However, the confidence limits extend above the targeted range (too many pole-sized trees) after the first entry fires and below the targeted range (too few pole-sized trees) after the second entry fires. The PIAB monitoring type has the minimum number of plots required to overcome variability in pole-sized tree density. After first entry fires in the PIAB type, mean pole-sized tree density was within the targeted range; however, the confidence limits extend above the targeted range (too many pole-sized trees). After second entry fires in the PIAB type, mean pole-sized tree density was well below the targeted range.

For large tree density, minimum plot numbers have been reached for all monitoring types. Mean large tree density remained within the targeted range (and showed little change from pre-fire values) for first and second entry fires in the PIPO monitoring type. Mean large tree density decreased from pre-fire values in the PIPN monitoring type in both first and second entry fires, but mean values remained within the targeted range. In the PIAB monitoring type, mean large tree density decreased from pre-fire values, but remained within target values after first entry fire. However, after second entry fires mean large tree density fell below the desired range with confidence limits extending back into the targeted range (i.e. there is some uncertainty about whether tree density is at the low end of the target or below the target).

Table 7. Restoration Management Objectives and Monitoring Results for FMH plots in 2016. 1st entry and 2nd entry refer, respectively, to the first and second times an area has burned in any fire type (prescribed fire or wildfire).

Monitoring Unit	Restoration Management Objectives	Monitoring Results (n = # of plots)		Objectives Achieved?		Minimum Plot #s Achieved?
		1 st Entry	2 nd Entry	1 st Entry	2 nd Entry	
Ponderosa Pine (PIPO) South Rim	Reduce total fuel load to 0.2-9.3 tons/acre immediate post-burn	7.2 ± 0.8 tons/acre (-47%) (n=38)	7.9 ± 1.7 tons/acre (-48% due to fire 1 & 2) (-2% due to fire 2 only) (n=20)	YES	YES*	YES n=10
	Reduce poles (PIPO) with DBH of 1-6" to 16-81 trees/acre 2 years post-burn	77.0 ± 29.5 trees/acre (-24%) (n=39)	106.4 ± 42 trees/acre (-33% due to fire 1 & 2) (-8% due to fire 2 only) (n=20)	YES*	NO*	NO n=61
	Maintain overstory (PIPO) density with DBH ≥16" of >14 trees/acre 5 years post-burn	19.9 ± 2.5 trees/acre (-0%) (n=36)	19.2 ± 3.4 trees/acre (-0% due to fire 1 & 2) (-1% due to fire 2 only) (n=20)	YES	YES	YES n=14
Ponderosa Pine (PIPN) North Rim	Reduce total fuel load to 0.2-15.7 tons/acre immediate post-burn	12.1 ± 1.6 tons/acre (-56%) (n=30)	9.8 ± 2.4 tons/acre (-62% due to fire 1 & 2) (-42% due to fire 2 only) (n=22)	YES	YES	YES n=11
	Reduce conifer poles with DBH of 1-6" to 16-81 trees/acre 2 years post-burn	70.1 ± 33.4 trees/acre (-58%) (n=30)	20.2 ± 7.9 trees/acre (-76% due to fire 1 & 2) (-24% due to fire 2 only) (n=22)	YES*	YES*	NO n=48
	Maintain overstory conifer density with DBH ≥16" of >17 trees/acre 5 years post-burn	40.9 ± 3.8 trees/acre (-10%) (n=30)	40.0 ± 11.1 trees/acre (-19% due to fire 1 & 2) (-10% due to fire 2 only) (n=9)	YES	YES	YES n=4
Ponderosa Pine w/ White Fir Encroachment (PIAB) North Rim	Reduce total fuel load to 1.7-19.0 tons/acre immediate post-burn	17.5 ± 3.3 tons/acre (-49%) (n=20)	16.9 ± 5.6 tons/acre (-58% due to fire 1 & 2) (-44% due to fire 2 only) (n=15)	YES*	YES*	YES n=5
	Reduce conifer poles with DBH of 1-6" to 16-100 trees/acre 2 years post-burn	85.9 ± 23.5 trees/acre (-64%) (n=21)	1.6 ± 1.5 trees/acre (-98% due to fire 1 & 2) (-63% due to fire 2 only) (n=10)	YES*	NO	YES n=9
	Maintain overstory conifer density with DBH ≥16" of >20 trees/acre 5 years post-burn	28.3 ± 2.6 trees/acre (-22%) (n=19)	18.0 ± 6.4 trees/acre (-38% due to fire 1 & 2) (-33% due to fire 2 only) (n=11)	YES	NO*	YES n=7

NOTE: Assessment of objective success and fulfillment of minimum plot requirements are based on 80% confidence intervals. Minimum plot calculations are based on pre-fire values, with R-value of 20 for overstory tree and fuel assessment and R-value of 25 for pole-sized tree assessment; variable fire conditions increase the minimum number of recommended plots for post-fire analysis.

YES* indicates that the mean value meets stated objectives but the confidence interval is outside the range of objective values.

NO* indicates that the mean value does not meet stated objectives but the confidence interval is inside the range of objective values.

Maintenance objectives help to refine long-term desired states for each monitoring type and are described briefly in Table 8. On the South Rim, maintenance burning will likely continue in the form of prescribed fires, while on the North Rim, the expectation is that wildfires will be managed to achieve maintenance objectives. These objectives are for the general state of the landscape and will help define return intervals for prescribed fires on the South Rim and initiate planning for prescribed fires on the North Rim if wildfires are regularly suppressed. Measurement periods currently correspond to those for restoration targets but can be adjusted based on management need.

Maintenance burning in the PIPO and PIPN monitoring types has resulted in achievement of the fuel loading objectives for each type. However, in these monitoring types we cannot realistically install and maintain the number of plots needed to overcome the variability in tree density. In the PIPO monitoring type, mean tree density now falls outside the targeted range after maintenance burning, but the confidence limits extend within the targeted range of objective values. However, it should be noted that in this instance, the PIPO plot type does not currently have the minimum number of plots (current $n=16$; minimum $n=43$). Thus, each additional plot reading in the PIPO monitoring type will likely highly influence this result and any interpretation should take this into account. A similar caution should be extended in the PIPN type, where only two plots have data two years following third entry fire (minimum $n=48$), and they both burned two years after the second entry fire. The small plot number and anomalous burn interval in the PIPN type make the pole-sized tree results unreliable.

Table 8. Maintenance Management Objectives and Monitoring Results for FMH plots in 2016. 3rd entry refers to the third time an area has burned in any fire type (prescribed fire or wildfire).

Monitoring Unit	Maintenance Management Objectives	Monitoring Results 3 rd Entry (n = # of plots)	Objectives Achieved?	Minimum Plot #s Achieved?
Ponderosa Pine (PIPO) South Rim	Maintain total fuel load of 0.2-9.3 tons/acre immediate post-burn	6.4 ± 1.9 tons/acre (-59% due to fire 1, 2, & 3) (-25% due to fire 3 only) (n=16)	YES	YES n=10
	Maintain tree (PIPO) density with DBH ≥1" of 43-135 trees/acre 5 years post-burn	151.3 ± 34.5 trees/acre (-21% due to fire 1, 2, & 3) (-8% due to fire 3 only) (n=16)	NO*	NO n=43
Ponderosa Pine (PIP) North Rim	Maintain total fuel load of 0.2-15.7 tons/acre immediate post-burn	10.0 ± 4.6 tons/acre (-62% due to fire 1, 2, & 3) (-16% due to fire 3 only) (n=11)	YES	YES n=11
	Maintain conifer pole density with DBH of 1-6" of <81 trees/acre 2 years post-burn	16.2 ± 24.9 trees/acre (-82% due to fire 1, 2, & 3) (-25% due to fire 3 only) (n=2)	YES	NO n=48
Ponderosa Pine w/ White Fir Encroachment (PIAB) North Rim	Maintain total fuel load of 1.7-19.0 tons/acre immediate post-burn	Not analyzed (n=0)	N/A	NO n=5
	Maintain conifer pole density with DBH of 1-6" of <100 trees/acre 2 years post-burn	Not analyzed (n=0)	N/A	NO n=9

NOTE: Assessment of objective success and fulfillment of minimum plot requirements are based on 80% confidence intervals. Minimum plot calculations are based on pre-fire values, with R-value of 20 for overstory tree and fuel assessment and R-value of 25 for pole-sized tree assessment; variable fire conditions increase the minimum number of recommended plots for post-fire analysis.

NO* indicates that the mean value does not meet stated objectives but the confidence interval is inside the range of objective values.

Year 1 Burn Severity –MTBS data and CBI plots

As part of the Monitoring Trends in Burn Severity (MTBS) program, Composite Burn Index (CBI) burn severity assessments have been occurring annually at Grand Canyon since 2001. Between 2001 and 2016, 1,451 post-fire year 1 CBI-style plots have been measured, providing field-verified data for the satellite-derived differenced Normalized Burn Ratio (dNBR) – which is translated into a severity classification – on 60 NPS-GRCA fires totaling 144,244 acres. This process is designed for field data and satellite imagery gathered one year following a fire; hence, 2016 work was performed on fires which burned in 2015. In 2015, 4,438 acres burned in the Emma wildfire, which straddled BLM and NPS ownership (422 acres BLM; 4,016 acres NPS). A total of 37 CBI plots were installed on the Grand Canyon National Park side in 2016 to assess severity.

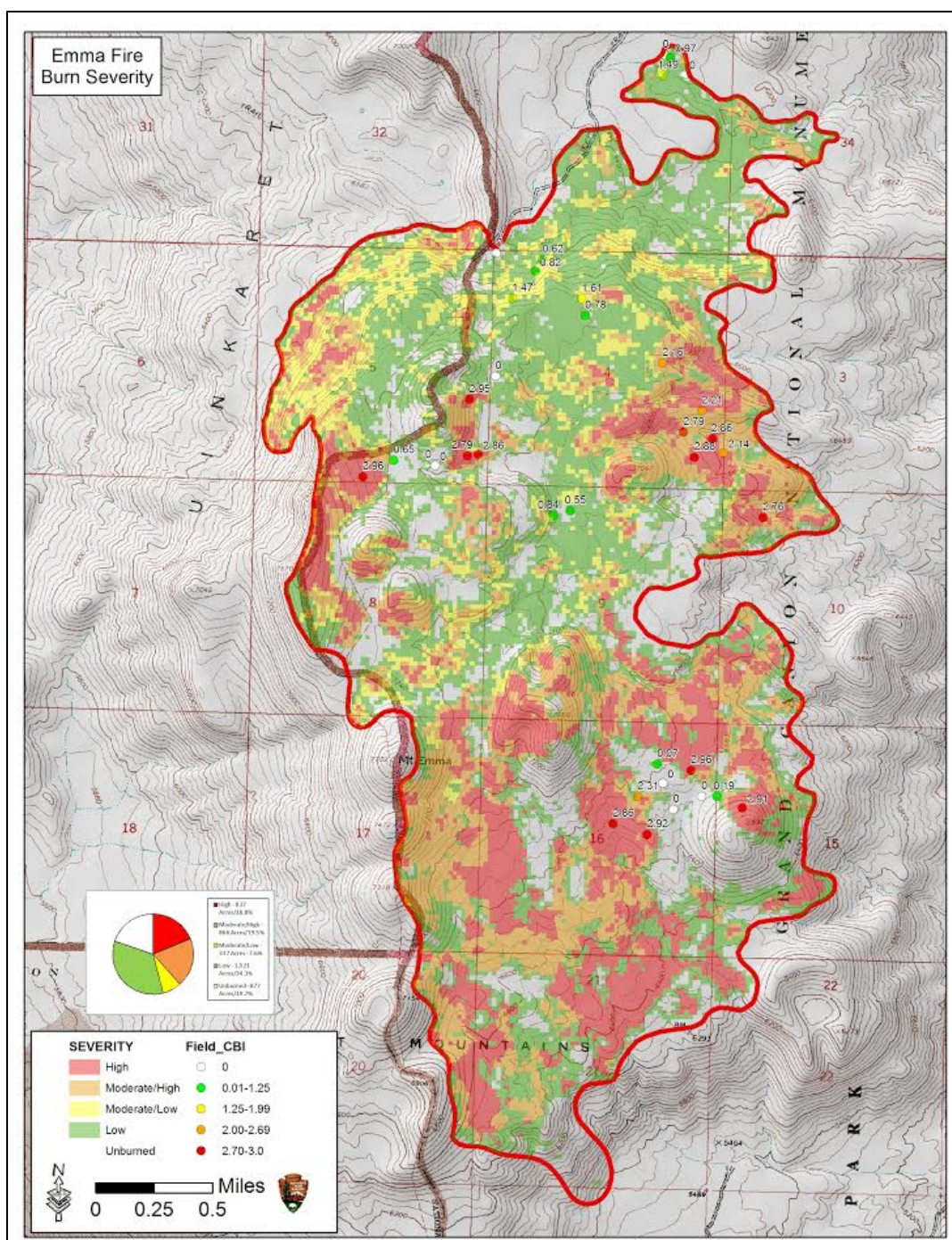


Figure 1. Burn severity for the 2015 Emma Fire from plot data collected within Grand Canyon National Park one year post-fire; the fire also burned on BLM ownership.

Within the 2015 Emma Fire perimeter (the only fire for the year), there was a combined total of 877 unburned acres (20% of the total fire area), 1,521 acres burned with low severity effects (34% of the total fire area), 337 acres burned with moderate/low severity effects (8% of the total fire area), and 1,703 acres burned with moderate/high or high severity effects (38% of the fire area). These numbers include area burned on BLM land. Figure 1 shows the Emma severity map; although 38% of the total fire area burned in moderate/high to high severity, much of the high severity effects occurred in an area dominated by a pinyon-juniper forest type in the southern portion of the fire (83% of the total moderate/high and high severity occurred in this forest type). Figure 2 shows the high severity patch distribution overlaid on forest type.

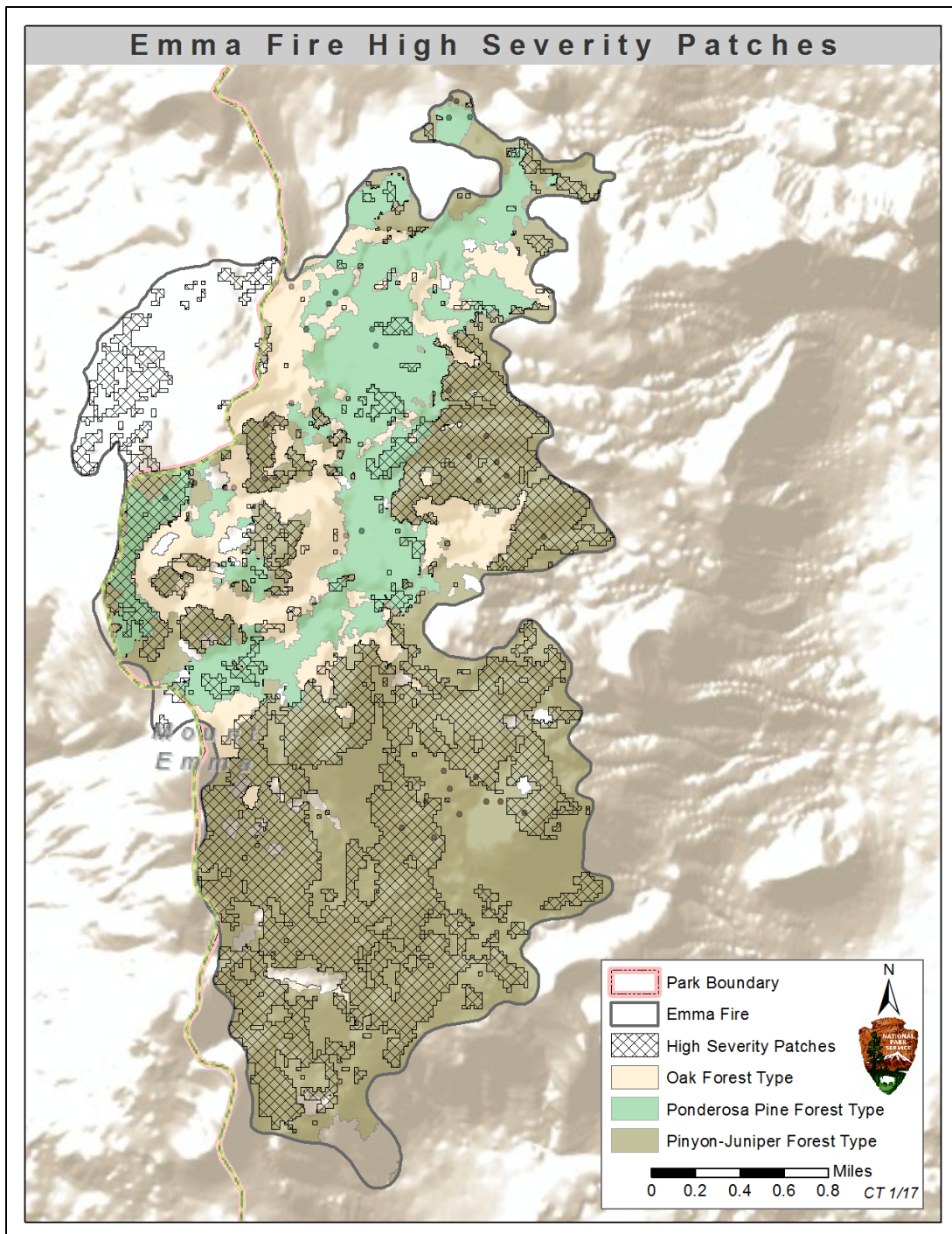


Figure 2. High severity patches in relation to forest type for the 2015 Emma Fire.

Because ponderosa pine and pinyon-juniper forest types are so unique with regard to burn severity mapping and the range of the dNBR threshold numbers, each of the forest types had their own unique set of threshold ranges for severity classifications. These severity numbers are not reflected in Table 9, as the Emma Fire did not occur in an area where monitoring severity patch size is required by the Fire Management Plan (FMP)/EIS. When combining the moderate/high and high severity together into a single 'high severity' class, the largest patches in the Emma Fire were 992 acres and 273 acres, both occurring in forests dominated by pinyon-juniper (where infrequent fires in old growth forests can yield high severity patches).

Cumulative Burn Severity –MTBS data and CBI plots

Landscape-scale severity objectives apply to the three monitoring types in which high severity fire was historically infrequent (PIPO, PIPN, and PIAB) and to the mixed conifer forest type (currently not an FMH monitoring type). The following table provides information on the extent of moderate/high and high severity fire in each monitoring type, although it excludes data from the 2015 Emma fire as described previously.

In all monitoring/forest types, the percentage of moderate/high and high severity fire on the landscape falls within the objective range. Some patches of moderate/high and high severity fire exceed the objective size in the PIPO, PIPN, and PIAB monitoring types. This has not changed in the past year, as the only fire occurred outside of areas which we monitor.

Table 9. Management Objectives and Monitoring Results for fire severity.

Monitoring Unit	Management Objectives	Monitoring Results (all patches >0.1 acres)	Objectives Achieved?
Ponderosa Pine (PIPO) South Rim	Limit high severity fire to patches <5 acres across ≤5 % of monitoring type 10 year period fires from 2006 to 2015	1% moderate/high and high severity 6 patches >5 acres largest patch: 7 acres	YES - percent NO - size
Ponderosa Pine (PIP) North Rim	Limit high severity fire to patches <5 acres across ≤5 % of monitoring type 10 year period fires from 2006 to 2015	3% moderate/high and high severity 18 patches >5 acres largest patch: 52 acres	YES - percent NO - size
Ponderosa Pine w/ White Fir Encroachment (PIAB) North Rim	Limit high severity fire to patches <10 acres across ≤15 % of monitoring type 10 year period fires from 2006 to 2015	9% moderate/high and high severity 37 patches >10 acres largest patch: 288 acres	YES - percent NO - size
Rocky Mountain Montane Conifer (Mixed Conifer) North Rim	Limit high severity fire to ≤30 % of monitoring type fires from 2000 to Present	16% moderate/high and high severity ¹	YES

¹Updated mapping during 2013 altered the percentage of moderate/high and high severity fire in mixed conifer forests compared with previous years.

ADDITIONAL PROGRAM INFORMATION

TABLE 10. Additional Program Information for 2016.

Program Category	Measurement	Grand Canyon National Park	Flagstaff Area National Monuments
Planning	Does park have written Desired Future Conditions (DFCs)?	Yes	Yes
Planning	Date park-level monitoring plan completed (or revised)	2010	Not Completed
Planning	Total # project- or community-level monitoring plans	0	0
Planning	Assisted with how many Burned Area Emergency Rehabilitation (BAER) plans in 2016?	1 ¹	0
Monitoring	% 2016 data entered	100	100
Monitoring	% 2016 data quality checked	100	100
Monitoring	# 2016 prescribed fires monitored (# total prescribed fires monitored) ²	0 (4)	0 (0)
Monitoring	# non-fire fuels treatments monitored	0	0
Monitoring	# 2016 wildfires monitored (# total wildfires monitored) ²	1 (3)	0 (0)
Monitoring	# BAER treatments monitored	0	0
Communication	# project monitoring reports completed in 2016 ³	1	0
Communication	# annual meeting(s) with park staff	4	1
Communication	# formal presentations of results	4	0
Communication	Do you use Minitab?	No	
Research	Are research needs identified in Fire Management Plan (FMP) or monitoring plan?	Yes	Yes
Research	# proposals submitted in 2016	1	0
Research	# proposals funded in 2016	0	0
Research	# research projects supported in 2016 ⁴	7	0
Research	Additional Comments		

¹Fuller Fire; BAER/ES data request and assistance requested by KNF and GRCA jointly.

²Number of fires/treatments completed in 2016 with fire/treatment effects monitoring conducted. Includes pre- and post-fire/treatment monitoring, but not on-site fire behavior monitoring. Number in parentheses represents 2016 post-fire/treatment monitoring of fires/treatments that occurred prior to 2016.

³Existing GRCA protocol burn-day monitoring reports are not included in this number. Project monitoring results for 0 projects included as part of this annual report

⁴Number of research projects supported including logistical info or support, staffing, data sharing, product reviews, etc.

NPS FIRE FUNDED RESEARCH UPDATE

Spatial analysis of the influence of fire severity on forest structure on the North Rim of Grand Canyon National Park using LiDAR and CBI corrected MTBS data (Valentijn Hoff, Eric Rowell, and LLoyd Queen, The University of Montana)

This research project was funded by the NPS Intermountain Region in January 2015 and a cooperative agreement through the Rocky Mountains CESU was completed. University of Montana researchers traveled to GRCA and met with fire management staff in October to finalize project objectives and work plan, and collect additional data. A progress meeting was held in April, and UM researchers presented their findings thus far at the IJWF conference (April), as well as the AFE conference (November); these include structure metrics such as canopy cover (%), canopy bulk density, and canopy base height, and electronic data and maps. Findings thus far visually make sense in terms of what LiDAR is showing vs. what CBI-corrected MTBS data are showing. A trip to the field to validate the maps occurred in the fall of 2016, and a no-cost extension to the agreement was approved allowing travel to do field work and present at a conference. Currently, researchers and GRCA Fire Ecologist are working on a publication of findings.

The research project is expected to be completed by March 30, 2017. Project deliverables include:

- Electronic and/or hard copies of datasets with Federal Geographic Data Committee (FGDC) compliant metadata, this includes the severity / structure relationships and all geospatial data and maps indicating the allocation of structure / severity classes on the landscape
- Presentation to Grand Canyon fire managers
- Presentation at a national scientific conference
- Article submitted to peer-reviewed publication

ON-GOING RESEARCH COLLABORATIONS

GRCA Fire Ecology staff members fulfill data requests from numerous federal and university researchers each year. In addition to the projects described above, the following list illustrates the diversity of collaborators and the types of research to which GRCA Fire Ecology staff (shown in **bold**) made substantial contributions in 2016.

How Does Climatic Stress at Intermediate Timescales Influence Fire Severity? PI: Phillip van Mantgem (USGS); Co-PIs: Emma Williams (U of AZ), Don Falk (U of AZ), Adrian Das (USGS), Jeffrey Kane (Humboldt State University), Mary Beth Keifer (NPS), Jonathan Nesmith (NPS), Nathan Stephenson (USGS). Western Ecological Research Center (WERC). USGS funded. **Casey Teske** and **Li Brannfors** assisted with providing field data as well as some field data collection and plot access.

Identifying nest-roost habitat for Mexican spotted owl on the North Rim of Grand Canyon National Park. Co-PIs: Kurtis Nelson (USGS), Birgit Peterson (USGS Contractor). Funded by USGS EROS Data Center. **Eric Gdula**, **Windy Bunn** and **Li Brannfors** provided data and assisted with field validation.

Fire and Smoke Model Evaluation Experiment (FASMEE). PI: Roger Ottmar (USFS PNW). Co-PIs: Tim Brown (DRI), Sim Larkin (USFS PNW), Nancy French (Michigan Tech). **Casey Teske** and **Dave Robinson** assisted with field/site visits and providing data.

LANDFIRE BPS Updates & Reviews. PI: Kori Blankenship (TNC). **Casey Teske** assisted with review for LANDFIRE BPS types in Grand Canyon.

Publications and Presentations by Collaborators

The following list of publications and presentations highlights the written and oral communication of research done this year (and in which Grand Canyon fire ecology and effects data have been used) by our collaborators. While explicit substantial contributions by Park Fire Ecology staff are not documented, these research projects are the culmination of past funding and partnerships with the GRCA Fire Ecology Program.

Publications

Flatley, W.T., and P.Z. Fulé. 2016. Are historical fire regimes compatible with future climate? Implications for forest restoration. *Ecosphere* 7(10):e01471. 10.1002/ecs2.1471.

Presentations

Fulé, P.Z., P.M. Brown, and T.W. Swetnam. How can managers interpret contradictory literature on historical fire regimes? A case study. 3rd Southwest Fire Ecology Conference, Tucson, AZ, November 28-December 2, 2016.

Fulé, P.Z., D.W. Huffman, M.T. Stoddard, and A.B. Stan. 2016 Southwestern fire use as a climate adaptation tool. Natural Areas Conference, Davis, CA. October 19, 2016.

Fulé, P.Z., L.L. Yocom Kent, C. Cortés Montaña, A. Stan, J. Cerano, J. Villanueva, R. Vallejo, E. Gutiérrez, A. Christopoulou. Fire Regimes Can Be Conserved and Restored: Examples from México, Spain, Greece and U.S.A. AmeriDendro 2016 Conference, Mendoza, Argentina. March 28-April 2, 2016.

Poling, M., A. Thode, and J. Iniguez. Increasing trends in high severity fire in the southwestern USA from 1984-2014. AFE Conference 2016, Tucson, Arizona. November 28-December 2, 2016.

FUTURE PROGRAM DIRECTION

One of the top priorities for the future is to uphold the integrity of our long-term datasets by continuing to hire a full field crew at GRCA, including maintaining the Assistant Lead and Lead positions as permanent status, funded more than the minimum 13 payperiods. Reinstating the internship program for fire ecology would help move the program forward while simultaneously providing real-world experience to interns. The ability of the GRCA Fire Ecology Program to continue to assist in ecology, monitoring, and data management efforts for other parks and the regional and national offices is entirely dependent on maintaining full staffing and continuity within our program.

A long-term monitoring strategy for Walnut Canyon is recommended, with future plot measurements and data management being coordinated between the GRCA Fire Ecology Program and the Southern Colorado Plateau Network I&M Program. In addition, thought needs to be given to the best way to provide adaptive, quantitative monitoring for experimental prescribed burns that have no set boundaries and overlap established burn units, before said projects are more widely implemented.

Fire-related measurements have been added to all unburned mixed conifer plots installed by the I&M program and the data through 2015 have been converted into a workable FFI database. Future collaboration efforts will focus on ensuring that the data management and plot visit protocols will work for both groups. The CBI plot workload will be challenging as the continued struggle with multiple entry fire will persist and be compounded by large areas of overlapping high severity from the 2000 Outlet and 2016 Fuller Fires. RAP plots will be analyzed to provide data for burn plans, and, personnel allowing, be re-measured if planned large-scale fall prescribed burns occur. As usual, the North Rim will presently be the site of most 2017 GRCA field work, hosting ~65% of FMH plot and 100% of RAP, I&M, and CBI plot reads.

Building on our multiple years of testing and implementation with FFI Lite, fire monitoring software, and tablet hardware platforms, we would like to continue providing insight into the refinement of applications and protocols for mobile device-based data collection on both plots and active fires. Moving from paper datasheets to mobile applications has been realized and maintained within our program, and we hope to stay heavily involved in the development and implementation of future products. We will be asking the IMR to support the Lead in terms of time spent assisting and travel to other parks to help train Fire Ecology staff with tablet-based electronic data collection and management. The program will also continue our commitment to working with researchers to develop solid scientific datasets for management decision-making and with outreach staff to educate internal and external audiences about fire in GRCA and the NPS. Finally, we'd like to initiate more robust analyses of our data (whether in-house or by collaborating with researchers) to better understand the space-time dimensions of our data in relation to our FMP objectives.



Figure 3. Teamwork (GRCA, ZION, & SAGU) makes us all better.

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GRCA Fire Ecology 2016 Annual Report