Assessing Effects of Large Wildland Fires in Mexican Spotted Owl Protected Activity Centers

By Don Normandin

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School of Forestry

Northern Arizona University

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Abstract

Wildland fire sizes in the American Southwest have increased over the last few decades creating challenges for managing public lands, including habitat for Mexican spotted owls (*Strix occidentalis lucida,* MSO). The US Forest Service (USFS) Region 3 defines MSO habitat as pine-oak (*Pinus* spp.-*Quercus* spp.), mixed-conifer or forest stands dominated by Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and white fir (*Abies concolor* (Gordon & Glend.) Lindl. Ex Hilderbr.). The US Fish and Wildlife Service (1995) listed the MSO as "threatened" in 1993 prompting the USFS to identify Protected Activity Centers (PACs) and reduce high-severity wildland fires therein, which can endanger MSO habitat. Understanding the trends of high-severity wildland fires in MSO habitat since the species was listed provides another tool for managers to protect limited habitat for this species. I overlaid spatial data layers of fire severity and vegetation with 387 PAC boundaries to assess patches of high-severity burned area of fires >405 ha from 1992 through 2011 on MSO PACs on the Four Forest Restoration Initiative landscape. I used Fragstats to acquire average-weighted mean area of high-severity burn patches within each fire boundary and for individual PACs. I analyzed forest types burned by high-severity fire and assessed impacts to MSO habitat. High-severity burn patches in MSO PACs occur at higher rates in fires >4,047 ha than fires <4,047 ha. Wildland fires burned some portion of 180 PACs, 86% of which were affected by high-severity fire. Given trends in size of wildland fires and high-severity burn patches I recommend extensive treatments outside PACs, maximum allowable treatments inside PACs, and aggressive fire suppression efforts of fires ≥4,047 ha.

Introduction

The U.S. Fish and Wildlife Service (FWS) listed the Mexican spotted owl (*Strix occidentalis lucida*; hereafter MSO) as "threatened" in 1993 citing threats to its habitat by "destruction or modification" and "overutilization" (USDI Fish and Wildlife Service 1995). In more recent years concerns focused on stand-replacing wildfire (USDI Fish and Wildlife Service 2013). Though not mandated by law to adhere to the recovery plan, federal and state management agencies protect habitat of "threatened" or "endangered" species (USDI Fish and Wildlife Service 1995) by adopting FWS recommendations. The FWS First Revision of the MSO Recovery Plan (U.S. Fish and Wildlife Service 2012) outlines management actions for three types of habitat used by the MSO: Protected Activity Centers (PACs), Recovery Habitat, and Other Forest and Woodland Types. Of these, the most important and regulated areas are PACs, which occur in an uneven patchwork across the landscape; ecosystems at lower elevations include pinyon-juniper (*Pinus* spp., *Juniperus* spp.) and pine-oak (*Pinus ponderosa*, *Quercus* spp.), whereas forests at higher elevations are deciduous-evergreen (Ganey and Balda 1989, Ganey 2004, Ganey et al. 2011). Recommended minimum PAC size is 243 ha, although the Recovery Plan (USDI Fish and Wildlife Service 1995) does allow smaller PAC sizes. MSO select habitat with multi-layered canopies with high percent cover (>40) for nest and roost sites but are not as restrictive when selecting foraging locations (Ganey et al. 1999) although owls tend to avoid managed (e.g., thinned, burned with prescribed fire) forests when unlogged stands are available (Ganey and Balda 1994). Set inside a PAC boundary, the core designates a 40 ha section encompassing known locations of nests or potential nesting habitat (USDI Fish and Wildlife Service 1995). The PACs, and to a greater extent the cores, are protected by and from management actions to minimize disturbance to MSOs during reproduction as the recovery plan

suggests limiting management actions temporally and spatially (U.S. Fish and Wildlife Service 2012). The FWS requests that all actions except the monitoring of mating or reproduction take place during non-breeding times from September to March (U.S. Fish and Wildlife Service 2012).

The MSO is genetically unique from the Northern (*Strix occidentalis caurina*) and California spotted owls (*Strix occidentalis occidentalis*) (Barrowclough et al. 1999) with MSO being the smallest of the three. However, the three species are morphologically similar standing 43-48 cm tall with a wingspan of 100 cm (Sibley 2014) and weighing approximately 500-600g (Gutierrez et al. 1995) with the female larger than the male (Sibley 2014). The MSO is not considered a migrating species.

The habitat range for MSO occurs from southern Utah and southwestern Colorado through Arizona and New Mexico, including parts of west Texas, reaching the southern range in the Sierra Madre Occidental and Sierra Madre Oriental in Mexico (USDI Fish and Wildlife Service 2004). Within the U.S., habitat for the MSO is primarily on federal lands and is divided into landscape scale sections designated as Ecological Management Units (EMU) (U.S. Fish and Wildlife Service 2012). In Arizona, the U.S. Forest Service (USFS) manages most designated habitat as it falls within the boundaries of USFS National Forests.

Select national forests are the focus of the Four Forest Restoration Initiative (hereafter 4FRI) started the planning process to restore "priority forest landscapes" (Four Forest Restoration Initiative. 2011. Memorandum of Understanding. <http://4fri.org/pdfs/MOU_with_signatures.pdf> Accessed 11 Oct. 2014). Developed from the Collaborative Forest Landscape Restoration Program, 4FRI treatments propose thinning ponderosa pine stands to mitigate uncharacteristically large wildland fires and allowing for a safe

return of fire to the ecosystem (Four Forest Restoration Initiative. 2011. Management Recommendations for Firescape 3 of the First Analysis Area. <http://4fri.org/pdfs/documents/collaboration/management_recommendations_firescape3.pdf> Accessed 11 Oct. 2014).

MSO habitat exists scattered throughout the 4FRI landscape, primarily in pine-oak and mixed conifer stands, much of which evolved with low-intensity, frequent fire (Weaver 1951, Swetnam and Baisan 1996, Heinlein et al. 2005). Over a century of fire suppression and domestic livestock grazing allowed overstocking of small trees, which serve as ladder fuels (Moore et al. 1999, Fulé and Laughlin 2007) has led to the need for restoration of these forests as FWS cites concerns for high-severity fire endangering MSO habitat (U.S. Fish and Wildlife Service 2012). Heinlein et al. (2005) documented such an increase in density in mixed-conifer forest in northern Arizona from 52 trees per hectare prior to fire suppression to over 1,606 trees per hectare. These conditions can facilitate the advancement of wildfire from the forest floor into the canopy endangering the vital structure of MSO habitat, especially if it burns at high-severity potentially leaving little more than dead trees and downed logs in an early seral stage forest (Brown et al. 2004). Fires across the western U.S. are starting earlier in the fire season (Westerling et al. 2006), which may be enhanced by projected increased temperatures and decreased moisture (Williams et al. 2010). Dennison et al. (2014) demonstrate trends of increasing number of fires per year and increasing fire size for the mountains of Arizona and New Mexico.

Management actions to mitigate high-severity fires often include removal of ladder fuels while creating openings in the forest canopy. These treatment objectives may be in direct conflict with habitat selection by owls (see Ganey et al. 1999 and Ganey et al. 2003). Owls select

roosting sites in closed canopy forests, possibly to avoid high daytime temperatures (Ganey and Balda 1989) and often select unmanaged forests instead of thinned stands (Ganey and Balda 1994). Recommendations from the Recovery Plan (U.S. Fish and Wildlife Service 2012) allow ≤20% of an EMU to be treated and suggest treatments in other forest and woodland types outside of PACs first to provide a buffer for PACs and recovery habitat. Guidelines stipulate PACs (outside the 40 ha core) can be treated and all thinning activities must be scheduled during the non-breeding season unless a determination has been made that resident owls are not breeding in a given year (U.S. Fish and Wildlife Service 2012).

Over the last few decades, published literature on spotted owls shows broader understanding of sub-species genetic variation (Barrowclough et al. 1999), temperature sensitivity (Ganey et al. 1993), call identification and use (Ganey 1990), and home range and habitat use (Ganey and Balda 1989, Ganey et al. 1999, Ward and Salas 2000, May and Gutierrez 2002, Ganey 2004). Although Bond et al. (2009) illuminated habitat use by California spotted owls in post-fire forests, little information exists in the published literature summarizing effects of wildland fire on MSO habitat (see Bond et al. 2002). Four years post-fire, California spotted owls used habitat with all burn severities; foraging activities included use of high-severity burn areas, which contained high levels of understory growth thought to benefit prey species and roosting in low severity burn areas that maintained higher live basal area and higher canopy cover percent than other moderate- or high-severity burned areas (Bond et al. 2009). Here, I provide an analysis of the extent of high-severity wildland fire in MSO habitat with the following objectives: 1) analyze trends of large wildland fire (>405 ha) from 1992 to 2011 in MSO habitat within the boundary of 4FRI in Arizona 2) quantify high-severity burn area using average-weighted mean area of high-severity burn patches for individual PACs in 4FRI MSO

habitat from 1992 to 2011. Biologists may use this information coupled with owl populations to determine specific thresholds for tolerance of high-severity fire patches within MSO PACs. Planning for 4FRI is ongoing which may allow land managers to incorporate these results in treatments.

Methods

The study area for this project was the 4FRI landscape in Arizona, U.S.A. (Figure 1). The scope of the 4FRI collaborative restoration effort is 971,246 ha including all or part of the Coconino, Kaibab, Tonto, and Apache-Sitgreaves National Forests. Inside the 4FRI boundary the USFS identified 25 different categories of vegetation, which in total are dominated by ponderosa pine followed by stands of pine-oak. Higher elevations support stands of aspen (*Populus tremuloides* Michx.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), white fir (*Abies concolor* (Gordon & Glend.) Lindl. Ex Hilderbr.), and white pine (*Pinus strobiformis* Engelm.). At lower elevations pinyon-juniper stands prevail interspersed with grassland. Precipitation patterns for the area are bimodal with approximately 50% by winter snowfall and 50% by summer monsoon storms with annual mean precipitation approximately 50 cm. At the northern end of the 4FRI boundary Williams has an annual mean maximum temperature of 18°C and mean minimum temperature of 3°C. In the middle of the study area, Heber has an annual mean maximum temperature of 18°C and minimum mean temperature of 2.5°C. At the southeastern end of the 4FRI boundary Alpine has an annual mean maximum temperature of 17°C and a mean minimum temperature of -3.5°C (National Oceanic and Atmospheric Administration. 2014. Annual Climatology Summaries from 1992 to 2011 for Williams, Heber, and Alpine, AZ. <http://www.climate.gov/maps-data>. Accessed 3 November 2014.).

Flagstaff is the most populated city in the 4FRI area with the 2010 census recording >65,000 residents (City of Flagstaff. 2014. <http://www.flagstaff.az.gov/index.aspx?NID=1095> Accessed 21 Oct. 2014) with many smaller municipalities interspersed in the study area. The presence of so many human establishments creates wildland-urban interfaces and increases potential human-wildfire interaction and enhances the need for forest treatments.

GIS Procedures

I summarized the impact of wildfire on MSO PACs in the 4FRI area for a period encompassing two decades (1992 to 2011) corresponding with the time frame the MSO was listed as "threatened" using ArcMap (version 10.2.1.3497, ESRI 2013). Specifically, this study considered the intersection of MSO PACs and forest fires ≥ 405 ha (at the time of data acquisition, comprehensive data layers were only available for fires ≥405 ha from Monitoring Trends and Burn Severity website (www.MTBS.gov)) within the 4FRI boundary.

I downloaded data layers for wildland fires ≥405 ha from MTBS.gov (MTBS Data Search and Distribution Tools. 2014. <http://www.mtbs.gov/data/customquery.html> Accessed 1 Feb. 2014) using the following criteria: years 1992 to 2011 (2011 was the most recent year all fires are represented on MTBS.gov), spatial = Arizona, size ≥ 1,000 acres (405 ha), administrative ownership= Forest Service, type = all, assessment type = both, and data version = both. Analysts create MTBS GIS layers by comparing pre- and post-fire satellite imagery, defining fire area by the "multi-spectral difference" between the images (Miller and Thode 2007). The USFS Region 3 office provided the GIS data layer for MSO PACs for all of Region 3 (C. Bogart, GIS and Photogrammetry Unit Leader, USFS, Southwestern Region, personal comm. 31 Jan 2014). I compiled fire layers on a map showing MSO PACs within the 4FRI boundary. Fires that burned

any part of a PAC (any intersection ≥1 pixel overlap of fire layer and PAC layer) contributed to the analysis. Due to influences of multiple fires overlapping individual PACs, I separated the fires into four groups (Table 1) so that any PAC would show an effect from only one fire in each fire group. For each fire group, I merged all fire boundaries onto one data layer then used the *clip* function in ARCMap to intersect the PACs layer with the merged layer of each of the four fire groups. This produced patches of burned area in individual, affected PACs from individual fires within each of the four fire groups. After clipping the PACs layer by each fire group layer, I recalculated areas of the PAC polygons to acquire area affected by each fire for any PAC burned. Downloaded data from MTBS.gov included raster layers delineating pre-classified burn severity areas for each fire. For the four fire groups, I used the *mosaic-to-new-raster* feature in ArcMap to compile rasters for each group of fires then converted these to polygons and extracted the high-severity data for each group. Once high-severity burn data were acquired for each PAC, I used the *clip* function in ARCMap on the mid-level vegetation layer with this data to assess which vegetation types burned at high-severity. Areas burned by low and moderate-severity were not assessed due to the specific concern for high-severity fire by FWS (U.S. Fish and Wildlife Service 2012).

I used the "class" category to evaluate high-severity pixels identified as class 4 in MTBS rasters converted to image files at 600 dots per inch. I put image files for 57 fires into Fragstats 4.2 (McGarigal et al. 2012) to acquire an average-weighted mean area for patches of high-severity burns within individual PACs and an average-weighted mean area for high-severity burn patches within entire individual fire boundaries.

Analysis

To identify trends in wildland fire I calculated high-severity burn area within PACs and then standardized by percent of PAC area, since each PAC size is unique. I used a Kruskal-Wallis non-parametric test (Breslow 1970) to test for differences between fire size classes with respect to percentage of high-severity burned area within PACs. Following statistically significant results ($P<0.05$), I used Mann-Whitney tests (DeLong et al. 1988) to make pairwise comparisons between fire size classes. Alpha levels for pairwise tests were adjusted using a Bonferroni correction ($\alpha < 0.05/10 = 0.005$). Tests were conducted using SAS JMP PRO (version 10, SAS International Inc. 2012). I used a two by two contingency table (Table 2) to compare fire size and occurrence of high-severity fire within any PAC to assess probability for high-severity fire occurring in PACS within fires >4,047 ha.

Results

GIS data layers revealed 387 MSO PACs inside the 4FRI boundaries delineating 101,380 ha of total PAC area with average PAC size of 259 ha. Wildland fires ≥405 ha from years 1992 to 2011 affected 180 of 387 PACs (46%) (Table 3). Fires affected 38 PACs (10%) multiple times and four different fires affected one PAC.

I obtained data for 278 fires in National Forests in Arizona; 124 of those burned at least partially inside the 4FRI boundary. Fifty seven fires (20%) burned some portion of at least one MSO PAC, and one fire (2011 Wallow Fire) burned within 72 PACs. Forty one fires showed high-severity burn patches in at least one PAC. Five years (1992, 1993, 1997, 1998, and 2001) did not have fires ≥405 ha that affected any MSO PAC (Figure 2). All five of the years that did not affect PACs were in the first half the 20-year period (1992-2001), while fire burned through

some portion of a PAC in all of the last 10 years of this study. Fires per year showed an increasing trend as well as demonstrating recurrence of fires >150,000 ha (Figure 3). A trend of increased burned area on the 4FRI landscape developed in 2002 and continued through 2011, with obvious surges in hectares burned due to the Rodeo Fire in 2002 and the Wallow Fire in 2011. Years analyzed produced a range of annual total burned area from 7,553 to 234,420 ha with a cumulative total of 586,488 ha. Cumulative high-severity burn in PAC area increased dramatically in individual years; in two separate fire years cumulative totals doubled (Pumpkin Fire in 2000, Wallow Fire in 2011) and in one fire year the cumulative total quadrupled (Rodeo Fire in 2002 a.k.a. Rodeo-Chediski Fire) (Figure 4). Fire at all severity levels in the 20-year span burned 43,977 ha of PAC territory (43% of total PAC area), of which 8,402 ha (19%) burned at high-severity.

From 1992 to 2011, 9,345 ha of 48,776 ha (19%) designated PAC area in Coconino National Forest burned (all burn-severity types). In the portion of the Tonto National Forest inside the 4FRI boundary 5,326 ha of 13,749 ha (39%) of all PAC area burned. Fires burned through 847 ha of 1,432 ha (59%) of all PAC area within the portion of the Kaibab National Forest inside the 4FRI boundary and through 28,460 ha of 37,398 ha (76%) of all PAC area in the Apache-Sitgreaves National Forests. PAC area burned at high-severity at the following percentages in each national forest: Coconino 1,207 ha of 48,776 ha (2%), Tonto 1,077 ha of 13,749 ha (8%), Kaibab 308 ha of 1,432 ha (22%), and the Apache-Sitgreaves 5,811 ha of 37,398 ha (16%).

Average-weighted means for area of high-severity burn patches in individual fires ranged from 0.04 ha (Lost Eden Fire) to 896 ha (Rodeo Fire). Average-weighted means for area of high-severity burn patches in all PACs from any one fire ranged from 0.04 ha (Reno Fire) to 83.6 ha

(Pumpkin Fire). Average-weighted means for area of high-severity burn patches for individual PACs from any one fire ranged from <0.1 ha (PAC SPOW030101022 from the Reno Fire) to 93.9 ha (PAC SPOW030105004 from the Rodeo Fire). Although no individual PAC experienced high-severity burn for 100% of the PAC area, 18 PACs had >50% area burned at high-severity. Analysis of average-weighted mean area of high-severity patch sizes within PACs shows patch sizes to be significantly larger in fires >8,094 ha.

Within affected PACs in the 4FRI boundary, 57% of all vegetation area was designated as ponderosa pine or ponderosa pine-mix. The aspen-evergreen-tree-mix accounted for 7% and upper-evergreen-forest-tree-mix vegetation type accounted for 6% of all area. The remaining 22 vegetation types each accounted for 3% or less of the total area within affected PACs. Post-burn, ponderosa pine vegetation type comprised 46% of all 4FRI PAC area burned by high-severity fire. Of all PAC hectares burned by high-severity fire, other vegetation types in the 4FRI area affected are aspen-evergreen-tree-mix at 17%, grass-forb-mix at 10%, upper-evergreen-forest-tree-mix at 5%, white fir at 4%, and upper-deciduous-evergreen-forest-tree-mix at 4%. The remaining 19 vegetation categories combined for the balance of 13% of the high-severity burned area, each accounting for <4% of the total burned area.

Since the MSO was listed as “threatened” fires <4,047 ha accounted for 111 of 124 fires that burned into a PAC in the 4FRI area. Fires <4,047 ha contributed <17% of high-severity burned area within PACs over the 20 years analyzed, whereas fires >4,047 ha accounted for >83% of high-severity burned areas within PACs in the study area.

Discussion

One of two criteria proposed by the FWS to delist the MSO by the year 2022 stipulates owl nesting and roosting habitat must be stable or improving for 10 years based on habitat variables presented in the recovery plan. Desired conditions for MSO habitat include minimum canopy cover in pine-oak of 40% and mixed-conifer of 60% with small canopy openings (0.04 to 1 ha) in nest/roost sites (U.S. Fish and Wildlife Service 2012). Although current conditions of most PACs meet those parameters, given the potential for stand-replacing fire within PACs, meeting proposed canopy cover percentages after treatments may be extremely difficult while maintaining viable MSO habitat. Although Bond et al. (2002) suggest MSO may have evolved with western forests and may be able to adjust to the effects of wildland fires in the short-term, the selection of unmanaged forests by the MSO (Ganey and Balda 1994) calls into question the amount of area to treat and what level of fuel and canopy cover to remove.

The Recovery Plan (U.S. Fish and Wildlife Service 2012) guidelines on fire management acknowledges that prescribed and wildland fire use outside of PACs will be necessary to allow low- to moderate-severity fire to reduce fuels mitigating high-severity fires. Mechanical thinning concentrated outside of PAC areas may be required prior to returning fire to the landscape with projections for 4FRI treatments set at 121,406 ha over 10 years (Four Forest Restoration Initiative. Proposed Action for Four Forest Restoration Initiative. 2011. <http://4fri.org/documents.html> Accessed 15 Oct. 2014). The continued threat of large wildland fires exists (Agee and Skinner 2005, Fulé et al. 2007, Prather et al. 2008) until managers initiate 4FRI prescriptions or other treatments. The increase of annual total PAC area burned by high-severity fire (Figure 2) coupled with a decrease in percent of high-severity burned hectares in PACs relative to all hectares burned (Figure 5) indicates that annual burned forest area continues

to increase in this study area. These larger fires require that finite, suppression resources protect higher value assets such as communities and residential structures in Wildland Urban Interface areas, drawing resources away from MSO habitat. Even smaller fires challenge fire managers to allot limited resources. Although habitat for "threatened" and "endangered" species is a consideration for incident commanders, safety of firefighters and the public is paramount followed by protection of property (B. Greco, Director of Outreach, Ecological Restoration Institute, personal comm. 17 April 2014).

Cumulative totals of all severity (Figure 4) and high-severity burned (Figure 6) area in PACs show a trend for doubling of burned hectares in individual fire years. In 2000, due to substantial burning of five PACs, the Pumpkin Fire doubled the total PAC hectares burned by high-severity fire in the previous eight fire years. This trend increased during 2002, when the Rodeo-Chedeski Fire quadrupled the PAC area burned at high-severity, in only 15 PACs, totaling 3,537 ha burned. Prather et al. (2008) stated 55 PACs were affected by the Rodeo-Chedeski Fire. Any PACs previously designated in the 4FRI area and now decommissioned could have elevated these totals. The 2011 fire year almost doubled the cumulative high-severity burn area making the final total for this study 8,393 ha burned by high-severity fire, representing >8% of all area designated as MSO habitat in PACs. Projected into the future following the demonstrated pattern from 1992 to 2011, total burned area at any severity could see above 86% of all designated PAC area affected by fire by the year 2031. Extending the pattern forward for high-severity burns results in 16% of PAC area lost. Including additional burned PAC area lost and unaccounted for in this study from the Rodeo-Chedeski Fire, total projected PAC area burned could easily exceed the total area currently designated as PACs. There is no way to

definitively predict PAC area loss due to high-severity fire; however, continued loss of PAC area forces greater reliance on recovery habitat and other woodland and forest types.

Average-weighted mean area of high-severity burn patches (Appendix A) varied throughout the range of fire sizes. The average-weighted mean area of patch sizes within PACs demonstrate a pattern when sorted by fire size (Figure 7) showing a definitive increase for fires >8,094 ha. Identifying specific levels of habitat destruction may be correlated with occupancy rates to illuminate post-fire MSO habitat selection.

These results are based on the returns from searches and subsequent data layers from the MTBS website. Any fires not recorded or returned from the search would not be included in this analysis. Uncertainty exists in the mapping of fire boundaries either by satellite or on the ground; irregular burn patterns of wildland fire accentuate this uncertainty. Due to these uncertainties, inconsistencies may exist in mapping high-severity burns for individual fires. In addition, effects of moderate-severity fires may be underestimated creating an increased impact to MSO habitat not accounted for in this work. Regardless of the date a PAC was designated or fire occurrence during the study period, I assumed that area designated as a PAC has represented MSO habitat throughout the 20-year period analyzed.

I caution in definitively extrapolating from this assessment as fires <405 ha were not included and would certainly affect total hectares and may affect percentages burned in similar analysis. Hypothetically, a high-severity fire as small as 40 ha in a PAC core could cause enough damage to nesting sites to render that PAC unsuitable for owl reproduction for years. This study did not include analysis of nesting or cores areas within any PAC. Additionally, I assumed PACs represented MSO habitat throughout the entire study period without consideration of actions possibly taken by USFWS and USFS to address environmental changes or newly acquired

biologic information pertinent to MSO and its habitat. Biologists on two national forests involved with 4FRI acknowledged adjustments to PAC boundaries to address habitat loss and new information on specific owls (C. Thompson, Wildlife Biologist, Coconino National Forest, personal comm. 8 April 2014, and J. Wilcox Wildlife Biologist, Tonto National Forest, personal comm. 14 April 2014). Therefore, managerial adjustments to PACs over the entire MSO range might be expected.

Management implications

Given the trends of increasing number of fires per year and increasing size of fires shown by Dennison et al. (2014), without intervention wildland fires in the 4FRI area are expected to increase in size; forest treatments will be pivotal in securing MSO habitat by mitigating uncharacteristically large wildland fires. Throughout the area bounded by 4FRI, treatment efforts should carry on at the projected or an increased rate in all areas designated other woodland and forest types as well as recovery habitat reducing the possibility of wildland fire burning into adjacent PACs. Thinning treatments inside PACs should continue up to the maximum allowable area provided by the recovery plan (U.S. Fish and Wildlife Service 2012) and further research on the tolerance of MSO to disturbance by high-severity wildland fire in both the short and long-terms is needed. In spite of recognizing the dangers of fires >4,047 ha, one of the greatest challenges will be to provide adequate resources to assist fire managers to quell wildland fires before exceeding that size and likely losing more designated MSO habitat.

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Figures and Tables

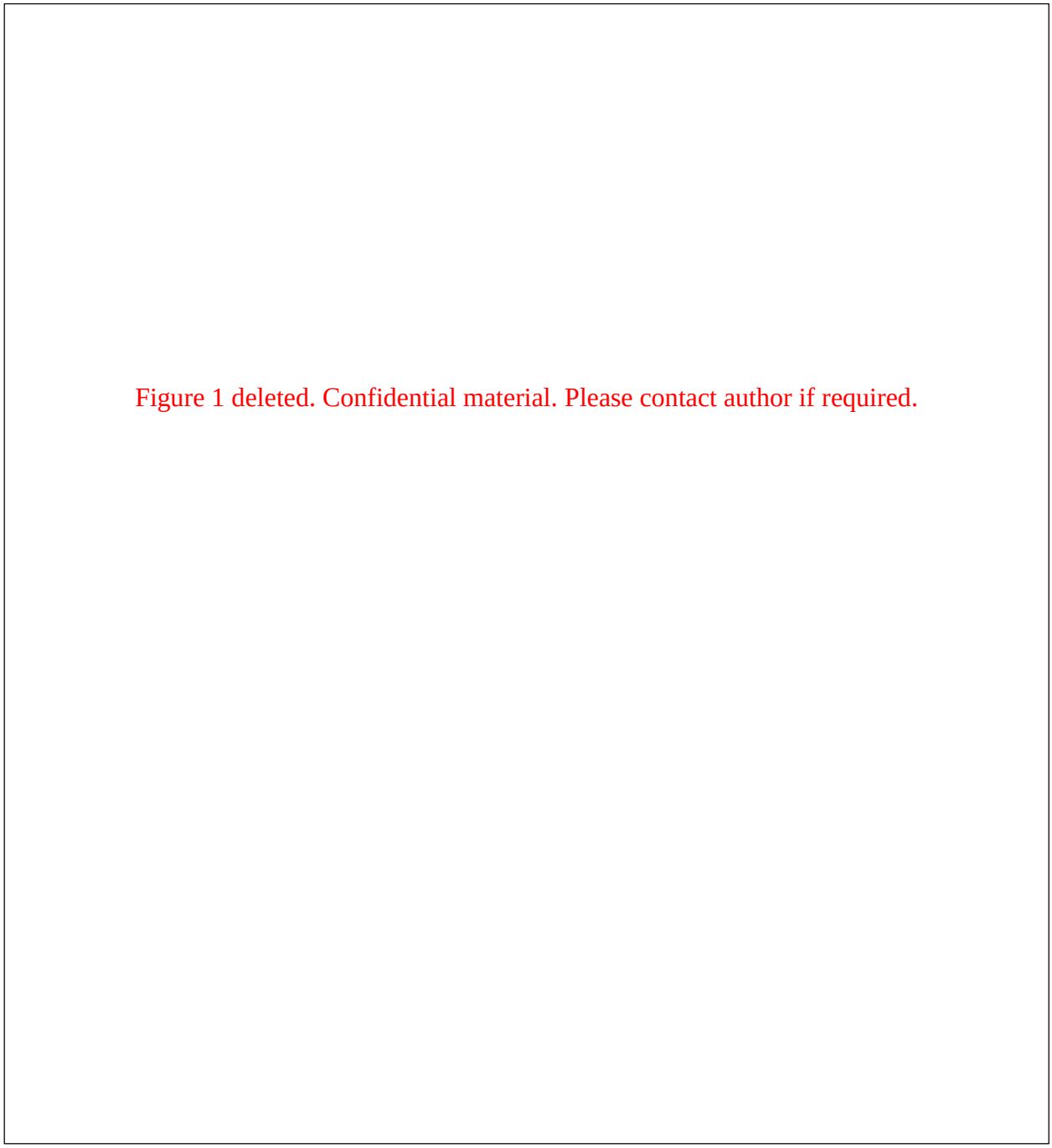

Figure 1. Boundary of Four Forest Restoration Initiative (4FRI) over US. Forest Service National Forests in Arizona, USA. Mexican spotted owl PACs shown as black polygons within 4FRI boundary.

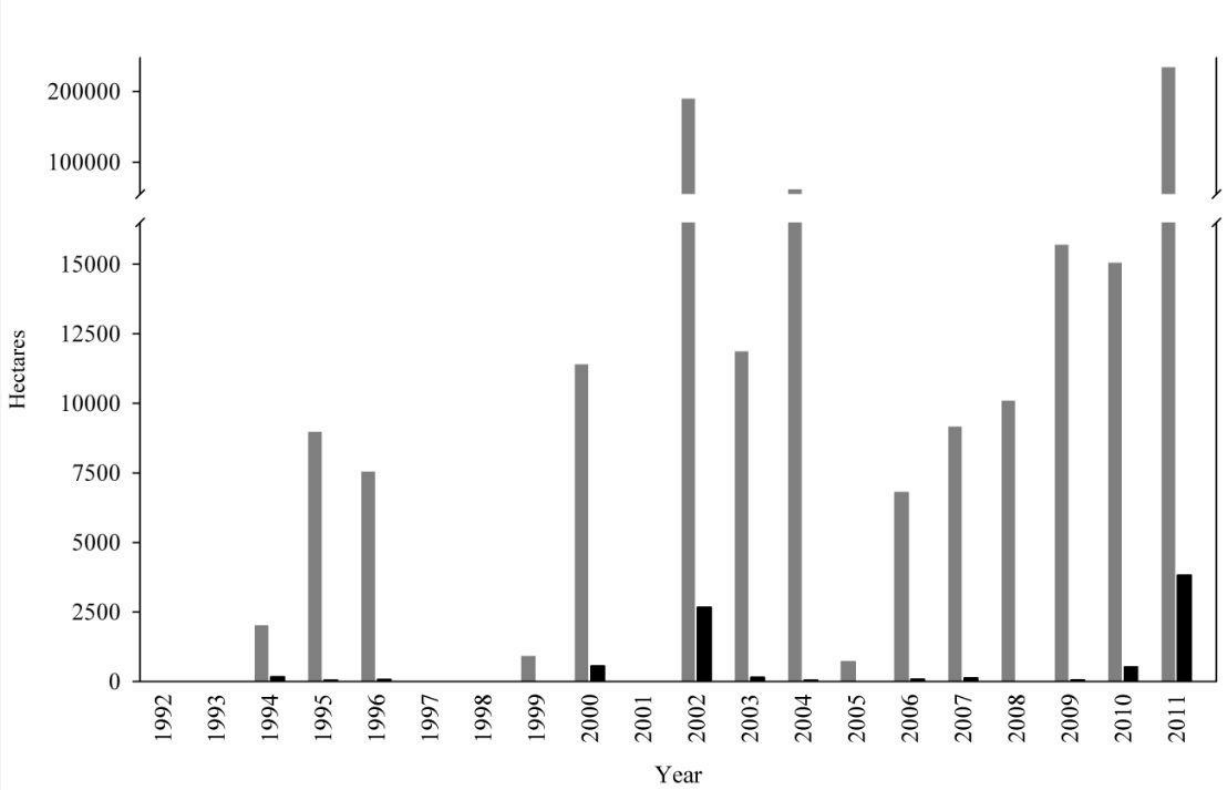

Figure 2. Total annual Mexican spotted owl (MSO) Protected Activity Centers (PAC) area burned (gray) and total PAC area burned at high-severity (black). MSO PACs affected by 405 ha fires within the boundary of The Four Forest Restoration Initiative.

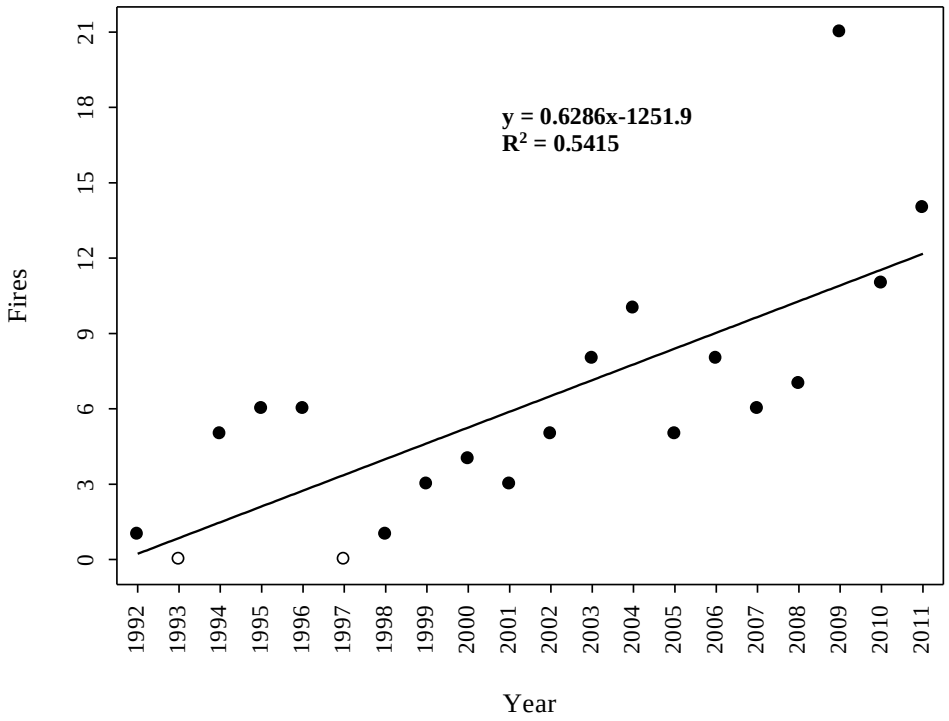

Figure 3. Between 1992 and 2011, 124 fires >405 ha burned within the boundary of the Four Forest Restoration Initiative and burned some part of a Mexican spotted owl Protected Activity Center (PAC). Hollow circles indicate years that had no fires >405 ha that burned into a PAC.

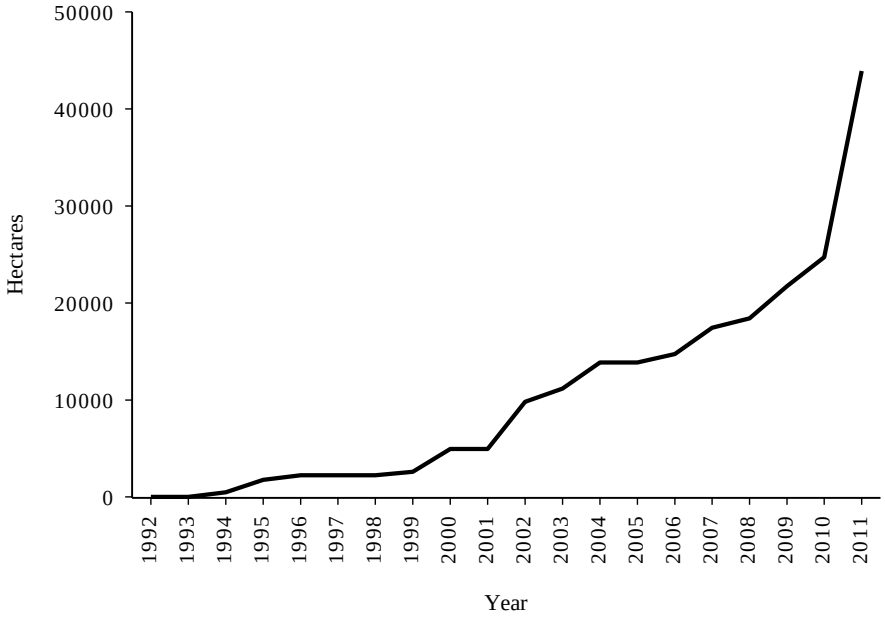

Figure 4. Cumulative Protected Activity Center (PAC) area burned at all burn severities. After the 2002 fire year, the total PAC area burned almost doubled (4,948 to 9,812 ha). In the years 2003 to 2011, cumulative hectares burned in PACs by all burn severities more than quadrupled to 43,922 ha with the spike in 2011 from the Wallow Fire.

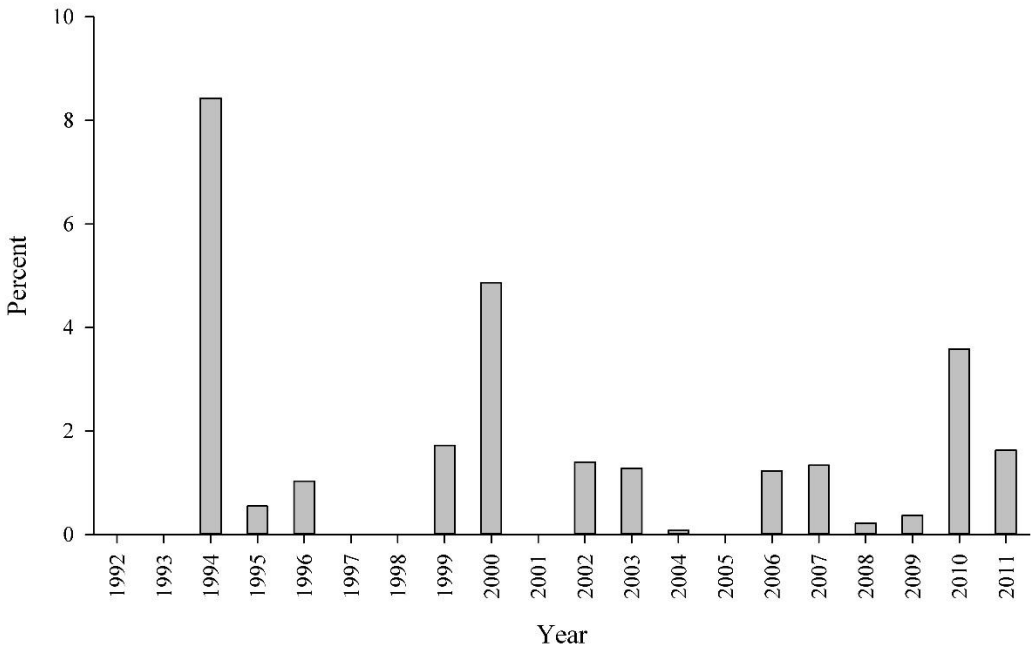

Figure 5. Annual Protected Activity Center (PAC) area burned as a percentage of all Four forest Restoration Initiative area burned by fires >405 ha. The drop in percent of total area burned coupled with the increase of PAC area burned in the same time period (figure 2) indicates fires are getting larger.

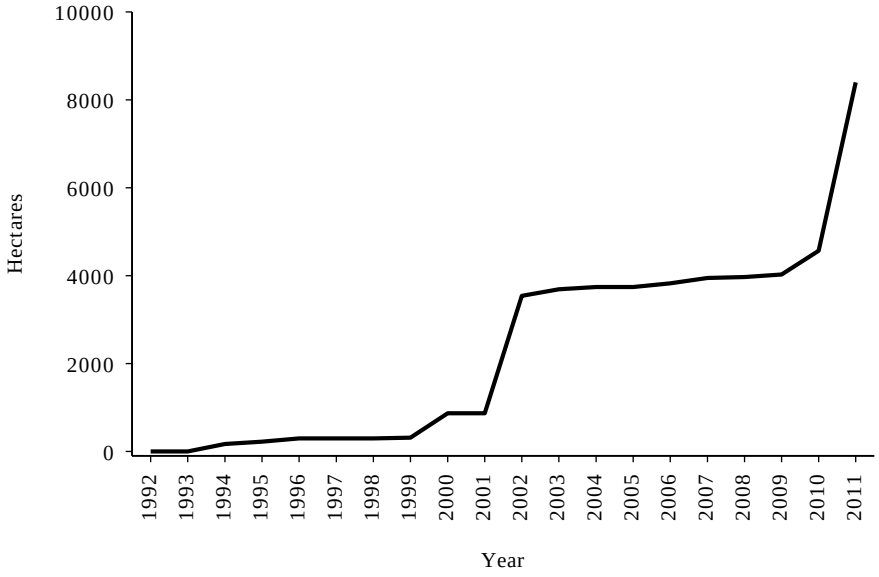

Figure 6. Mexican spotted owl Protected Activity Center (PAC) area burned by high-severity fire. The trend illustrates a series of years increasing the number of high-severity burned hectares in PACs by a factor of two, three or four. Fire year 2000 doubled high-severity burned area from the previous 9 years (312 to 867 ha). Fire year 2002 quadrupled cumulative totals from previous years of this study. In 2011, the Wallow Fire again almost doubled the cumulative PAC area burned at high-severity from 4,564 ha to 8,394 ha.

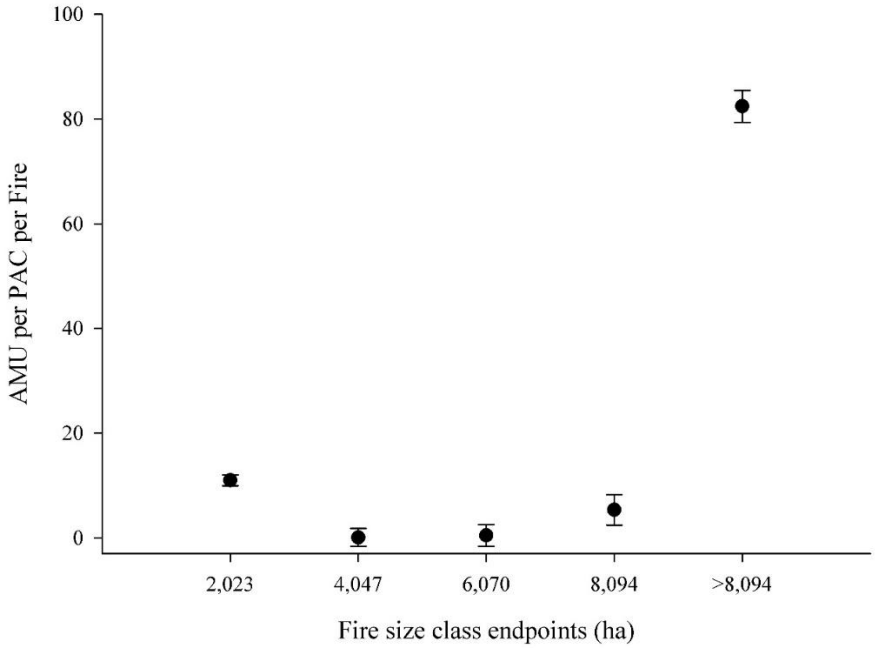

Figure 7. Average-weighted mean (AMU) by fire size. Using high-severity burn patch sizes from Fragstats, patch sizes for each Protected Activity Center (PAC) affected within individual fires were grouped by overall fire size. The elevated average for the largest fire-size group represents larger patch sizes in burned PACs affected by several of the largest of wildland fires. Graph shows AMU mean with SE bars.

Table 1. Fires ≥405 ha that occurred from 1992 to 2011 within the Four Forest Restoration Initiative (4FRI) boundaries used for analysis of high-severity fire in Mexican spotted owl Protected Activity Centers (PACs) in the 4FRI. Separate groups isolated fire effects to individual PACs from single fires for GIS processing. Fire IDs and Fire Names are the U.S. Forest Service labels acquired from GIS data layers from the Monitoring Trends in Burn Severity website.

Group	Year	Fire ID	Fire Name	Fire Size (ha)
1	1994	FS-0304-333-940729	LOST	833.5
1	1996	FS-0304-119-960620	HOCKDERFFER	5,345.9
1	1999	FS-0304-105-990617	TURKEY	907.6
1	2000	FS-0312-038-000426	COON CREEK	3,733.0
1	2000	FS-0307-023-000525	PUMPKIN	6,509.8
1	2000	FS-0304-016-000409	WILLOW	626.2
1	2000	FS-0301-384-000908	ARROW	532.0
1	2002	FS-0307-124-020821	TRICK	2,014.3
1	2003	FS-0312-061-030617	PICTURE	5,477.4
1	2004	FS-0312-062-20040624	WILLOW	47,952.7
1	2004	FS-0301-032-20040608	THREE FORKS	2,770.3
1	2004	FS-0301-020-20040517	ROSE	1,347.1
1	2004	AZ-ASF-000020-20040520	PIGEON	1,682.8
1	2005	FS-332942-1092105-20050411	UNNAMED	712.4
1	2006	FS-0312-014-20060205	FEBRUARY	1,587.9
1	2006	AZ-ASF-060304-20060615	BEAVERHEAD	574.8
1	2006	AZ-COF-091-20060618	BRINS FIRE	1,771.0
1	2007	FS-0312-041-20070513	PROMONTORY	1,718.4
1	2007	AZ-COF-066-20070706	BIRDIE	2,062.5
1	2007	AZ-ASF-070537-20070912	WILKINS	3,289.0
1	2008	FS-0304-199-20080907	LOST EDEN	632.2
1	2008	FS-0301-056-20080622	BEAR MOUNTAIN	900.3
1	2009	FS-0304-183-20090816	TAYLOR	1,454.6
1	2009	FS-0304-102-20090704	FOURTH OF JULY COMPLEX	1,302.2
1	2009	FS-0304-048-20090526	TUCKER	1,091.4
1	2009	FS-0301-153-20090907	RENO	2,823.1
1	2009	FS-0301-118-20090806	CHEVLON COMPLEX (WEIMER)	4,856.6
1	2009	FS-0301-121-20090807	CHEVLON COMPLEX (CROSSING)	1,195.8
1	2010	FS-0307-012-20100616	EAGLE ROCK	1,351.2
1	2010	FS-0304-069-20100620	SCHULTZ	5,648.4
1	2010	FS-0304-164-20100816	WEIR	716.9
1	2011	AZ34468111482201107 21	SANDROCK	1,642.1
1	2011	AZ34987111594201107 09	BOLT	1,019.3
1	2011	AZ34725111550201107 18	ROCKY	612.1
1	2011	AZ34189110853201108 01	BLUFF	861.3
2	1994	FS-0301-006-940423	S CANYON	1,187.0
2	1996	FS-0304-125-960621	POT	2,207.6
2	2002	UNK-34441-111291-20020901	UNNAMED	1,278.8
2	2003	FS-0301-138-030712	STEEPLE	2,075.9
2	2003	FS-0301-055-030606	THOMAS	4,317.0
2	2004	FS-0312-020-20040329	WEBBER	1,277.6
2	2006	UNK-34542-110718-20060608	UNNAMED	2,409.2
2	2006	AZ-ASF-060100-20060422	SAND/Encino	450.0
2	2007	AZ-ASF-070249-20070630	CHITTY	2,102.1
2	2008	FS-0301-055-20080622	HOT AIR	3,685.7
2	2009	FS-0304-058-20090601	REAL	1,922.8
2	2010	FS-0304-101-20100717	RANGER COMPLEX	1,155.7
2	2010	FS-0301-113-20100910	CIRCLE BAR	1,860.9
2	2011	AZ33835111010201108 20	TANNER	2,178.8
3	1995	FS-0301-159-950717	RHETT	8,983.0
3	2002	BIA-H50H52-0251-20020618	RODEO	186,873.3
3	2004	FS-0301-018-20040517	KP	6,607.8
3	2008	FS-0301-014-20080422	EAGLE	4,880.2
3	2009	FS-0312-097-20090720	RIM	1,051.5
3	2010	FS-0304-177-20100821	RANGER COMPLEX (BRAVO)	1,724.2
3	2010	FS-0301-034-20100607	PARADISE	2,596.4
4	2011	AZ33602109449201105 29	WALLOW	228,107.0

Table 2. Two by two contingency table showing Mexican spotted owl (MSO) Protected Activity Centers (PACs) with high-severity (HS) burn patches. Fires >4,047 ha are significantly ($P < 0.001$) more likely to burn an MSO PAC with high-severity fire than fires <4,047 ha (n=125).

	Yes	No	% PACs with HS fire
<4,047 ha	28	83	25.2%
>4,047 ha	13	1	92.9%

Table 3. Information regarding Mexican spotted owl (MSO) PACs within the Four Forest Restoration Initiative (4FRI) boundary. All information stems from fires recorded between 1992 and 2011 with a minimum size of 405 hectares. The PAC information used was current as of 1 February 2014 and assumed to represent MSO habitat throughout the 20 year period analyzed, regardless of when a PAC was designated.

PACs in 4FRI boundary	387
PACs affected by fires ≥ 405 ha	180
PACs affected by high severity fire	154
PACs affected only once by fire	142
PACs affected 2 times by fire	32
PACs affected 3 times by fire	5
PACs affected 4 times by fire	1
Total hectares designated by PACs	101,380.2
Cumulative hectares burned in PACs from 1992 to 2011 from fires ≥405 ha (any severity rating)	43,977.3
Cumulative PAC hectares burned by high severity fire	8,402.5
Average hectares/PAC in 4FRI area	259.3

Appendix A. Mexican spotted owl Protected Activity Centers (PACs) affected by individual fires. Average-weighted mean (AMU) area for individual fires and for cumulative AMU listed once on line with the first PAC listed for each fire. All numbers represent area measured in hectares. (H-S = high-severity, * = indicates not applicable)

Year	Fire Size ha	Fire Name	AMU H-S patches per fire ha	AMU H-S patches all PACs per fire ha	National Forest	Protected Activity Center (PAC)	PAC size ha	PAC area burned all severities ha	PAC area burned H-S ha	PAC H-S AMU ha
1992		n/a					*			
1993		n/a					*			
1994	833.5	LOST	31.96	29.82	COC	PAC Secret Mountain 030406004	335.2	309.2	151.21	33.36
1994		LOST			COC	PAC Secret Cabin 030402022	245.1	86.2	16.92	2.16
1994		LOST			COC	PAC Secret Canyon 030406005	271.3	31.5	2.14	0.19
1994	1187.0	S CANYON	1.08		APS	SPOW030101043 Pueblo Park PAC	256.0	51.4	*	
1995	8983.0	RHETT	6.21	2.62	APS	SPOW030101044 Franz PAC	265.6	265.6	18.06	5.72
1995		RHETT			APS	SPOW030101039 Lanphier Creek PAC	273.3	259.6	7.88	1.46
1995		RHETT			APS	SPOW030101045 Dutch PAC	267.5	253.9	13.43	0.95
1995		RHETT			APS	SPOW030101146 Telephone PAC	259.0	221.3	7.08	0.77
1995		RHETT			APS	SPOW030101053 Sawmill PAC	271.7	222.6	1.22	0.15
1995		RHETT			APS	SPOW030103003YAMCANYON	280.4	62.8	1.51	0.21
1996	2207.6	POT	3.58	1.56	COC	PAC Aztec 030404019	263.0	262.1	52.78	1.43
1996		POT			COC	PAC Pecks Point 030404042	292.2	169.6	11.28	1.05
1996	5345.9	HOCKDERFFER	112.22	3.92	COC	PAC Hochderffer 030402032	337.6	38.1	13.38	3.92
1997		n/a					*			
1998		n/a					*			
1999	907.6	TURKEY	1.10	0.58	COC	PAC Jack in the Box 030407028	254.9	168.7	10.75	0.60
1999		TURKEY			COC	PAC Jackie O 030407029	251.2	189.7	4.82	0.50
2000	3733.0	COON CREEK	40.83	5.63	TON	MSO PAC 031205029	265.1	265.1	3.49	0.33
2000		COON CREEK			TON	MSO PAC 031205021	276.0	276.0	3.33	0.44
2000		COON CREEK			TON	MSO PAC 031205030	237.6	117.8	5.35	1.73
2000		COON CREEK			TON	MSO PAC 031205028	273.6	129.2	22.50	7.83
2000		COON CREEK			TON	MSO PAC 031205014	229.4	102.2	16.09	6.34
2000	6509.8	PUMPKIN	160.95	83.64	KAI	Kendrick PAC 070201	228.8	228.8	160.18	60.52
2000		PUMPKIN			KAI	Newman PAC 070210	230.1	230.1	23.15	3.12
2000		PUMPKIN			COC	PAC Jeep 030402029	274.9	274.9	154.05	60.33

Appendix A (con't)

Year	Fire Size ha	Fire Name	AMU H-S patches per fire ha	AMU H-S patches all PACs per fire ha	National Forest	Protected Activity Center (PAC)	PAC size ha	PAC area burned all severities ha	PAC area burned H-S ha	PAC H-S AMU ha
2000		PUMPKIN			COC	PAC Crater Spring Tank 030402037	339.2	339.2	137.64	50.26
2000		PUMPKIN			COC	PAC Stock Tank 030402030	261.2	261.2	29.38	8.57
2000	626.2	WILLOW	*		COC	PAC Wingfield 030404035	271.2	115.7	*	
2000	532.0	ARROW	0.47		APS	SPOW030103004BLUEVISTA2	280.9	15.3	*	
2001		n/a					*			
2002	1278.8	UNNAMED	14.16	14.51	TON	MSO PAC 03120412	261.8	247.7	101.01	12.22
2002		UNNAMED			TON	MSO PAC 031204008	253.8	166.3	65.32	14.99
2002		UNNAMED			COC	PAC Immigrant 030404014	244.3	98.7	3.18	0.28
2002	2014.3	TRICK	13.14	7.97	KAI	Tule PAC 070115	326.6	326.5	87.76	7.97
2002	186873.3	RODEO	896.08	44.73	TON	MSO PAC 031205004	213.7	213.7	185.06	71.10
2002		RODEO			TON	MSO PAC 031205002	244.6	244.6	128.63	18.93
2002		RODEO			TON	MSO PAC 031205008	268.8	268.8	81.43	9.00
2002		RODEO			TON	MSO PAC 031205011	250.6	232.5	136.27	36.22
2002		RODEO			TON	MSO PAC 031205012	147.6	147.6	29.22	1.00
2002		RODEO			TON	MSO PAC 031205013	214.1	214.1	104.37	14.35
2002		RODEO			APS	SPOW030105001 Eubank Tank PAC	245.9	245.9	126.77	17.14
2002		RODEO			APS	SPOW030105002 East Fork PAC	244.4	244.4	173.01	65.69
2002		RODEO			APS	SPOW030105003 Twin Lakes PAC	244.7	244.7	161.69	1.38
2002		RODEO			APS	SPOW030105004 Bull Flat PAC	247.6	247.6	234.53	93.86
2002		RODEO			APS	SPOW030105005 Chediski PAC	243.0	243.0	181.02	35.41
2002		RODEO			APS	SPOW030105006 Blue Lake PAC	243.2	243.2	161.81	54.12
2002		RODEO			APS	SPOW030105007 Bear Canyon PAC	245.6	245.6	163.38	23.75
2002		RODEO			APS	SPOW030105014 Hangman's PAC	243.1	243.1	179.27	69.13
2002		RODEO			APS	SPOW030105010 Jersey Canyon PAC	252.5	252.5	97.86	5.67
2002		RODEO			APS	SPOW030105008 Horse Tank PAC	245.6	242.3	136.29	38.32
2002		RODEO			APS	SPOW030105009 Cemetery PAC	251.1	251.1	141.12	17.03
2003	5477.4	PICTURE	95.64	17.51	TON	MSO PAC 031205017	243.5	239.7	89.94	17.54
2003	2075.9	STEEPLE	56.13	4.76	APS	SPOW030101054 Butterfly PAC	267.9	54.3	14.36	5.51
2003		STEEPLE			APS	SPOW030101027 Upper KP Creek PAC	258.8	43.7	2.53	0.81
2003	4317.0	THOMAS	20.00	1.59	APS	SPOW030101060 Foote Creek PAC	263.9	263.9	12.59	1.25
2003		THOMAS			APS	SPOW030101057_1993 Castle Rock PAC	293.6	293.6	11.49	2.29
2003		THOMAS			APS	SPOW030101015 Hannagan Creek PAC	285.6	68.3	1.92	0.21
2003		THOMAS			APS	SPOW030101026 East Castle PAC	282.8	170.7	11.59	1.86
2003		THOMAS			APS	SPOW030101058_1994 Oliver PAC	268.2	236.0	7.95	0.99

Appendix A (con't)

Year	Fire Size ha	Fire Name	AMU H-S patches per fire ha	AMU H-S patches all PACs per fire ha	National Forest	Protected Activity Center (PAC)	PAC size ha	PAC area burned all severities ha	PAC area burned H-S ha	PAC H-S AMU ha
2004	47952.7	WILLOW	11.93	0.09	TON	MSO PAC 031204017	277.2	277.2	0.68	0.07
2004		WILLOW			TON	MSO PAC 031204018	282.9	282.9	0.54	0.12
2004	1277.6	WEBBER	2.98	0.29	TON	MSO PAC 031204024	308.4	171.8	0.12	0.04
2004		WEBBER			TON	MSO PAC 031204021	245.2	237.5	0.42	0.05
2004		WEBBER			TON	MSO PAC 031204020	216.4	76.7	4.46	0.32
2004	2770.3	THREE FORKS	1.67	1.57	APS	SPOW030101006	247.5	164.6	27.19	1.57
2004		THREE FORKS			APS	SPOW030106003 OD Ridge PAC	243.3	1.0	*	
2004	6607.8	KP	2.36	0.89	APS	SPOW030101051 Rim PAC	281.1	281.1	0.81	0.33
2004		KP			APS	SPOW030101027 Upper KP PAC	258.8	258.8	12.30	1.03
2004		KP			APS	SPOW030103008RASBERRY	299.2	299.2	*	
2004		KP			APS	SPOW030101054 Butterfly PAC	267.9	207.1	2.14	0.33
2004		KP			APS	SPOW030101028 Lower KP Creek PAC	276.4	248.0	*	
2004		KP			APS	SPOW030103004BLUEVISTA2	280.9	4.8	*	
2004	1347.1	ROSE	0.14		APS	SPOW030103001BRIGHAM_1993	299.2	2.8	*	
2004	1682.8	PIGEON	*		APS	SPOW030103HLCANYON PAC 030110	260.7	172.9	*	
2005	712.4	UNNAMED	0.13		APS	SPOW030103005HOTAIR	450.7	0.5	*	
2006	2409.2	UNNAMED	11.42	0.98	APS	SPOW030105017 Grapevine PAC	244.0	85.6	3.36	0.78
2006		UNNAMED			APS	SPOW030105018 Oxbow PAC	243.8	30.4	4.43	1.14
2006	1587.9	FEBRUARY	1.33	1.82	TON	MSO PAC 031204014	332.7	332.7	37.53	1.86
2006		FEBRUARY			TON	MSO PAC 031204020	216.4	58.5	0.82	0.15
2006		FEBRUARY			TON	MSO PAC 031204008	253.8	4.9	0.03	0.09
2006	450.0	SAND/ENCINO	0.37		APS	SPOW030104024 N. Alder PAC	245.6	8.7	*	
2006	574.8	BEAVERHEAD	4.79	4.45	APS	SPOW030101015 Hannagan Creek PAC	285.6	55.1	12.87	4.45
2006	1771.0	BRINS FIRE	3.99	0.86	COC	PAC Lost 030406007	360.5	348.3	24.57	0.86
2007	1718.4	PROMONTORY	0.70	0.70	TON	MSO PAC 031204016	243.1	243.1	0.49	0.06
2007		PROMONTORY			TON	MSO PAC 031204007	248.7	243.5	8.93	0.76
2007		PROMONTORY			TON	MSO PAC 031204004	243.1	192.6	0.13	0.04
2007	2062.5	BIRDIE	4.13	3.16	COC	PAC Milos Butte 030405005	267.6	266.6	3.72	0.83
2007		BIRDIE			COC	PAC Girdner 030405027	294.2	294.2	32.50	4.33
2007		BIRDIE			COC	PAC Two Holes 030405028	251.5	189.4	10.37	1.24
2007		BIRDIE			COC	PAC Racetrack Tank 030405017	269.7	202.5	*	
2007		BIRDIE			COC	PAC Bar M 030405030	250.2	250.2	1.34	0.42
2007		BIRDIE			COC	PAC Iris Tank 030405006	284.1	55.2	2.96	1.17
2007		BIRDIE			COC	PAC Bristow Tank Limpios 030405018	336.7	6.0	*	

Appendix A (con't)

Year	Fire Size ha	Fire Name	AMU H-S patches per fire ha	AMU H-S patches all PACs per fire ha	National Forest	Protected Activity Center (PAC)	PAC size ha	PAC area burned all severities ha	PAC area burned H-S ha	PAC H-S AMU ha
2007		BIRDIE			COC	PAC Foxhole 030405038	249.4	85.8	*	
2007		BIRDIE			COC	PAC T6 Tank 030405016	317.3	155.0	4.29	0.68
2007	3289.0	WILKINS	0.26		APS	SPOW030104028 S. Wilkins PAC	245.6	245.6	*	
2007	2102.1	CHITTY	6.99	2.93	APS	SPOW030103004BLUEVISTA2	280.9	280.9	58.30	2.93
2008	632.2	LOST EDEN	0.04	0.04	COC	PAC Todd Draw 030407039	234.0	180.4	0.06	0.04
2008	900.3	BEAR MOUNTAIN	0.07		APS	SPOW030101045 Dutch PAC	267.5	13.8	*	
2008		BEAR MOUNTAIN			APS	SPOW030101146 Telephone PAC (EAST)	259.0	9.8	*	
2008	3685.7	HOT AIR	2.46	0.25	APS	SPOW030103001Brigham_1993	299.2	92.9	*	
2008		HOT AIR			APS	SPOW030103007engineer_spring	271.3	227.7	3.33	0.27
2008		HOT AIR			APS	SPOW030103005hot air	450.7	271.1	1.18	0.22
2008	4880.2	EAGLE	1.54	2.35	APS	SPOW030103005HOTAIR	450.7	180.4	17.84	2.35
2009	1051.5	RIM	6.13		COC	PAC Aqueduct 030407034	316.9	126.1	*	
2009	1454.6	TAYLOR	41.24	0.11	COC	PAC Bunker 030402025	259.9	21.2	0.53	0.11
2009	1302.2	FOURTH OF JULY COMPLEX	1.40	0.16	COC	PAC Aqueduct 030407034	316.9	317.3	0.27	0.11
2009		FOURTH OF JULY COMPLEX			COC	PAC Turkey 030407035	250.5	250.5	2.19	0.17
2009		FOURTH OF JULY COMPLEX			COC	PAC General Springs 030407004	254.1	101.1	0.06	0.04
2009	1922.8	REAL	3.90	2.31	COC	PAC Milos Butte 030405005	267.6	264.0	9.49	0.83
2009		REAL			COC	PAC Two Holes 030405028	251.5	178.2	16.76	1.87
2009		REAL			COC	PAC T6 Tank 030405016	317.3	166.0	4.08	0.56
2009		REAL			COC	PAC Bristow Tank Limpios 030405018	336.7	92.5	*	
2009		REAL			COC	PAC Racetrack Tank 030405017	269.7	69.4	*	
2009		REAL			COC	PAC Bar M 030405030	250.2	224.5	1.99	0.46
2009		REAL			COC	PAC Foxhole 030405038	249.4	84.2	0.29	0.07
2009		REAL			COC	PAC Iris Tank 030405006	284.1	51.0	3.02	0.55
2009	1091.4	TUCKER	0.13	0.04	COC	PAC Dane Barber 030407019	240.7	45.9	0.06	0.04
2009		TUCKER			COC	PAC South Barbershop 030407041	228.4	80.0	0.35	0.04
2009	2823.1	RENO	2.39	0.04	APS	SPOW030101024 Gobbler Tank PAC	298.4	297.8	*	
2009		RENO			APS	SPOW030101034 Bear Wallow Trail 62 PAC	289.7	10.2	*	
2009		RENO			APS	SPOW030101022 Bear Wallow Confluence PAC	253.4	100.7	0.16	0.04
2009		RENO			APS	SPOW030101023 Fish Barrier PAC	261.2	225.1	0.03	*
2009	4856.6	CHEVLON COMPLEX (WEIMER)	1.85	0.46	APS	SPOW030105018 Oxbow PAC	243.8	224.4	5.55	0.50
2009		CHEVLON COMPLEX (WEIMER)			APS	SPOW030105017 Grapevine PAC	244.0	128.8	0.39	0.10
2009	1195.8	CHEVLON COMPLEX (CROSSING)	14.54	3.36	APS	SPOW030104030 Waters Draw PAC	251.3	251.3	12.91	3.36
2010	1351.2	EAGLE ROCK	37.97	13.33	KAI	Sitgreaves PAC 070205	244.6	61.0	37.32	13.33

Appendix A (con't)

Year	Fire Size ha	Fire Name	AMU H-S patches per fire ha	AMU H-S patches all PACs per fire ha	National Forest	Protected Activity Center (PAC)	PAC size ha	PAC area burned all severities ha	PAC area burned H-S ha	PAC H-S AMU ha
2010	5648.4	SCHULTZ	574.24	65.44	COC	PAC Jack Smith 030402009	244.3	241.7	115.91	19.71
2010		SCHULTZ			COC	PAC Pipeline 030402001	265.7	265.7	227.54	89.68
2010		SCHULTZ			COC	PAC Weatherford 030402008	264.0	237.5	123.30	31.35
2010		SCHULTZ			COC	PAC Aspen Spring 030402035	252.6	50.1	31.29	11.42
2010	716.9	WEIR	*		COC	PAC Fain Mountain 030404010	272.3	209.8	*	
2010		WEIR			COC	PAC Weir 030401004	246.9	166.5	*	
2010		WEIR			COC	PAC Rattlesnake 030401002	327.8	126.7	*	
2010	1724.2	RANGER COMPLEX (BRAVO)	0.22	0.22	COC	PAC North Miller 030407010	255.0	172.5	*	
2010		RANGER COMPLEX (BRAVO)			COC	PAC Rock Crossing West 030407030	242.3	1.1	*	
2010		RANGER COMPLEX (BRAVO)			COC	PAC McCarty 030407024	244.3	6.8	*	
2010		RANGER COMPLEX (BRAVO)			COC	PAC Mid Miller Canyon 030407011	241.0	241.0	0.54	0.22
2010		RANGER COMPLEX (BRAVO)			COC	PAC East Miller Canyon 030404015	268.4	113.1	*	
2010		RANGER COMPLEX (BRAVO)			COC	PAC Turkey 030407035	250.5	3.6	*	
2010	1155.7	RANGER COMPLEX	0.23	0.15	COC	PAC Clear Creek 030407031	251.8	1.7	*	
2010		RANGER COMPLEX		0.00	COC	PAC McCarty 030407024	244.3	201.0	0.12	0.07
2010		RANGER COMPLEX			COC	PAC Rock Crossing West 030407030	242.3	165.6	0.33	0.08
2010		RANGER COMPLEX			COC	PAC North Miller 030407010	255.0	253.7	0.94	0.24
2010		RANGER COMPLEX			COC	PAC Rock Crossing 030407012	244.4	26.1	0.45	0.05
2010	2596.4	PARADISE	25.86		APS	SPOW030101060 Foote Creek PAC	263.9	9.7	*	
2010	1860.9	CIRCLE BAR	0.18	0.22	APS	SPOW030104015 Circle Bar PAC	249.1	241.2	0.54	0.22
2010		CIRCLE BAR			APS	SPOW030104022 Chevelon Lake PAC	244.0	86.3	*	
2010		CIRCLE BAR			APS	SPOW030104018 Telephone PAC (WEST)	252.2	107.0	*	
2011	1642.1	SANDROCK	*		COC	PAC Sand 030404045	258.8	161.8	*	
2011	1019.3	BOLT	*		COC	PAC Coulter Ridge 030405015	258.3	24.5	*	
2011		BOLT			COC	PAC Bonita Tank 030405014	362.2	49.8	*	
2011	612.1	ROCKY	0.07		COC	PAC Jones Mountain 030404029	247.4	155.5	*	
2011		ROCKY			COC	PAC Rocky Gulch 030404033	248.8	19.0	*	
2011	2178.8	TANNER	14.81	8.06	TON	MSO PAC 031205018	245.3	244.3	50.51	8.06
2011	861.3	BLUFF	1.79		TON	MSO PAC 031205016	267.6	94.8	*	
2011	228107.0	WALLOW	137.81	26.56	APS	SPOW030101007	280.9	280.9	32.64	1.94
2011		WALLOW			APS	SPOW030101008	328.1	328.1	13.35	1.21
2011		WALLOW			APS	SPOW030101065 Alpine West	317.9	317.9	47.60	3.54
2011		WALLOW			APS	SPOW030101050 Auger	252.0	252.0	94.34	18.00
2011		WALLOW			APS	SPOW030106011 Badger Knoll	310.2	1.4	*	

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2011		WALLOW			APS	SPOW030101019 Bear Creek	266.0	266.0	150.39	27.16
2011		WALLOW			APS	SPOW030101022 Bear Wallow Confluence PAC	253.4	253.4	3.22	0.21
2011		WALLOW			APS	SPOW030101021 Bear Willow Schell	259.9	259.9	26.95	1.95
2011		WALLOW			APS	SPOW030101034 Bear Wallow Trail 62 PAC	289.7	289.7	72.12	5.37
2011		WALLOW			APS	SPOW030106015 Benton Creek PAC	306.2	306.2	170.30	58.92
2011		WALLOW			APS	SPOW030103004BLUEVISTA2	280.9	261.1	*	
2011		WALLOW			APS	SPOW030101037 Bob Thomas Creek PAC	263.3	263.3	13.91	0.74
2011		WALLOW			APS	SPOW030101062 Brent's Box PAC	273.3	36.7	*	
2011		WALLOW			APS	SPOW030101011 Bull Canyon PAC	259.2	259.2	59.12	6.58
2011		WALLOW			APS	spow030106010 Burro PAC	243.1	243.1	57.92	6.87
2011		WALLOW			APS	SPOW0301010RedHillRoadSurvey_1993 Bush PAC	271.1	271.1	*	
2011		WALLOW			APS	SPOW030101063 Butler PAC	249.0	249.0	0.24	0.15
2011		WALLOW			APS	SPOW030101054 Butterfly PAC	267.9	267.9	2.88	0.51
2011		WALLOW			APS	SPOW030101025 Campbell Blue PAC	247.3	247.3	65.13	12.24
2011		WALLOW			APS	SPOW030101057_1993 Castle Rock PAC	293.6	293.6	0.06	0.04
2011		WALLOW			APS	SPOW030101066 Colby PAC	259.4	259.4	137.82	14.23
2011		WALLOW			APS	SPOW030101003 Conklin Creek PAC	265.3	265.3	116.42	18.24
2011		WALLOW			APS	SPOW030101052 Conklin Crossing PAC	266.4	266.4	9.47	0.44
2011		WALLOW			APS	SPOW030101036 Double Cienega PAC	254.4	254.4	89.68	10.60
2011		WALLOW			APS	SPOW030101026 East Castle PAC	282.8	282.8	50.24	5.44
2011		WALLOW			APS	SPOW030106012 E. Fork of the Little CO PAC	254.7	254.7	87.48	7.24
2011		WALLOW			APS	SPOW030101029 Escudilla PAC	264.2	264.2	27.56	1.59
2011		WALLOW			APS	SPOW030101023 Fish Barrier PAC	261.2	261.2	14.58	1.62
2011		WALLOW			APS	SPOW030101049 Flat PAC	247.8	1.0	*	
2011		WALLOW			APS	SPOW030101060 Foote Creek PAC	263.9	263.9	2.72	0.29
2011		WALLOW			APS	SPOW030101024 Gobbler Tank PAC	298.4	298.4	10.16	1.50
2011		WALLOW			APS	SPOW030106005 Greer PAC	250.4	250.1	29.83	1.69
2011		WALLOW			APS	SPOW030101035 Hagen Creek PAC	244.9	244.9	102.57	14.83
2011		WALLOW			APS	SPOW030101015 Hannagan Creek PAC	285.6	285.6	40.13	5.42
2011		WALLOW			APS	SPOW030106009 Hay PAC	253.2	253.2	118.18	38.08
2011		WALLOW			APS	SPOW030101001 Hoodoo Knoll PAC	244.8	244.8	39.39	2.22
2011		WALLOW			APS	SPOW030101016 Horton Creek PAC	268.4	268.4	217.84	86.90
2011		WALLOW			APS	SPOW030101040 Jackson Springs Timber Sale	308.2	308.2	68.35	14.33
2011		WALLOW			APS	SPOW030101038 JC Tank PAC	265.3	265.3	95.41	28.92

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2011		WALLOW			APS	SPOW030101017 Lost Bear PAC	265.1	265.1	189.25	66.78
2011		WALLOW			APS	SPOW030101028 Lower KP Creek PAC	276.4	276.4	12.65	0.55
2011		WALLOW			APS	SPOW030101032 Lower Snake Creek PAC	264.2	264.2	7.47	0.64
2011		WALLOW			APS	SPOW030101061 Lower Stone Creek PAC	232.3	232.3	1.50	0.17
2011		WALLOW			APS	SPOW030101031 McKibbins Pond PAC	248.1	248.1	2.66	0.58
2011		WALLOW			APS	SPOW030101018 Middle Turkey Spring PAC	244.1	244.1	104.10	13.07
2011		WALLOW			APS	SPOW030101047 Molly's Nipple PAC	269.4	269.4	41.70	3.03
2011		WALLOW			APS	SPOW030106003 OD Ridge PAC	243.3	243.3	91.12	13.68
2011		WALLOW			APS	SPOW030101058_1994 Oliver PAC	268.2	268.2	*	
2011		WALLOW			APS	SPOW030101010 Oscar PAC	243.0	243.0	71.75	7.71
2011		WALLOW			APS	SPOW030103008RASBERRY	299.2	299.2	0.39	0.18
2011		WALLOW			APS	SPOW030101006 Redondo PAC	247.5	247.5	3.55	0.28
2011		WALLOW			APS	SPOW030101041 Reservation Tank PAC	297.1	297.1	0.53	0.14
2011		WALLOW			APS	SPOW030101059 Right Fork Foote Creek PAC	255.7	231.6	*	
2011		WALLOW			APS	SPOW030101051 Rim PAC	281.1	281.1	0.06	0.04
2011		WALLOW			APS	SPOW030101012 Rogers Reservoir PAC	300.2	300.2	123.14	14.86
2011		WALLOW			APS	SPOW030106014 Rudd Creek PAC	396.8	396.8	105.36	6.29
2011		WALLOW			APS	SPOW030101020 Side Canyon PAC	281.6	281.6	201.06	78.83
2011		WALLOW			APS	SPOW030101005 Slaughter Draw PAC	260.6	260.6	158.47	47.33
2011		WALLOW			APS	SPOW030101030 Snake Creek PAC	260.6	260.6	10.94	0.83
2011		WALLOW			APS	SPOW030106004 South Fork PAC	243.5	243.5	77.84	8.82
2011		WALLOW			APS	SPOW030101033 Tenney PAC	247.5	247.5	63.02	3.94
2011		WALLOW			APS	SPOW030101013 Thomas Creek PAC	278.7	278.7	105.83	8.84
2011		WALLOW			APS	SPOW030101064 Turkey Hunt PAC	266.3	266.3	64.22	8.67
2011		WALLOW			APS	SPOW030101056 Turkey Track PAC	272.9	272.9	26.07	2.25
2011		WALLOW			APS	SPOW030101042 Upper Blue PAC	257.5	197.4	0.06	0.04
2011		WALLOW			APS	SPOW030101004Upper Conklin Creek PAC	271.0	271.0	26.39	2.18
2011		WALLOW			APS	SPOW030101027 Upper KP Creek PAC	258.8	258.8	9.61	0.88
2011		WALLOW			APS	SPOW030106001 Water Canyon PAC	247.2	247.2	16.76	2.16
2011		WALLOW			APS	SPOW030106013 W. Fork of the Little CO River PAC	260.7	256.5	67.30	6.43
2011		WALLOW			APS	SPOW030106007 West Fork PAC	241.9	241.9	90.17	7.80
2011		WALLOW			APS	SPOW030101009 Wildcat Point PAC	256.2	256.2	5.08	0.41
2011		WALLOW			APS	SPOW030101014 Willow Creek PAC	260.4	260.4	32.71	2.36