Yosemite National Park

Division of Resources
Management and Science

Looking Downstream

2016 Update

Physical and Ecological Responses to River Flow Downstream of Hetch Hetchy Reservoir, Yosemite National Park

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Summary

The Looking Downstream project is an interdisciplinary study designed to better understand the physical processes and ecology of the main stem Tuolumne River corridor between O'Shaughnessy Dam and the western boundary of Yosemite National Park. The project consists of hydrology, vegetation, and wildlife (bird, bat, and benthic macroinvertebrate) study components. An overarching goal of the Looking Downstream project is to provide information that water managers can use to manage environmental water releases from O'Shaughnessy Dam in ways that will more closely replicate natural physical processes and benefit water-dependent ecosystems downstream of the dam.

Hydrology studies in 2016 primarily consisted of continued monitoring of water levels in the Tuolumne River, tributary streams, Poopenaut Valley seasonal pond, and groundwater within the meadows adjacent to the river. The 2016 water year was near average, with water year precipitation at approximately 114% of average as measured in Yosemite Valley. April 1st snow water equivalent was slightly below average at 93%. Spring runoff began on 25 February 2016, and peaked on 2 June 2016 at 2,780 cubic feet per second (cfs). Peak flows added approximately 0.5 meters of water to the seasonal pond on the north side of the river. Water levels were within 30 cm of the ground surface for at least 14 consecutive days (the minimum hydrologic requirement for a wetland 5 out of every 10 years) only at Well 3. Using modeling tools in ArcGIS, we calculated the inundation area in Poopenaut Valley for Tuolumne River flows ranging from approximately 900 to 9,000 cfs.

Periodic wetland vegetation monitoring and wetland delineation in Poopenaut Valley have been ongoing since 2008. For the 2016 monitoring year, we improved study design by increasing the sample size of vegetation transects to provide a robust dataset for more powerful data analysis and detection of changes in vegetation composition over time in relation to changes in river flow. We monitored new and existing vegetation transects over a period of three weeks in late June to mid-July. Results show that there was an overall increase in native vegetation from 2008 to 2011, followed by a steady decrease from 2013 to 2016. For wetland vegetation, there was an initial decrease in cover from 2008 to 2010, then a steady increase from 2010 to 2013, followed by a steady decrease from 2013 to 2016. The earlier monitoring years correspond with higher average April 1st snow pack and higher dam releases during peak spring run-off. Conversely, the latter monitoring years correspond with lower April 1st snow pack and lower dam releases during peak spring runoff. These results suggest that native and wetland vegetation cover are generally higher when snowpack and spring runoff are higher.

Past avian studies focused on area search and point count surveys, which are widely used tools to assess overall bird population composition and abundance. In 2016, we completed the tenth year of standardized area search surveys (2007–2016) and the ninth year of standardized point count surveys (2008–2016) in Poopenaut Valley with the goal of estimating bird species abundance, community composition, and habitat use in wet meadow and montane riparian habitats. 2016 avian studies also integrated spot mapping, target netting, color banding, territory mapping, nest searching, and bird tissue sampling to provide information relating to breeding status, territory selection, space use, phenology, nesting success, and

trophic dynamics. These efforts focused primarily on four riparian focal species that commonly breed in Poopenaut Valley: Song Sparrow, Yellow Warbler, Black-headed Grosbeak, and Warbling Vireo. Preliminary results suggest that changes in the timing and magnitude of flood events and annual discharge explain a large portion of the variation in abundance, species richness, and breeding behavior of riparian birds. In addition, both the 2013 Rim Fire and the 2012-2015 drought decreased abundance and richness of upland and riparian birds.

From April 2011 to July 2016 we conducted acoustic bat surveys at two sites in Poopenaut Valley to determine species presence and activity level. In May 2016 we added a third detector directly adjacent to the Tuolumne river on the south bank in order to assess differences in bat foraging activity and species composition between river and meadow habitat. We documented a high diversity of bat species in Poopenaut Valley from spring 2011 through summer 2016. Over this five year monitoring period, we detected all 17 bat species known to occur within Yosemite National Park in Poopenaut Valley; thus, Poopenaut Valley alone is as diverse as the entirety of Yosemite National Park. Five of the 17 detected species are California species of special concern (pallid bat, spotted bat, western mastiff bat, Townsend's big-eared bat, and western red bat). Decreased bat activity in the winter is likely attributable to lower ambient temperature, as well as reduction in prey availability. Annual and monthly shifts in bat activity and community composition may be attributable to changes in abundance of emergent aquatic prey. We observed distinct patterns in bat activity that may correspond to spatial hydrologic patterns. Bat activity at both the north and south sites increased in April, decreased in May and June correlating with the flood, and jumped to record highs for the Poopenaut north site in July. In addition, activity levels were higher at the Poopenaut river site in both June and July than ever recorded for the north and south locations. This pattern may indicate a proclivity of bats for inundated conditions. Preliminary results suggest that the experimental flood lead to a short-term decrease in the abundance of emergent aquatic insects – and therefore bat activity – due to river scouring causing mortality and drift of benthic aquatic insects.

Chapter 1. Introduction

The primary goals of the Looking Downstream project are 1) to fill in first-order information gaps by collecting baseline information on the hydrology, vegetation, birds, and bats. and benthic macroinvertebrates tied to river flow downstream of O'Shaughnessy Dam, 2) provide a general characterization of the river reach, and 3) assess its overall hydrological and ecological condition. An important overarching goal of these studies is to work collaboratively to produce science-based information and recommendations that the San Francisco Public Utilities Commission (SFPUC) can use to design environmental water releases that will be most beneficial to maintaining and enhancing ecosystems downstream of the dam.

This type of investigation is important considering that nearly all of California's rivers are inexorably altered by water control structures, and the impact of dams can be dramatic. Dams across the western United States reduce maximum annual discharges by an average of 67%, change the timing of peak flows up to 6 months and reduce the range of discharge by an average of 64% (Graf 2006). Flow regimes affect the overall ecosystem structure of a watershed with biomass increasing with increased mean daily discharge (Stromburg, 1993; Poff et al., 1997). The reduction of peak flows and sediment flushing events caused by dams have also been identified as a factor contributing to the channelization of rivers (Ligon et al., 1995).

Poopenaut Valley, a broad, low gradient valley located approximately 5.5 km (3.5 miles) downstream of O'Shaughnessy Dam (Figure 1-1), is one of the most ecologically diverse and productive areas in the river reach between the dam and the western boundary of Yosemite National Park. As a result, we consider Poopenaut Valley to be the location most sensitive to habitat disruption resulting from an altered hydrologic regime (National Park Service, 2009). For these reasons, we have focused our research efforts primarily in Poopenaut Valley, specifically on the meadow, wetland, and riparian ecosystems found there (National Park Service, 2009, 2010, 2011, 2012a, 2012b, 2014, 2015).

As in prior years, our 2016 research in Poopenaut Valley consisted of five main subject areas: (1) surface and ground water hydrology, (2) upland, meadow, wetland, and riparian vegetation, (3) riparian-dependent bird species, (4) bats, and (5) benthic macroinvertebrate assemblages. Results from benthic macroinvertebrate research are reported separately by researcher Jeff Holmquist of the University of California, Los Angeles, White Mountain Research Center (Holmquist and Schmidt-Gengenbach, 2016). This status report presents the other subjects in Chapters 2 through 5. This report details findings from our 2016 research in Poopenaut Valley.

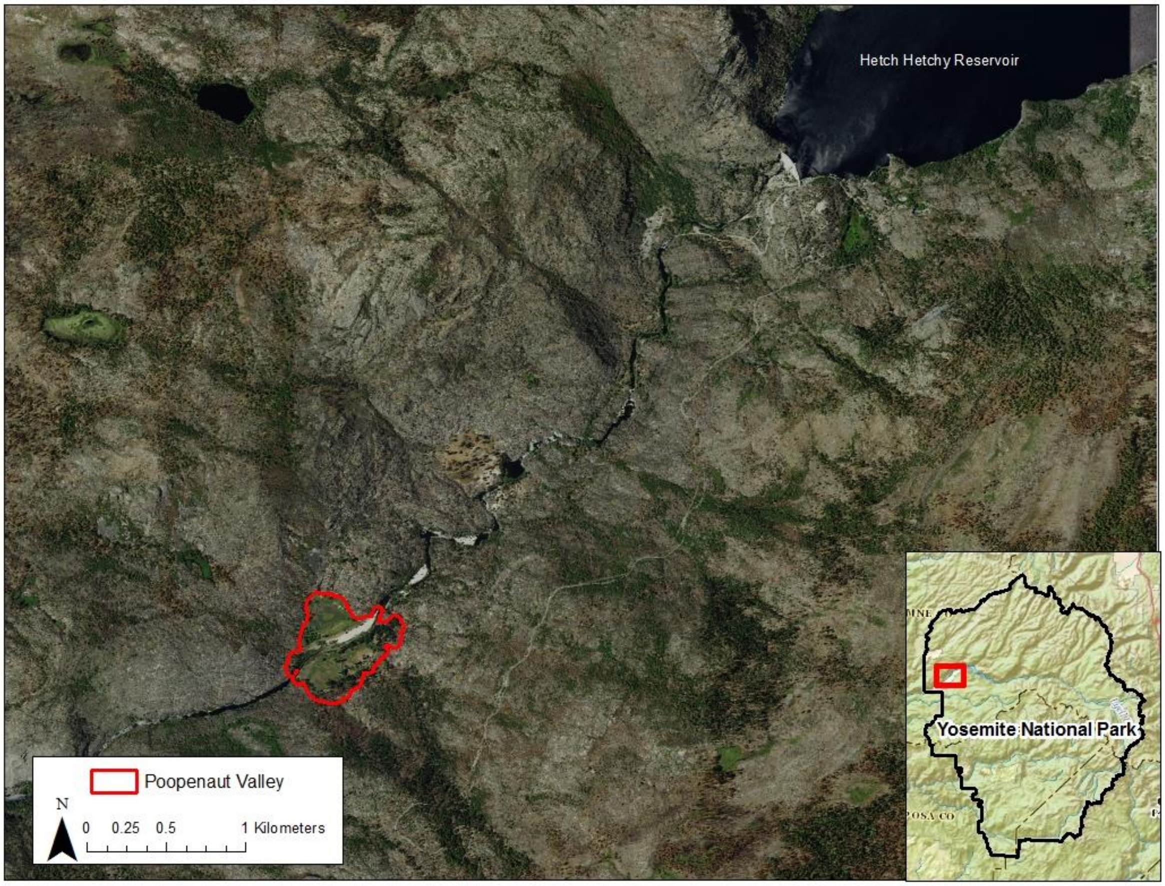


Figure 1-1. Location of Poopenaut Valley, a roughly one km^2 floodplain meadow complex located along the Tuolumne River 5.5 km downstream of Hetch Hetchy Reservoir within Yosemite National Park, California.

Chapter 2. 2016 Hydrology studies in Poopenaut Valley

2.1 Introduction

Hydrology studies in 2016 primarily consisted of continued monitoring of water levels in the Tuolumne River, tributary streams, the seasonal pond on the north side of Poopenaut Valley, and groundwater within wetlands and meadows adjacent to the river. After several years of extremely low snowpack and runoff, 2016 represented a more typical “average” year, with an opportunity for an experimental pulse flow to achieve certain ecological conditions.

2.2 Overview of the 2016 water year

The 2016 water year was near average, with water year precipitation at approximately 114% of average as measured in Yosemite Valley (the rain gauge at Hetch Hetchy ceased to function after mid-April). April 1st and May 1st snow water equivalent were slightly below average measured at 93% and 53% of the April 1st average respectively (Table 1). Precipitation in Yosemite Valley for WY2016 (California Data Exchange Center site YYV) was 104.9 cm (41.3 inches).

Spring runoff began on 25 February 2016, as determined using the maximum negative cumulative deviation from annual average flows at the USGS gage in the Grand Canyon of the Tuolumne River upstream of Hetch Hetchy Reservoir. Spring runoff peaked at this gage on 2 June 2016 at 2,780 cfs.

Table 2-1. Summary snow water content for snow courses in the Tuolumne River watershed upstream of Hetch Hetchy Reservoir, 2016.

Snow Course	Course #	Elevation (m)	Apr 1st Average (cm)	April 1 2016 (cm)	May 1 2016 (cm)
Dana	157	2987	79	67.3	58.4
Rafferty	158	2865	83.3	80.0	--
New Grace	368	2713	121.9	124.5	96.5
Tuolumne	161	2621	57.7	54.6	24.1
Wilma	163	2438	109.7	113.0	83.8
Paradise	167	2332	101.3	113.0	76.2
Vernon	169	2042	56.9	55.9	8.9
Beehive	171	1981	59.7	35.6	0
Lower Kibbie	173	2042	66	38.1	0
			% April 1st Average	93%	53%

2.3 Hydrological observations in Poopenaut Valley

Figures 2-2 and 2-3 depict water surface elevations along the downstream and upstream valley cross-sections during the course of high flow releases in 2016. The duration of water levels within 30 cm of the surface at Wells 1, 15, and 3 were 4, 8, and 16 days respectively. As a reminder, the US Army Corps of Engineers defines the minimum hydrologic requirements for a jurisdictional wetland in the western mountain region as soil saturation within 30 cm (12-inches) of the ground surface for a period of 14 consecutive days during the growing season 5 out of every 10 years (USACOE, 2012).

Inundation extent was mapped during stable flows of approximately 4,100 to approximately 6,500 cfs on the south side of the river. These data, along with well locations and delineated wetlands, are shown in Figure 2-4.

During the experimental water release, river flows were increased from approximately 2,100 to approximately 4,100 cfs at 4am on 9 May 2016. Rising flows added approximately 0.5 meters of water to the seasonal pond on the north side of the river (Figure 2-3). A temporary pond overflow sensor, which was located just below the overflow crest on the river side, started recording water between 5 am and 6 am, and overflow began between 9 am and 10 am. The pond was completely full by about 5 am on 10 May 2016. Note that the pond started with about 1.3 meters of water in it, derived from local sources beginning 21 December 2015, and so would have taken longer to fill if it had been empty to begin with. It is also important to note that the depth of flow at the overflow was less than 0.2 meters, hence the long fill time (the pond did not respond until depth over the overflow sensor was > 0.3 m and peak depth over the same sensor during the fill period was 0.5 m). After augmentation by high flows the pond went dry by mid-July 2016 (Figure 2-3).

Note that all loggers now deployed in Poopenaut Valley are Solinst Levelogger Edge models, providing consistency across all hydrologic data sets.

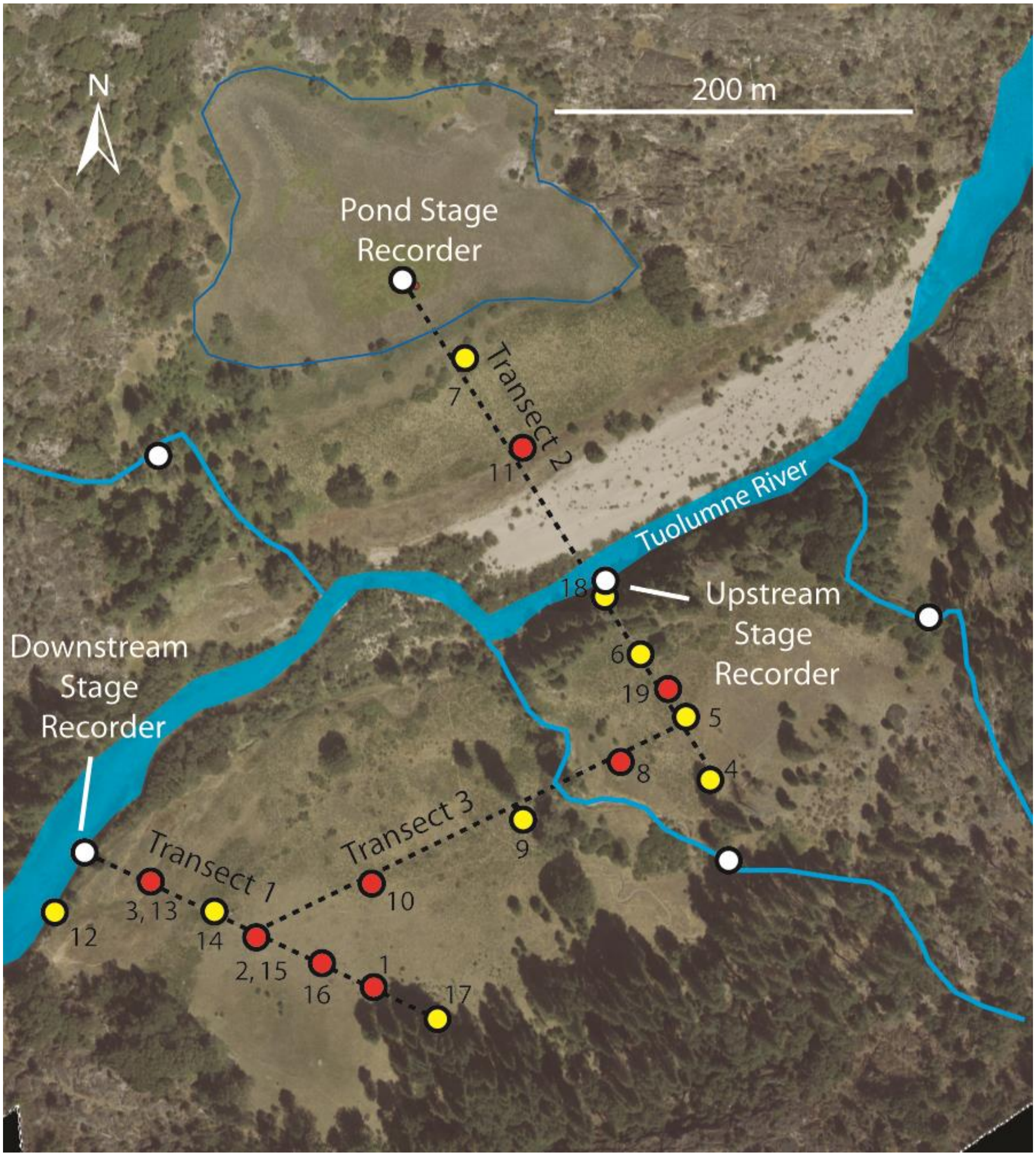


Figure 2-1. Poopenaut Valley water level monitoring locations. White dots indicate stage recorders in surface waters (Tuolumne River, tributaries, and seasonal pond). Red dots indicate existing groundwater monitoring wells. Yellow dots indicate former groundwater monitoring wells removed in October 2011.

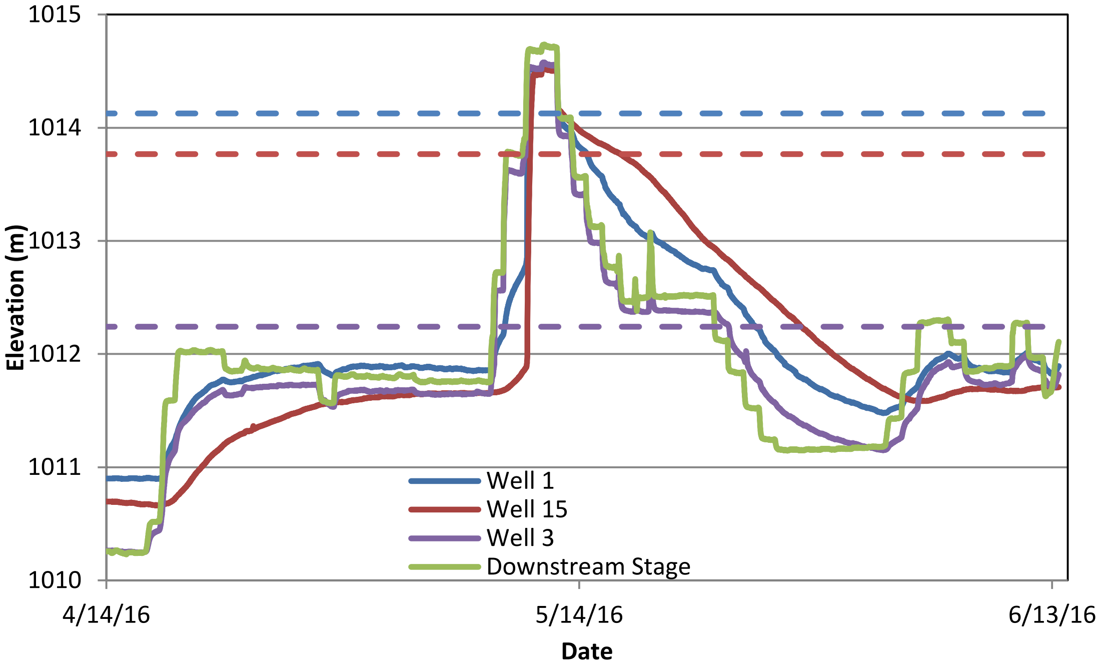


Figure 2-2. River and groundwater levels along Transect 1 (downstream transect) during 2016 peak flows.

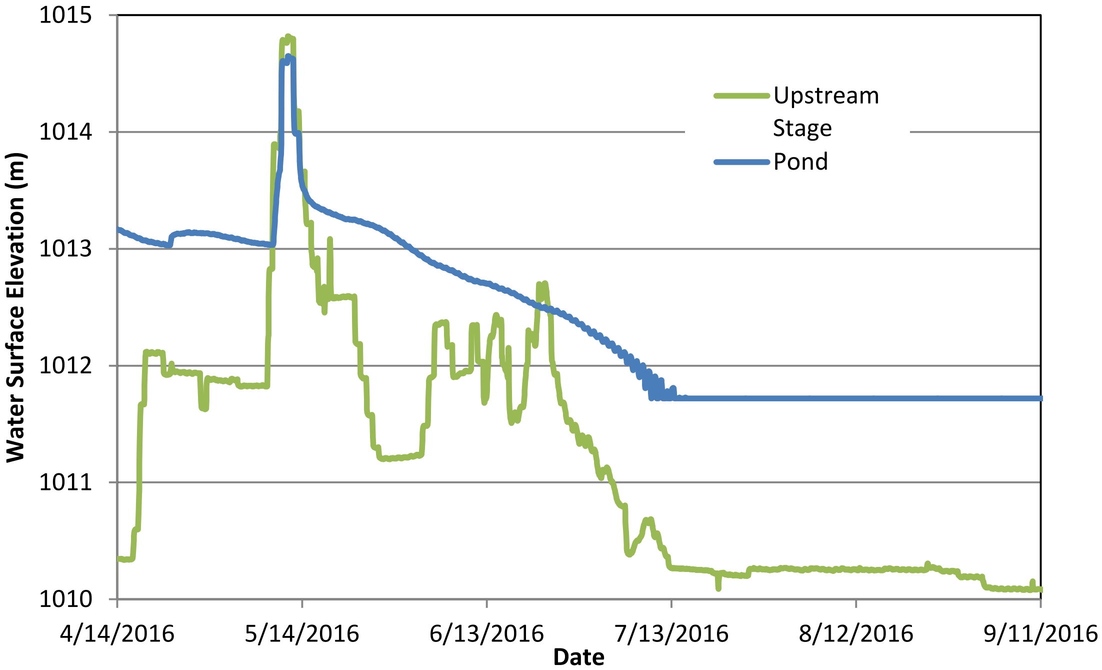


Figure 2-3. Tuolumne River and seasonal pond stages during and after the 2016 peak flows. The pond was essentially dry after mid-July.

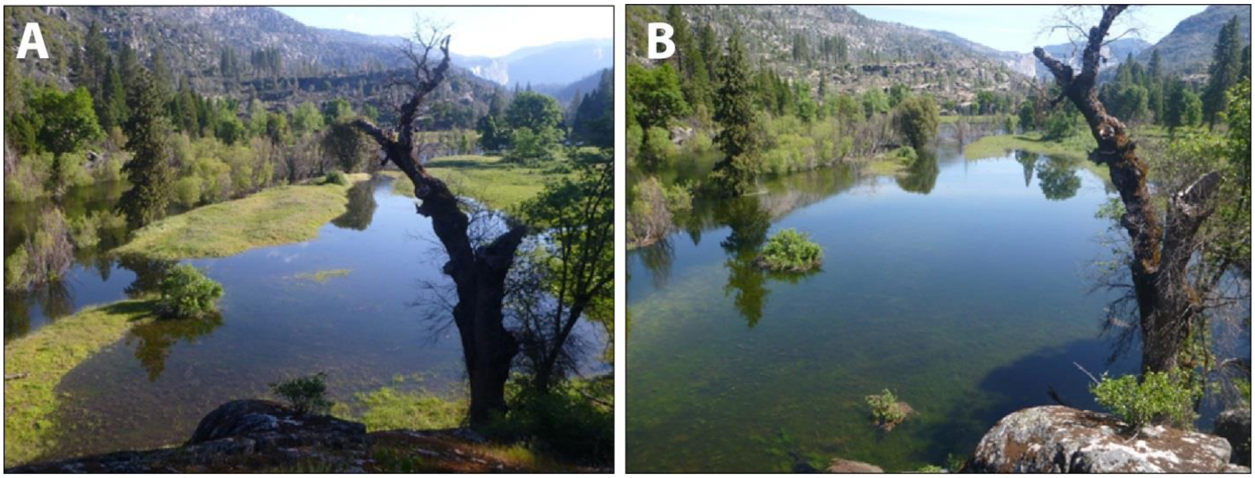


Figure 2-4. Inundation extent in the southwestern portion of Poopenaut Valley during the May 2016 experimental flow. (A) Inundation extent on 10 May 2016 at approximately 4,100 cfs. (B) Inundation extent on 12 May 2016 at approximately 6,500 cfs.

2.4 Estimates of inundation extents as a function of river discharge

In addition to the field data collection and observations described above, in the winter of 2016 we evaluated the extent of water inundation in Poopenaut Valley as a function of Tuolumne River discharge. Our evaluation tools were primarily mapping and flow modeling programs in ArcGIS, specifically ArcMap utilizing 1 meter-resolution airborne lidar data, and the ArcHydro (H&H Modeling, Map to Map) analysis tools utilizing stream surface elevation data from the upstream and downstream stage recorders in Poopenaut Valley. We calibrated the modeled inundation extent results against inundation extents mapped in the field at different time periods and during a range of river discharges. In general the mapped and modeled extents compare well (<10 cm vertical difference), suggesting that the model provides reasonable estimates of inundation extents for a range of Tuolumne River discharges (Figure 2-5). We then calculated inundation extents for river discharges ranging from approximately 900 to 9,000 cfs, which likely represents the full range of flows that can reasonably be expected in Poopenaut Valley (Figure 2-6; Table 2-2).

Interestingly, inundation area and Tuolumne River discharge show a strong linear correlation (Figure 2-7), resulting in a relatively straightforward relationship between the two. (A “step” in the data between approximately 4,000 and 5,000 cfs corresponds to filling of the seasonal pond on the north side of the valley; Figure 4-7). These relationships provides a useful tie between the amount of water released from O’Shaughnessy Dam, the corresponding area of inundation in Poopenaut Valley, and biological metrics that may directly relate to inundation (see Chapter 5).

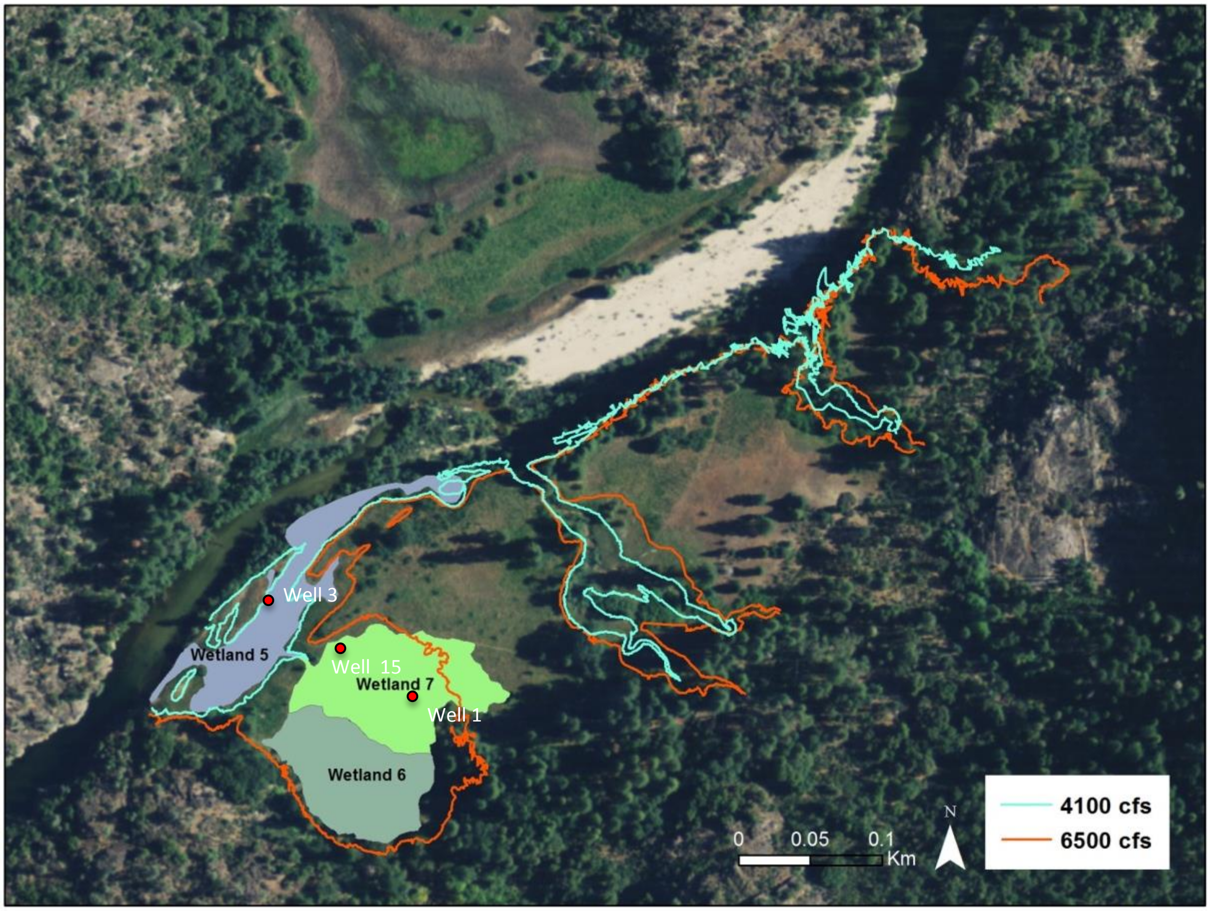


Figure 2-4. Mapped inundation extents at approximately 4,100 and 6,500 cfs, locations of Wells 1, 15, and 3, and wetland areas in the southwestern portion of Poopenaut Valley that were inundated by experimental flows in May 2016.

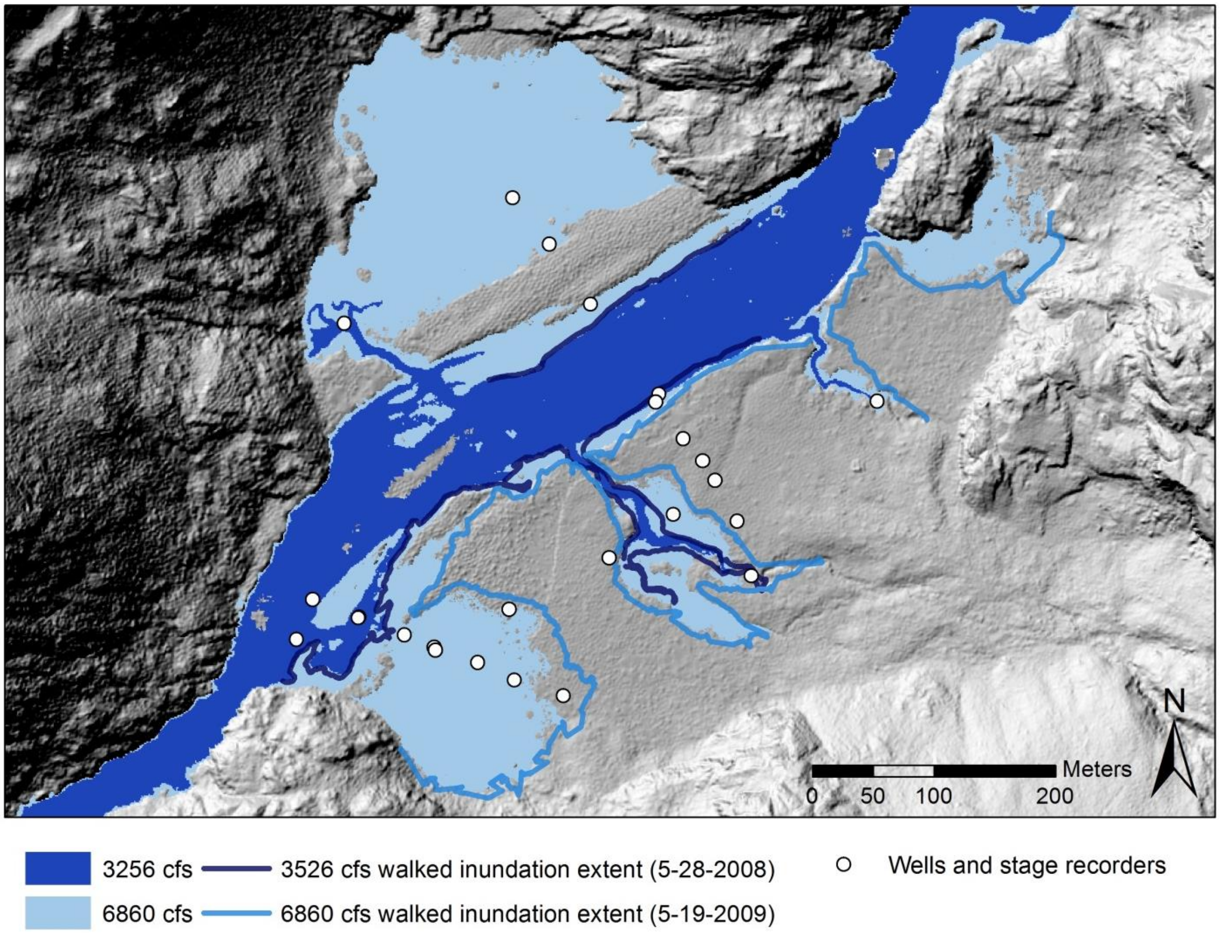


Figure 2-5. Comparison of actual inundation extents mapped in the field (lines) versus modeled inundation extents (polygons) for 3,260 and 6,860 cfs on the south side of Poopenaut Valley. In general the mapped and modeled extents compare well (<10 cm vertical difference), suggesting that the model can provide reasonable estimates of inundation extents for a range of Tuolumne River discharges.

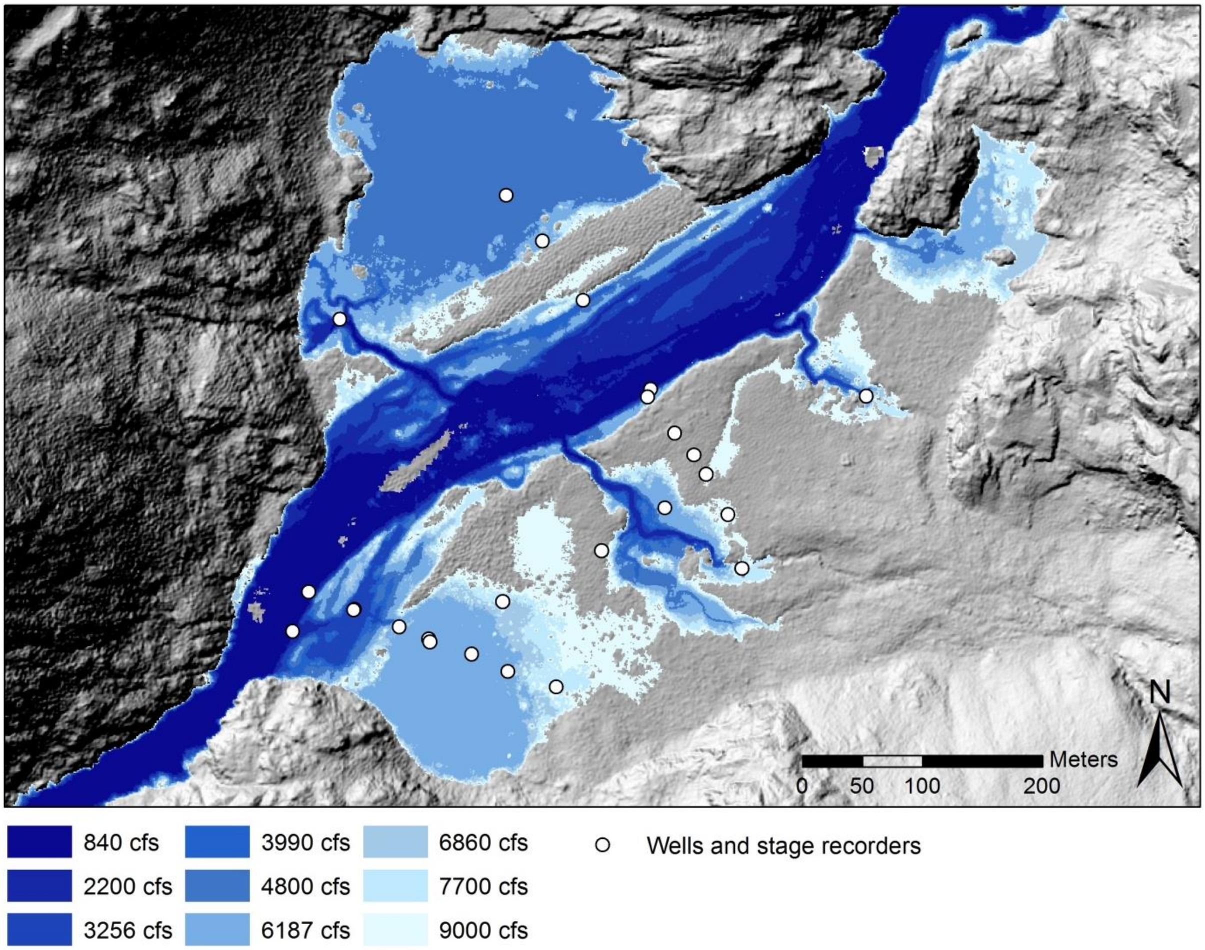


Figure 2-6. Modeled inundation extents in Poopenaut Valley for a range of Tuolumne River discharges.

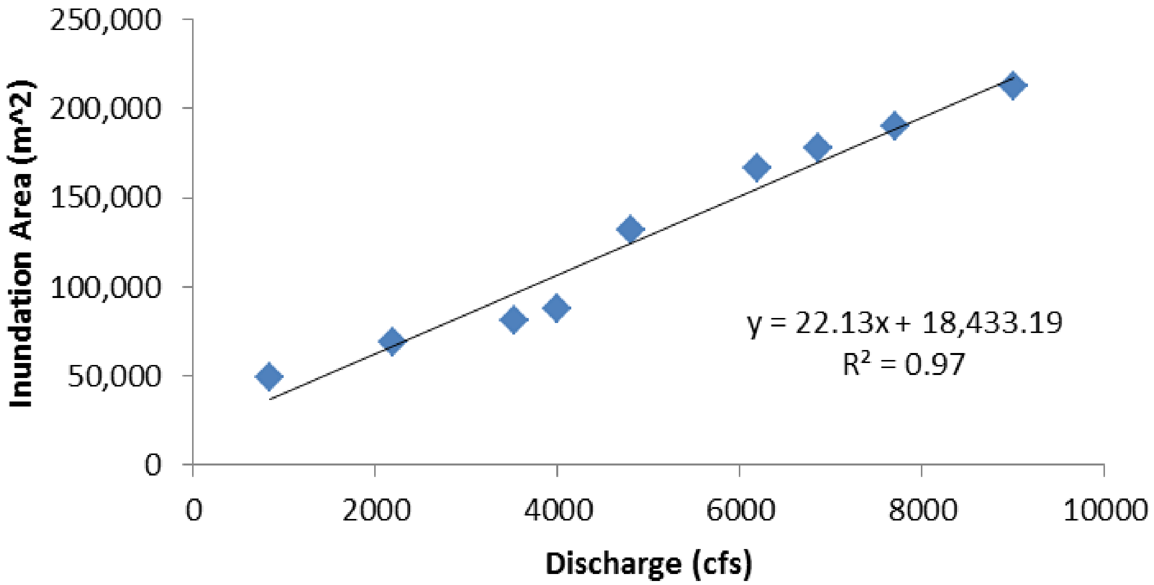


Figure 2-7. Inundation area in Poopenaut Valley as a function of Tuolumne River discharge, showing a strong linear relationship. The "step" in the data between approximately 4,000 and 5,000 cfs corresponds to filling of the seasonal pond on the north side of the valley.

Table 2-2. Inundation areas as a function of Tuolumne River discharge.

Discharge (cfs)	Upstream Stage WSE (m)	Downstream Stage WSE (m)	Inundation Area (m^2)	Inundation Area (hectare)	Date of measurement
840	1011.59	1011.48	28,224	2.82	13 June 2009
2200	1012.65	1012.46	44,733	4.47	3 June 2011
3526	1013.46	1013.25	55,656	5.57	5 May 2008
3990	1013.75	1013.59	61,151	6.12	1 June 2009
4800	1014.12	1013.99	104,512	10.45	8 June 2010
6187	1014.73	1014.58	138,561	13.86	14 May 2010
6860	1014.97	1014.80	149,268	14.93	19 May 2009
7700	1015.22	1015.00	161,117	16.11	28 May 2011
9000	1015.5	1015.25	182,462	18.25	N/A*

* measurements (stages and discharge) taken from rating curve

Chapter 3. 2016 Vegetation Studies in Poopenaut Valley

3. 1 Introduction

Herbaceous wetland and upland meadows intermixed with dense riparian trees and shrubs comprise the vegetation in Poopenaut Valley. The maintenance and enhancement of the ecological integrity of these communities requires flow magnitude, timing, frequency and duration sufficient to inundate wetlands and maintain the water table and soil moisture required for plants to establish and persist. The minimum hydrologic requirements for a jurisdictional wetland in the western mountain region is defined by the US Army Corps of Engineers to have soil saturation within 30 cm (12-inches) of the ground surface for a period of 14 consecutive days during the growing season 5 out of every 10 years (USACOE, 2012). Through hydrologic assessments and modeling, we have a good sense of the physical response (e.g. soil saturation, water table level, soil moisture retention) to different flow magnitudes and durations. However, measuring the biological response requires a longer time period and is much more complicated. For example, Russo et al. (2012) suggests that surface soil inundation was the most effective method, in terms of minimizing the volume of flow releases, for saturating soils and supporting wetland hydrology but the effects on plants dependent on a high water table is unknown.

3.2 Wetland Vegetation Monitoring and Updates (2008-2016)

Vegetation Monitoring

Background and Methods

Periodic wetland vegetation monitoring and wetland delineation in Poopenaut Valley have been ongoing from 2008 to 2016, where baseline data was initially collected in 2007 to inform monitoring efforts. In 2007, we mapped and described dominant vegetation communities using the Yosemite floristic classification system (NatureServe, 2007), which included a survey of invasive and rare plant species present. In 2008, we established nine monitoring transects, in order to detect any changes in plant communities in response to annual variations in temperature and available water. Transects are located along and perpendicular to five established river cross sections. Cross Section 1 is broken up into 3 transects (to improve the repeatability in subsequent recording), Cross Section 2 has one transect and Cross Section 3 is broken up into 3 transects (1 on the south side of the river and 2 on the north side). We also installed one additional transect perpendicular to Cross Section 1 to better monitor Wetland 6 and a final transect north of the river at the west end (see Figure 3-1).

Data collected on each transect include a point intercept reading every meter (on the whole number) and a varying number of nested frequency plots randomly placed along the transects. For each point, we measured and recorded the height and species of the tallest plant intercepted and recorded any other plant species below. Each plant species is only counted once. Point intercept methodology gives us cover (often expressed as relative cover), frequency and composition (although less common species are often underrepresented). This method is simple and easy to use and is appropriate for large areas and monitoring dominant vegetation (Elzinga et al., 2006). Measurements are repeatable but observer error is quite high as the tendency is to overestimate the number of “hits.” The same observer completed monitoring in all reads, lessening some of this inherent disadvantage.

For nested frequency quadrats, the nest sizes include: 0.25 meters (read the corner closest to the beginning point). 0.5 meters (the half perpendicular to the transect) and the full meter. In 2011, an additional nest of 0.1 meters was added to better monitor very common species. Beginning in the smallest quadrat we recorded all species observed. Each species is recorded only once in the smallest nest in which it occurs.

Frequency is one of the easiest and fastest methods available for monitoring vegetation. It describes the abundance and distribution of species and is useful to detect changes in a plant community over time (Elzinga et al., 2006). However, because frequency data are non-absolute (presence/absence), they only indicate a change is occurring and which species are changing but the nature of those changes cannot be established. For example, a change in frequency does not necessarily relate directly to more concrete parameters such as density, cover, weight, height, volume or any criteria related to the amount of a species present at a location.

Good sensitivity to change is obtained for frequency values between 20 percent and 80 percent (Despain et al., 1991). Frequency values between 10 percent and 90 percent are still useful, but values outside this range only indicate species presence and do not detect change (Despain et al., 1991). Because frequency values are measured separately for each species, an optimum size quadrat for one species may be less than optimum or even inappropriate for another and this is partially resolved by using nested quadrats of different sizes.

Progress Update

The monitoring plan calls for resampling of vegetation transects every other year, although there have been some deviations in this schedule over time, where sampling has occurred in 2008, 2010, 2011, 2013, 2014, and 2016. From 2008-2010, a willow seed dispersal study was conducted. In 2014, vegetation monitoring was conducted to assess effects from the Rim Fire, and we also added a metric to quantify soil surface cover so that basal cover of litter, bare ground and vegetation—important indicators of meadow condition—could be evaluated.

This year’s report provides a vegetation update on 1) the status of current and planned changes in wetland vegetation monitoring and delineation efforts, 2) a summary of annual changes in percent cover of wetland and native plant species in the South Meadow for vegetation monitoring years (2008, 2010, 2011, 2013, 2014, and 2016) in comparison with trends in hydrologic conditions for the Tuolumne River watershed upstream of Poopenaut Valley, and 3) a comparison of changes in wetland boundary extents for the 2007 and 2012 delineations.

For the 2016 monitoring year, we improved study design by increasing the sample size of vegetation transects to provide a robust dataset for more powerful data analysis and detection of changes in vegetation composition over time in relation to changes in river flow. Specifically, we randomly generated an additional 8 monitoring transects for installation, which resulted in a total sample size of 17 transects (new and existing) in the South Meadow and North Pond monitoring areas. Of the 17 transects, we installed a total 5 new monitoring transects and read a total of 6 existing transects, resulting in 11 transects that were read this monitoring year. We did not survey the North Pond survey site, which has 6 transects (3 new transects to install and 3 existing transects to read), due to high flows that prohibited crossing the river. We monitored new and existing vegetation transects over a period of three weeks in late June to mid- July.

While earlier transects established vary in length depending on the location of river cross section rebar, all transects established in 2016 are all 70m in length. Post field data collection this year, in the office, we identified unknown plant species and categorized them by their wetland status (Lichvar et. al., 2014) and native status (Baldwin et al., 2016). We also entered field data into a newly created geodatabase for storage of monitoring data and subsequent statistical analysis using R software and our R new script. Analysis work is planned for fall 2017.

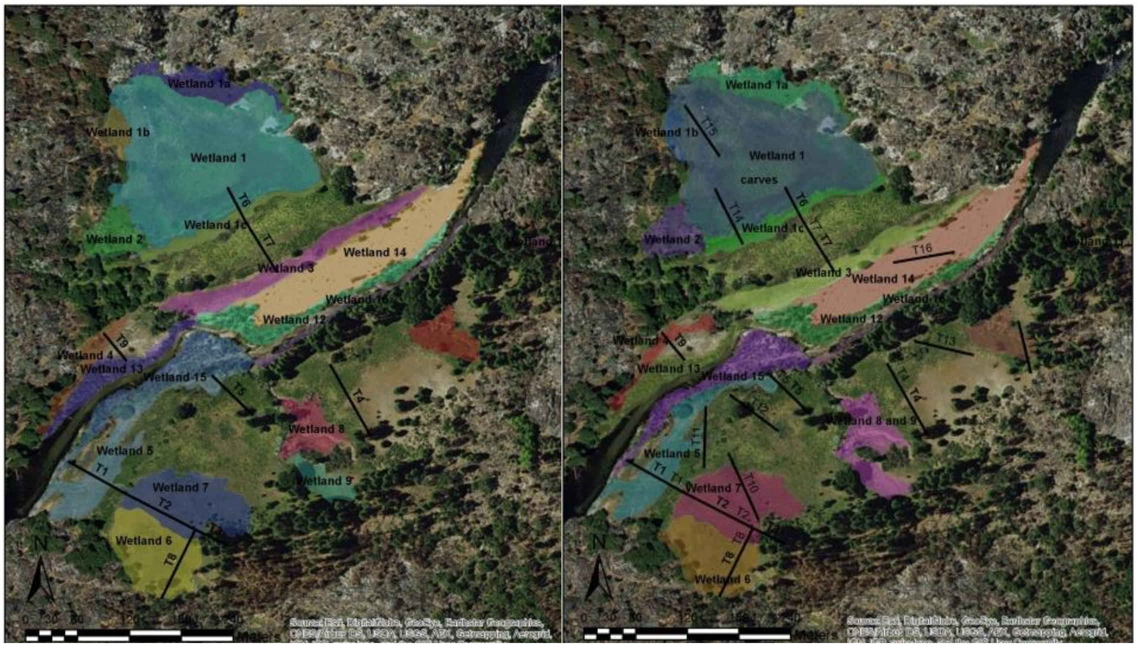


Figure 3-1. Map depicting Poopenaut Valley wetlands delineated in 2007 (left) and 2012 (right) and transects established for plant community monitoring in 2008 (*n* = 9, left) and 2016 (*n* = 17, right). Transects T14-T16 shown on the right are planned for installation in 2017.

3.3 Changes in Wetland Vegetation (2008-2016)

This year, we provide a brief summary and update on changes in wetland and native vegetation in Poopenaut Valley, specific to the South Meadow monitoring area, as the North Pond monitoring area was not surveyed this year due to high river flows. Specifically, we report on annual changes in wetland and native plant species percent cover in the South Meadow for vegetation monitoring years (2008, 2010, 2011, 2013, 2014, and 2016), in comparison with trends in hydrologic conditions upstream of Poopenaut Valley. These hydrologic data include Tuolumne River watershed percent of average April 1st snow water equivalents (SWE) and O'Shaughnessy Dam releases (cfs) during peak spring run-off. Next year, we plan to provide an in-depth analysis of 2016 and 2017 wetland vegetation changes at both the North Pond and South Meadow monitoring sites, using data analysis methods described below, which were reported on in the 2014 report and further developed in 2016.

Changes in wetland plant species and native plant species percentage from 2008 to 2016, are depicted in Figure 3-2 for the South Meadow monitoring site in Poopenaut Valley, in relation to hydrologic data, including Tuolumne River watershed percent of average April 1st snow water equivalents (SWE) and O'Shaughnessy Dam releases (cfs) during peak spring run-off.

Results show that there was an overall increase in native vegetation from 2008 to 2011, followed by a steady decrease from 2013 to 2016. For wetland vegetation, there was an initial decrease in cover from 2008 to 2010, then a steady increase from 2010 to 2013, followed by a steady decrease from 2013 to 2016. The earlier monitoring years correspond with higher average April 1st snow pack (as measured by snow water equivalent) and higher dam releases during peak spring run-off. Conversely, the latter monitoring years correspond with lower April 1st snow pack and lower dam releases during peak spring runoff. Specific to the South Meadow monitoring site within Poopenaut Valley, these data suggest that native and wetland vegetation cover are generally higher when snowpack and spring runoff are higher. The initial decrease in wetland cover from 2008 to 2010 can likely be explained by the decrease in snowpack in 2009, which was 81% of average April 1st for the Central Sierra Nevada range (DWR, CDEC 2016).

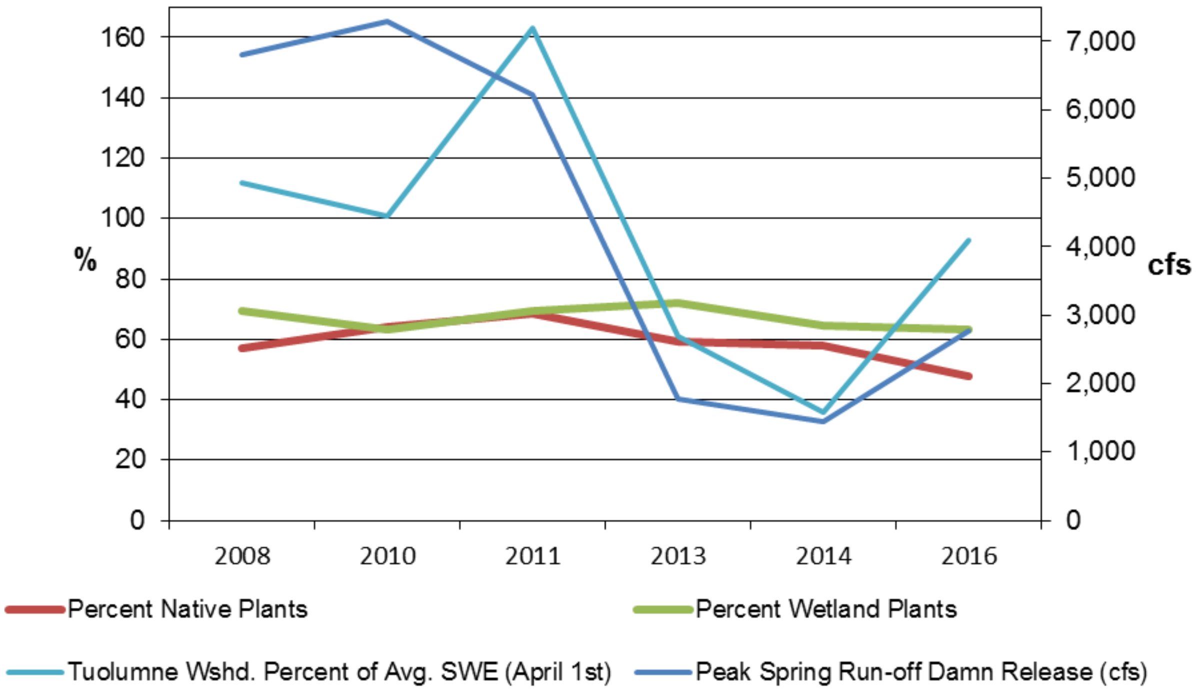


Figure 3-2. Changes in wetland vegetation from 2008 to 2016 for the meadow in the southwest portion of Poopenaut Valley, based on monitoring transect data on plant community composition and non-native species abundance.

3.4 Next Steps for Wetland Vegetation Monitoring

Vegetation Monitoring

In late-June to mid-July of 2017, we plan to re-sample all established vegetation transects at the South Meadow and North Pond monitoring sites. Specifically, we plan to read 11 established transects at the South Meadow, and we plan to read 3 established transects and install 3 new transects at the North Pond, pending crossable river conditions. This would result in a total of 17 transects read for the entire Poopenaut Valley wetland vegetation monitoring effort for 2017.

If we deem it necessary for improving our sample size with respect to delineated wetland polygons, we may choose to install up to 3 additional transects in one or more of the following wetland areas that are large enough to fit transects 70m in length: wetland 1a, 2, 8, 12, and 15. This would result in a total of 20 vegetation monitoring transects in Poopenaut Valley.

Wetland Delineation

Wetland delineation and mapping of wetland boundaries occurs on a 5-year mapping interval, which started in 2007. In 2007, we initially delineated and mapped wetland boundaries using the Cowardin system (Cowardin et al., 1979, Figure 3-1). In 2008, the USACE released supplements to the 1987 handbook, including one specifically for Western Mountains (USACE 2008). Hence, in 2008 and 2009, we further refined these boundaries and confirmed that parameters had not changed based on this supplement and the current delineation would not change. In 2012, we re-delineated wetlands in August using handheld Global Positioning System (GPS) units to determine if wetland boundaries had shifted substantially (Figure 3-1). Field remapping focused on vegetation rather than hydrology or soils as hydrologic conditions are available through modeling and soils are unlikely to have changed in this timeframe. There was a margin of error due to the inaccuracies of the GPS unit (average +/- 1 meter) and observer error. To minimize observer error, biologists completing the 2007 wetland delineation carefully documented which plant species they used to determine wetland boundaries.

To determine if wetland boundaries have shifted substantially, we will re-delineate wetlands in August of 2017, where prior wetland delineation occurred in August of 2012 and in 2007. In 2012, little change in wetland boundaries was observed, particularly in areas where topography defines wetland boundaries. Some differences in boundaries were attributed to GPS error, where the 2012 remapping was used to replace the 2007 delineation. Remapping indicated that there may have been a slight expansion of some wetlands in lower lying topographic areas.

Data Analysis

Field data for 2016 and 2017 will be entered into a newly created geodatabase for storage of vegetation data for all monitoring years. Subsequent statistical analysis for both the 2016 and 2017 monitoring years will be analyzed and reported on together for the 2017 annual report. Analysis methods used will be those described in the 2014 report (shown below), which have been further refined for statistical analysis using R software, rather than Systat. This approach will result in a 3-year interval of comprehensive wetland vegetation data analysis and reporting, where annual updates will be provided on data collection accomplishments and annual changes in wetland and native vegetation cover in relation to upstream hydrologic conditions.

Analysis of wetland vegetation data includes repeated-measures analyses, where we eliminate samples that are not repeated at each sampling event. Species names follow the Jepson Manual (Baldwin et. al., 2012). Wetland indicator status values are determined from the National Wetland Plant List (Lichvar, 2014) using the western valleys, mountain and coast region. Species not listed in that publication are rated as “upland”. Plants not identified to species cannot be assigned an indicator status value and are eliminated from the wetland analysis. In order to avoid this scenario, we will strive to key plants to species, where possible.

We calculate a wetland index (WI) as a weighted average of species cover in each transect following weighting methods developed in Wentworth et al. (1988) and Atkinson et al. (1993). We assign a score to wetland status categories as follows: 1 = obligate (OBL), 2 = facultative wetland (FACW), 3 = facultative (FAC), 4 = facultative upland (FACU) and 5 = upland (UPL). We calculate the relative contribution of each wetland category and multiplied it by its respective score by summing the number of intercepts of each category divided by the total number of intercepts in the transect:

$$WI = (P_{OBL} * 1 + P_{FACW} * 2 + P_{FAC} * 3 + P_{FACU} * 4 + P_{UPL} * 5)/ P_{transect}$$

Where: WI = wetland index
P = number of point intercepts

Wetland index values are then averaged across transects.

To evaluate if native species cover are changing, we calculate the mean percent cover of native species by transect:

$$\% \text{ cover native species } = P_{native}/P_{total}$$

We calculate species richness as the mean number of species per quadrat. To detect changes in non-native species cover we calculate the mean percent cover by non-native species.

To test for changes in wetland index, species richness, and non-native species cover over time, we use a repeated-measures ANOVA to test for differences among years and post-hoc pairwise comparisons with an alpha value of 0.1. We do not apply a correction for multiple tests. All statistical tests were previously performed using Systat statistical software (SYSTAT Software Inc., 2009). Statistical tests for 2017 will be performed us R Software (R Core Team 2016), and an R script we developed to allow for better detection of changes in vegetation composition over time in relation to changes in river flow.

Chapter 4. 2016 Bird Studies in Poopenaut Valley

4.1 Introduction

This chapter addresses changes in populations of breeding birds in Poopenaut Valley. In human-altered riparian areas, bird monitoring can be a valuable tool for assessing changes in habitat quality incurred from restoration efforts, water impoundment, and flooding events (National Park Service, 2009).

Because of its proximity to O'Shaughnessy Dam, Poopenaut Valley is among the areas most directly affected by river regulation. In addition, the upstream and downstream reaches of the Tuolumne River are highly confined, whereas the Poopenaut Valley is uniquely unconfined. This makes Poopenaut Valley a favorable place to investigate the relationship between hydrology and bird populations. The primary objective of this work is to understand how specific water-releases from O'Shaughnessy Dam impact bird habitat downstream of Hetch Hetchy Reservoir and to help operators make informed water release decisions that best balance ecological benefits with other demands. Drawing on ten years of data from bird surveys initiated in 2007, we have an opportunity to understand not only immediate changes in species diversity and avian abundance in response to river regulation, but also how hydrology influences bird populations through time. In addition to summarizing bird population dynamics within Poopenaut Valley, we also compare these data with similar avian survey data collected between 2010 and 2016 within Yosemite Valley along the Merced River, which is unregulated.

Changes in dam operations influence riparian bird species. For example, dam modifications allowing increased inundation downstream of the Roosevelt Dam increased abundance and nesting success of the Southwestern Willow Flycatcher (*Empidonax traillii extimus*) (Ellis et al. 2009). In addition, ramping rate, and minimum and maximum flow (all factors related to the magnitude and duration of flooding events) were more predictive of Willow Flycatcher responses than annual average discharge (Graf et al., 2002).

In addition to the ongoing influence of river regulation, two additional disturbances have occurred in Poopenaut Valley during the course of this study: The Rim Fire burned the majority of the valley in 2013 with mixed-severity and a drought resulting in precipitation levels well below average occurred between 2012 and 2015. Both of these disturbances are assumed to play an important role in present ecological conditions in Poopenaut Valley and across the surrounding Sierra Nevada range. Using data from the Looking Downstream project, we can quantitatively examine the continuing effects of these disturbances.

This study focuses on area search and point count surveys, which are among the most widely used tools to assess overall bird population composition and abundance (Ralph et al. 1993). As this study progresses, however, we are integrating more field techniques including target netting, color banding, territory mapping, nest searching, and bird tissue sampling to provide information relating to breeding status, territory selection, space use, phenology, nesting success, and trophic dynamics. These efforts focused primarily on four bird species identified as riparian focal species in the California Riparian Bird Conservation Plan (RHJV 2004) and that commonly breed in Poopenaut Valley. These four focal species (i.e., Warbling Vireo (*Vireo* *gilvus*), Yellow Warbler (*Setophaga petechia*), Song Sparrow (*Melospiza melodia*), and Black-headed Grosbeak (*Pheucticus melanocephalus*) (Table 4-1)) are closely associated with riparian habitat and represent diverse life histories. We also included Western Wood-Pewee (*Contopus sordidulus)* in select analyses because this species is also commonly observed nesting in riparian vegetation in both Poopenaut Valley and Yosemite Valley.

Table 4-1. Focal riparian bird species and their life history characteristics. Data compiled by Bryce (2006) and collected from Terres (1980), Ehrlich et al. (1988), and DeGraaf et al. (1991).

Common name	Scientific name	Neotropical migrant[a]	Nest type[a]	Diet[b]	Foraging type[c]
Western Wood-Pewee	*Contopus sordidulus*	Yes	HICUP	IN	HA
Warbling Vireo	*Vireo gilvus*	Yes	HICUP	IN	FG
Yellow Warbler	*Setophaga petechia*	Yes	LOCUP	IN	FG
Song Sparrow	*Melospiza melodia*	No	LOCUP	OM	GG,FG
Black-headed Grosbeak	*Pheucticus melanocephalus*	Yes	LOCUP	OM	FG

[a] Nest type: GRND = ground nester; LOCUP = cup nest generally 10 feet or less off the ground; HICUP = cup nest generally >10 feet off the ground

[b] Diet: IN = insectivore; OM = omnivore

[c] Foraging type: FG = foliage gleaner; GG = ground gleaner, HA = hawking insects from a perch

4.2 Field Methods

Area Search

In 2016, we completed the tenth year of standardized area search surveys (2007–2016) and the ninth year of standardized point count surveys (2008–2016) in Poopenaut Valley with the goal of estimating bird species abundance, community composition, and habitat use in wet meadow and montane riparian habitats. Area searches and point counts were conducted between dawn and 10 a.m. and took place between 15 May and 30 June. Surveys were ideally conducted three separate times each season, with visits occurring at least ten days apart. However, water releases from O'Shaughnessy Dam sometimes restricted access to the portions of the study area north of the Tuolumne River. In 2016, area search surveys took place on 12 May, 28 May, 13 June, and 19 June. The 13 and 19 June surveys were completed on both the north and side of the river.

During area searches, the observer surveyed for twenty minutes within a designated area, recording all individual birds seen or heard within the area's perimeter. To account for birds using edge habitat, birds observed 10 meters outside the perimeter were also included. The surveyor recorded the method of detection (either visual identification, or by identification of a bird's call or song) along with any additional observations that might indicate breeding status. We conducted searches in five areas, (each approximately 0.03 km^2 (3 ha) in size) which, together, cover a majority of the riparian area of Poopenaut Valley (Figure 4-1). Because increased discharge prevented access to a large portion of our survey area in some years, we only considered the areas which could be consistently surveyed every year (i.e., areas 3 and 4) for analysis.

For a more detailed description of area search protocols and of survey locations used in the Poopenaut Valley, see the 2007 Looking Downstream Report (National Park Service, 2009).

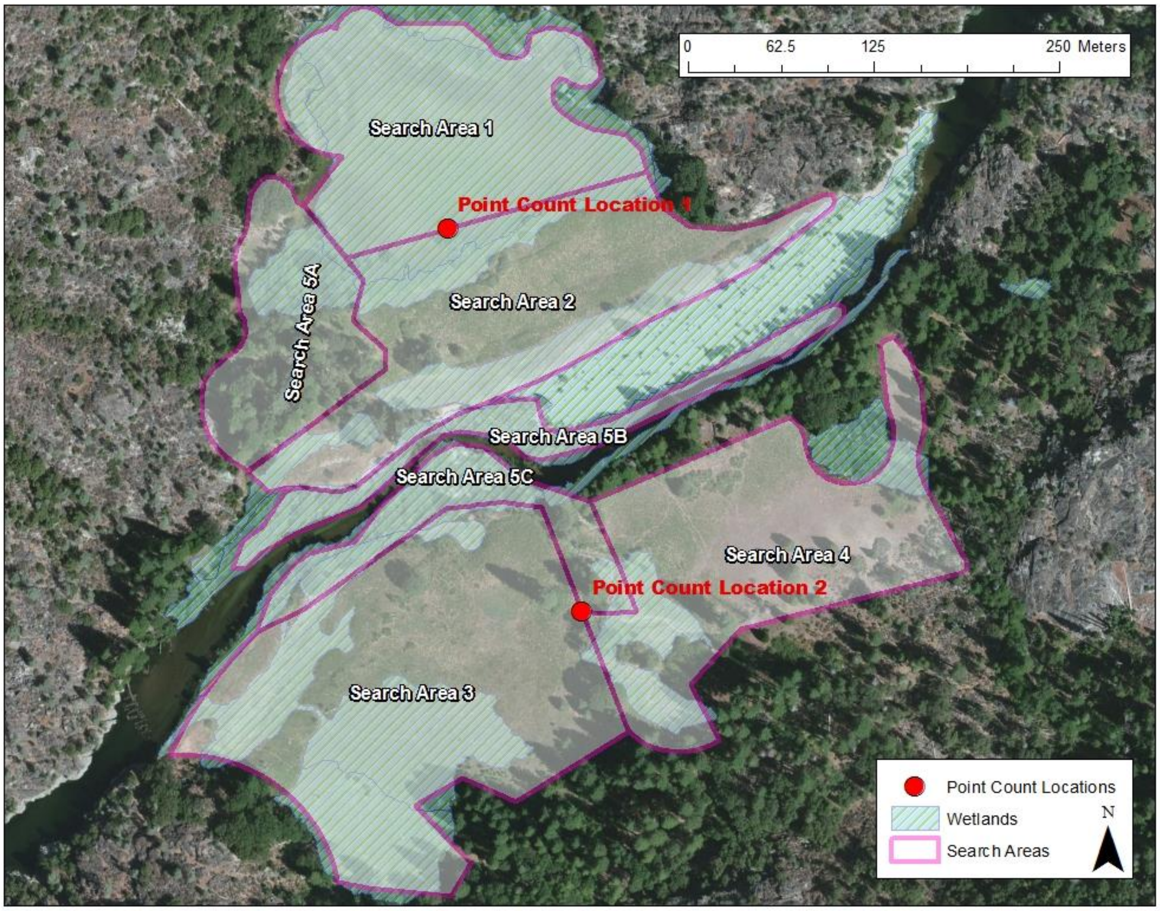


Figure 4-1. Bird search areas and point count locations in Poopenaut Valley.

Point Count

In Poopenaut Valley, point count surveys took place at two established points situated on opposite sides of the Tuolumne River. The northern point (point 1) is located at the intersection of Areas 1 and 2 (UTM 11S 0252076 4200794); and the southern point (point 2) at the intersection of Areas 3 and 4 (UTM 11S 0252165 4200535). These points were selected so that point count surveys would sample a similar area as the area searches; and provide complementary data that could be more directly compared with point count survey data from points with similar habitat characteristics surveyed within Yosemite Valley between 2012 and 2016 (Figure 4-2). This allowed us to use the unregulated Merced River in Yosemite Valley as a reference site to better inform our understanding of what trends in bird communities might be attributable to regulated hydrology rather than other environmental factors. Similar to area searches, point count locations in Poopenaut Valley and Yosemite Valley are ideally visited three time each season, although high flows only allowed for two surveys to be completed at the northern Poopenaut Valley point during the 2016 season. Because the northern point could not be accessed in years with greater flow, only the southern point was used for analysis. In 2016, the point counts took place on 12 May, 28 May, 13 June, and 19 June.

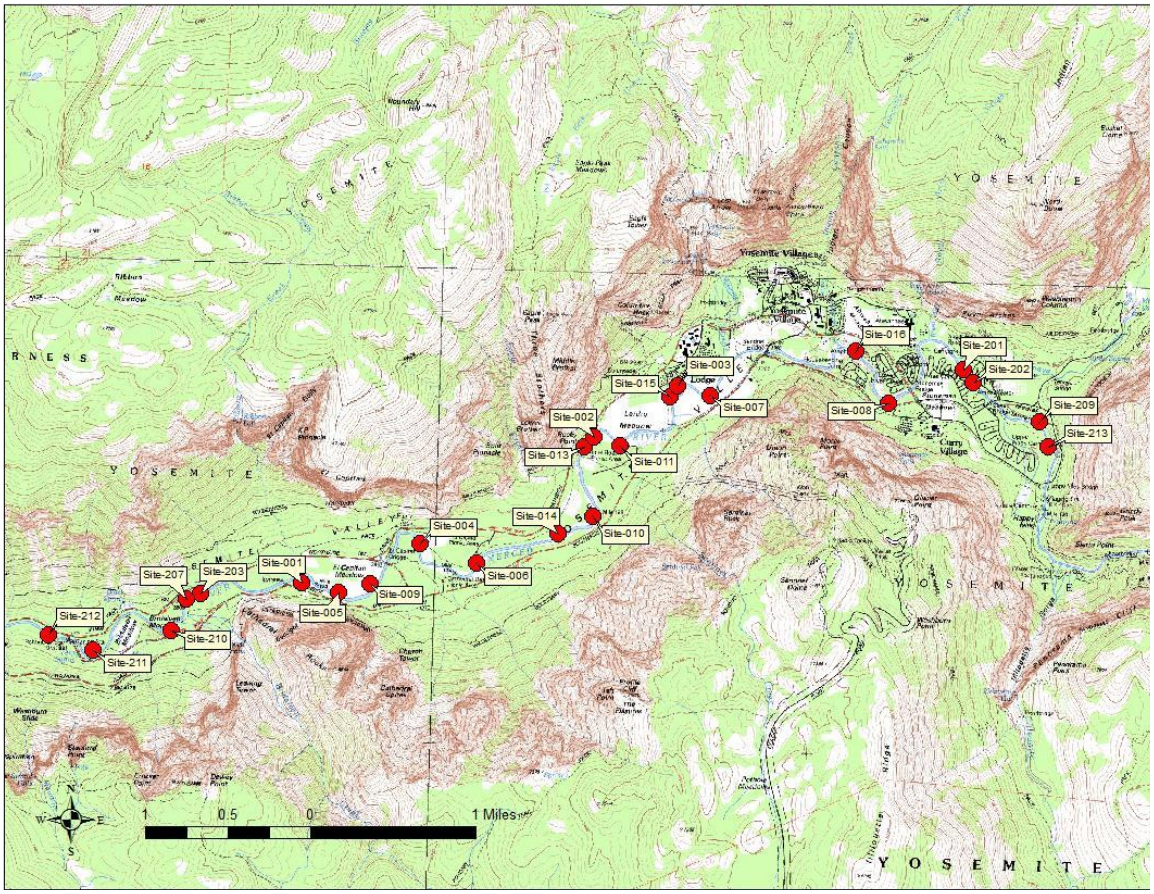


Figure 4-2. Point count locations sampled (*n* = 24) within the Merced River corridor in Yosemite Valley during summers 2010-2016.

In Poopenaut Valley, we used standardized variable circular plot (VCP) point count protocols established by Ralph et al. (1993). In Yosemite Valley, we collected data following the point count protocol used to conduct park-wide bird surveys as part of the Sierra Nevada Network bird-monitoring program (Siegel et al., 2010). This protocol is designed to be analytically compatible with the VCP and other point count protocols. At each visit to a survey point in Poopenaut Valley, counts were conducted for five minutes and all birds observed were recorded along with the method of detection, the distance from the observer where the bird was detected, and any indications of breeding status. Surveys took place starting 15 May and ending 30 June. Surveys were conducted at least 10 days apart, and when possible, each point was surveyed three times during the season. For a more detailed description of point count protocols and survey locations used in Poopenaut Valley, see the 2007 Looking Downstream Report (National Park Service, 2009).

In Yosemite Valley, we conducted point count surveys each summer from 2010 to 2016. Each point count survey lasted seven minutes, split into three separate intervals (one three-minute interval followed by two two-minute intervals).

Spot Mapping

In 2010, we began conducting spot map surveys of the four riparian focal species utilizing already established avian search areas (Areas 1-5; Figure 4-1) to identify habitat use and to infer location and extent of bird territories. After 2013 we started using color-banded individuals to more accurately identify bird territories. For this study, we adapted spot mapping methods from the standardized spot mapping protocol described by Bibby et al. (1992) and Ralph et al. (1993). We focused spot mapping on four of the five focal species: Warbling Vireo, Yellow Warbler, Song Sparrow, and Black-headed Grosbeak. The observer walked an area slowly, stopping for as long as necessary to mark the location of every target species detected on a map of the area. The observer also recorded locations of focal species detected outside of the immediate survey area. The observer distinguished males from females, if possible, noted if males were singing (denoted by circling the male), recorded any and all territorial behavior including chasing or counter-singing (denoted by drawing dotted lines between individuals), and noted the direction of movement of individuals using arrows. We also noted any observed color bands. During each visit, the observer recorded data on a new map. Because of conditions preventing access to the northern search areas, we primarily focused on Areas 3 and 4 and the unflooded portions of Area 5. In 2016, we visited Areas 3 and 5 eight times, and Area 4 nine times. Areas 1 and 2 were only surveyed twice. During each visit, we spent 40 to 90 minutes spot mapping each area. Surveys took place between dawn and noon while birds were most active. Occasionally, we supplemented these surveys with surveys conducted during the evening when bird activity increased.

Target Netting

Since 2012, we have target netted birds in Poopenaut Valley in order to determine age, condition, and breeding status of territorial birds. In 2013, we began applying color bands to focal species to make it possible to re-sight and identify banded birds from a distance and improve spot mapping data. We based our data collection on the established Monitoring of

Avian Productivity and Survivorship (MAPS) protocol, which is commonly used during the avian breeding season. Netting efforts were focused on the four target species (Black-headed Grosbeak, Song Sparrow, Warbling Vireo, and Yellow Warbler), and data were also collected from any birds captured incidentally. During the 2016 season, we increased capture efforts to facilitate tissue sampling for a new trophic dynamics study being implemented within the Poopenaut Valley (see Chapter 5).

Consistent with MAPS protocols, netting efforts were typically initiated at dawn and continued for up to six hours after sunrise while birds are most active and before the weather became too hot to continue safely handling birds. To capture birds, we set up 6-meter long 32 mm mesh mist nets in areas actively being used by our focal species and used recordings of these species to attract individuals to our nets. Once captured, birds were fitted with a uniquely numbered USGS-BRD (United State Geological Survey, Biological Resources Division) aluminum band. Most captured focal species also received three color bands placed in a unique combination. As in the MAPS protocol, we recorded each bird's species, age, sex, skull pneumaticization (an indicator of development), breeding condition (defined by the presence and prominence of a cloacal protuberance in males or brood patch in females), presence of juvenile feathers, molt characteristics, feather wear, wing chord, fat, and body mass. We also recorded where and when birds were captured.

We played vocalizations of the target species on portable speakers placed below the net to help attract individuals. Recordings included territorial calls to attract males and a combination of contact, distress, or male-female interaction calls to attract individuals of either sex. Recordings were all obtained from www.xeno-canto.org. When necessary, painted models of the focal species were also placed near the mist net to illicit a stronger territorial response.

Tissue Sampling

During the 2016 season, we began collecting tissue samples from captured birds as part of a wider study describing food-web architecture below O'Shaughnessy Dam (See Chapter 5). We collected blood, feathers, and feces when possible. Blood collection was conducted according to protocols described in Owen (2011). We drew blood from the brachial vein located on the ventral side humeral-radial-ulnar joint. The vein was punctured using a 26 ga beveled syringe needle and blood was collected in a 50 *μL* non-heparinized capillary tube. Blood samples were, at most, 0.6% of the bird's total body weight, well below the maximum 1% of total body weight recommended by the Field Manual of Wildlife Diseases (Friend et al. 1999). Once taken, samples were put into a 70% ethanol solution, and upon leaving the field site samples were put in a freezer for longer-term storage. Feathers were stored in key envelopes and fecal samples were stored in microcentrifuge tubes with silica beads as a desiccant. Although we focused on trapping and sampling from the four main riparian focal species, we also collected samples from incidental captures of species with similar life-history traits or feeding ecology to our focal species. When an individual of one of the focal species was captured more than once, we would take tissue samples each time if captures were more than 10 days apart.

Nest Searching and Breeding Observations

Since 2010, we have conducted nest search surveys and watched for behavior indicative of breeding while simultaneously conducting spot map surveys throughout the day when other surveys were not taking place. We have used a standardized nest searching protocol (PRBO, 2001) as a general guide. Birds of any species exhibiting probable or confirmed breeding activity such as foraging in pairs, carrying nesting material, or carrying food were followed in order to find their nests. We documented the location, status, and observed activity of each nest onto nest cards. . At the end of the season, we transferred information from the nest cards onto a nest record sheet and coded the fate of each nest. Documenting nests improves our understanding of how commonly and successfully each species breeds in Poopenaut Valley.

4.3 Analytical Methods

Area search and point counts

For area search surveys and point count surveys conducted in both Poopenaut and Yosemite Valleys, we calculated the relative abundance of all bird species, relative abundance of the riparian focal species, and overall species richness. These metrics were chosen to each represent some aspect of avian community composition. We define relative abundance as the average number of individuals observed during each visit to a particular area. Species richness is defined as the average number of species observed during each survey at a particular location. Because only relative abundance of the riparian focal species is available in all seven years for data collected in Yosemite Valley, we primarily focused on that metric; however, we still considered the results relating to the other two metrics using data from 2012 through 2016.

When investigating trends through time relating to river regulation, we opted to only consider survey areas and point count locations which were consistently accessible each year during all water conditions (Search Areas 3 and 4 and Point Count Location 2). However, for 2016 season summary we considered observations in all survey areas.

We assessed which hydrologic variables best predicted overall avian abundance, the abundance of riparian focal species, and overall species richness with linear models using the ‘glm’ function in the R spatial statistics software package (R core team 2016). We analyzed four independent variables relating to river conditions believed to be most important to riparian ecology downstream of dams: maximum discharge, date of peak release, mean daily discharge, and the number of years since mean daily discharge was at or above the historic average or ‘years since average’ (YSA). We calculated the historical average at 367 cfs based on mean daily discharge recorded between 1968 and 2015.

We assessed collinearity among independent variables using the ‘vif’ function in the R software package ‘car’. We considered variance inflation factors (VIF) values greater than 5 within a model containing all covariates as excessively collinear [R core team 2016]). Initially, we also considered including ramping rate and precipitation in our statistical models. However, each was highly correlated with mean daily discharge (correlation coefficient (CC) 0.89) and maximum discharge (CC 0.97) respectively and therefore unlikely to explain additional variation in bird assemblages.

We used Akaike's Information Criterion corrected for small sample size (AIC_c; Burnham and Anderson 2002) to assess which candidate models best explained relative abundance and species richness.

We assessed whether relative abundance, abundance of riparian species, and species richness after the Rim Fire were statistically different than what would be expected based on observations prior to the fire using a paired one-tailed t-test. We considered data collected from all survey areas since the fire affected survey sites on both the north and south side of the Tuolumne River.

We retrieved discharge data for both the Tuolumne River near Poopenaut Valley and the Merced River in Yosemite Valley from the United States Geological Service (USGS) water conditions dataset available at http://nwis.waterdata.usgs.gov/nwis/rt. For the Poopenaut Valley site, we used data collected between 2007 and 2016 by the Tuolumne River, Hetch Hetchy gage located at approximately one mile downstream of O'Shaughnessy Dam, and about two miles upstream of Poopenaut Valley (Latitude 37°56'15", Longitude 119°47'50" [NAD27]). For the Yosemite Valley sites, we used data collected from the Merced River Pohono Bridge gage located between Yosemite Valley point count locations (Latitude 37°43'01", Longitude 119°39'55" [NAD27]).

4.4 Results

During the 2016 season, we observed 72 bird species in Poopenaut Valley. We directly confirmed breeding (by observations of breeding behavior including nest building, incubating, carrying fecal sacs, carrying food, association with fledglings, or observing birds captured in breeding plumage) in 22 species, considered 11 species to be probable breeders (by observing singing or other territorial behavior at least three separate times, observing two individuals counter-singing, or observing pairs together), 20 to be possible breeders (by observing that species at least three separate times, but not necessarily singing or displaying territorial behavior), and 19 to be unlikely breeders (encountered less than three times) (Table 4-2).

Table 4-2. Breeding status for each species reported as unlikely, possible, probable, and confirmed (see National Park Service, 2007) in Poopenaut Valley for 2016. Unlikely species represent those species considered transient in Poopenaut Valley. Codes indicating breeding status are: X = detected in study area during the breeding season; D = heard drumming (for woodpeckers); S = more than one singing male in study area or male bird singing during at least 3 visits; T = territorial behavior; P = pair observed during the breeding season; C = courtship behavior or copulation observed; BC = breeding condition observed while banding; FC = bird observed carrying a fecal sac; CN = bird observed carrying nest material or nest building; CF = bird observed carrying food for young; F = recently fledged or downy young observed; ON = occupied nest observed.

Common Name	Scientific Name	Unlikely	Possible	Probable	Confirmed
Acorn Woodpecker	*Melanerpes formicivorus*				CF
American Coot	*Fulica americana*				F
American Dipper	*Cinclus mexicanus*			S	
American Kestrel	*Falco sparverius*	X			
American Robin	*Turdus migratorius*				BC, CN, F
Anna's Hummingbird	*Calypte anna*			T	
Ash-throated Flycatcher	*Myiarchus cinerascens*	X			
Band-tailed Pigeon	*Patagioenas fasciata*	X			
Belted Kingfisher	*Ceryle alcyon*				FS
Bewick's Wren	*Thryomanes bewickii*	X			
Black Phoebe	*Sayornis nigricans*				CF, F
Black-headed Grosbeak	*Pheucticus melanocephalus*				BC, F
Black-throated Gray Warbler	*Setophaga nigrescens*		S		
Blue-gray Gnatcatcher	*Polioptila caerulea*		S		
Brewer's Blackbird	*Euphagus cyanocephalus*				CN, CF
Brown Creeper	*Certhia americana*				CF
Brown-headed Cowbird	*Molothrus ater*			S,T	
Bullock's Oriole	*Icterus bullockii*			S,P	
Bushtit	*Psaltriparus minimus*				ON
Canyon Wren	*Catherpes mexicanus*				CN
Cassin's Vireo	*Vireo cassinii*				BC, CF, ON, F
Cedar Waxwing	*Bombycilla cedrorum*	X			
Chipping Sparrow	*Spizella passerina*		S		
Cliff Swallow	*Petrochelidon pyrrhonota*	X			
Common Merganser	*Mergus merganser*		X		
Common Nighthawk	*Chordeiles minor*	X			
Common Poorwill	*Phalaenoptilus nuttallii*	X			
Common Raven	*Corvus corax*				F
Dark-eyed Junco	*Junco hyemalis*		S		
Downy Woodpecker	*Picoides pubescens*				F
Dusky Flycatcher	*Empidonax oberholseri*		X		
Hairy Woodpecker	*Picoides villosus*		X		
Hermit Warbler	*Setophaga occidentalis*	X			
House Wren	*Troglodytes aedon*				BC
Lazuli Bunting	*Passerina amoena*		X		

Lesser Goldfinch	*Carduelis psaltria*		S		
Lincoln's Sparrow	*Melospiza lincolnii*	X			
MacGillivray's Warbler	*Oporornis tolmiei*	X			
Mountain Quail	*Oreortyx pictus*				ON
Mourning Dove	*Zenaida macroura*			S	
Nashville Warbler	*Oreothlypis ruficapilla*			S	
Northern Flicker	*Colaptes auratus*			D	
Northern Pygmy-Owl	*Glaucidium gnoma*		S		
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*		X		
Nuttall's Woodpecker	*Picoides nuttallii*		X		
Oak Titmouse	*Baeolophus inornatus*	X			
Orange-crowned Warbler	*Oreothlypis celata*		X		
Pacific-slope Flycatcher	*Empidonax difficilis*		X		
Pie-billed Grebe	*Podilymbus podiceps*	X			
Pine Siskin	*Carduelis pinus*				BC
Purple Finch	*Carpodacus purpureus*	X			
Red-breasted Nuthatch	*Sitta canadensis*			S	
Red-winged Blackbird	*Agelaius phoeniceus*				CN
Song Sparrow	*Melospiza melodia*				BC, CN
Spotted Owl	*Strix occidentalis*			S	
Spotted Sandpiper	*Actitis macularius*		X		
Spotted Towhee	*Pipilo maculatus*				BC
Steller's Jay	*Cyanocitta stelleri*		X		
Townsend's Warbler	*Setophaga townsendi*	X			
Violet-green Swallow	*Tachycineta thalassina*		X		
Virginia Rail	*Rallus limicola*	X			
Warbling Vireo	*Vireo gilvus*				BC, CN, ON
Western Scrub-Jay	*Aphelocoma californica*				F
Western Tanager	*Piranga ludoviciana*			S,P	
Western Wood-Pewee	*Contopus sordidulus*				BC, ON
White-faced Ibis	*Plegadis chihi*	X			
White-headed Woodpecker	*Picoides albolarvatus*		D		
White-crowned Sparrow	*Zonotrichia leucophrys*	X			
White-throated Swift	*Aeronautes saxatalis*		X		
Wilson's Warbler	*Wilsonia pusilla*	X			
Wrentit	*Chamaea fasciata*		S		
Yellow Warbler	*Setophaga petechia*				BC, ON
Yellow-rumped Warbler	*Setophaga coronata*			S	

Area Search

During the 2016 area search surveys we recorded a cumulative total of 365 individuals of 51 different species while conducting area searches. During each search, an average of 19.2 birds belonging to 10.8 species was detected within the search area. Because water conditions affected accessibility to the northern survey areas, we sampled Areas 1, 2, 5A, and 5B twice during the season while Areas 3 and 4 were visited four times. Across all sites, the five most common birds based on relative abundance were Western Wood-Pewee, Red-winged Blackbird, American Robin, Northern Rough-winged Swallow, and Black-headed Grosbeak (Table 4-3).

Table 4-3. Relative abundance of the five most commonly detected species during area search surveys.

Common Name	Scientific Name	Relative Abundance
Western Wood-pewee	*Contopus sordidulus*	1.63
Red-winged Blackbird	*Agelaius phoeniceus*	1.58
American Robin	*Turdus migratorius*	1.47
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	1.05
Black-headed Grosbeak	*Pheucticus melanocephalus*	1.00

We found support for one univariate predictive model (years since average water year (YSA)), as well as a bivariate model including mean daily discharge and YSA for predicting relative abundance of all bird species. Across models relative avian abundance was lower when YSA was longer. Conversely, increased mean daily discharge had a positive relationship with relative avian abundance (Table 4-4). YSA alone predicted 55.7% of the variation in relative avian abundance (F = 10.08, *p* = 0.013, Figure 4) while peak flow timing and mean daily discharge together explained 62.9% of the variation (F = 8.64, *p* = 0.013).

A univariate model including mean daily discharge received the most support in predicting relative abundance of riparian focal species during area search surveys (Table 4) and explained 76.9% of the variation (F = 26.58, *p* = 0.001, Figure 4-3A) followed by a model including both mean daily discharge and date of peak discharge (Table 4-4) explaining 80.0% of the variation (F = 19.00, *p* = 0.001). Relative abundance of riparian focal species was greater in years when the mean daily discharge was higher (Figure 4-3B) and lower when the date of peak discharge was later.

We found support for two univariate and one bivariate model predicting species richness. The two best supported models were both univariate with date of peak discharge explaining 55.4% and YSA explaining 51.3% of the variation in species richness respectively (F = 9.92, *p* = 0.014; F = 8.42, *p* = 0.020 respectively). Peak date and YSA together explained 57.6% of the variation in species richness (F = 7.11, *p* = 0.021). Similar to other metrics, species richness was greater in years when peak discharge was later and decreased as time since average annual discharge increased (Figure 4-3C, D).

Table 4-4. Retained regression models (ΔAICc ≤ 2) for predicting relative abundance, relative abundance of riparian focal species, and species richness calculated from area search surveys in Poopenaut Valley between 2007 and 2016 with corresponding Akaike Information Criterion for small sample size (AIC_c) scores, Akaike weights (w_i) and variation explained (Adj R^2). Null models (i.e., intercept only) are also included. YSA is years since the average annual discharge was at or above the historic mean, and peak date is the date of maximum discharge within the breeding season. Signs in parentheses indicate the direction of the relationship between predictor and response variables.

Avian response	AICc	ΔAICc	w_i	Adj R^2
Relative abundance				
YSA (-)	66.87	0.00	0.41	0.50
Mean daily discharge (+), Peak date (-)	68.58	1.71	0.17	0.63
Null	70.73	3.86	0.06	-
Relative abundance of riparian focal species				
Mean daily discharge (+)	38.11	0.00	0.63	0.74
Mean daily discharge (+), Peak date (-)	40.14	2.03	0.23	0.80
Null	48.47	10.36	0.00	-
Species richness				
Peak date (-)	55.34	0.00	0.35	0.50
YSA (-)	56.22	0.88	0.23	0.45
Peak date (-), YSA (-)	56.88	1.54	0.16	0.63
Null	59.12	3.78	0.05	-

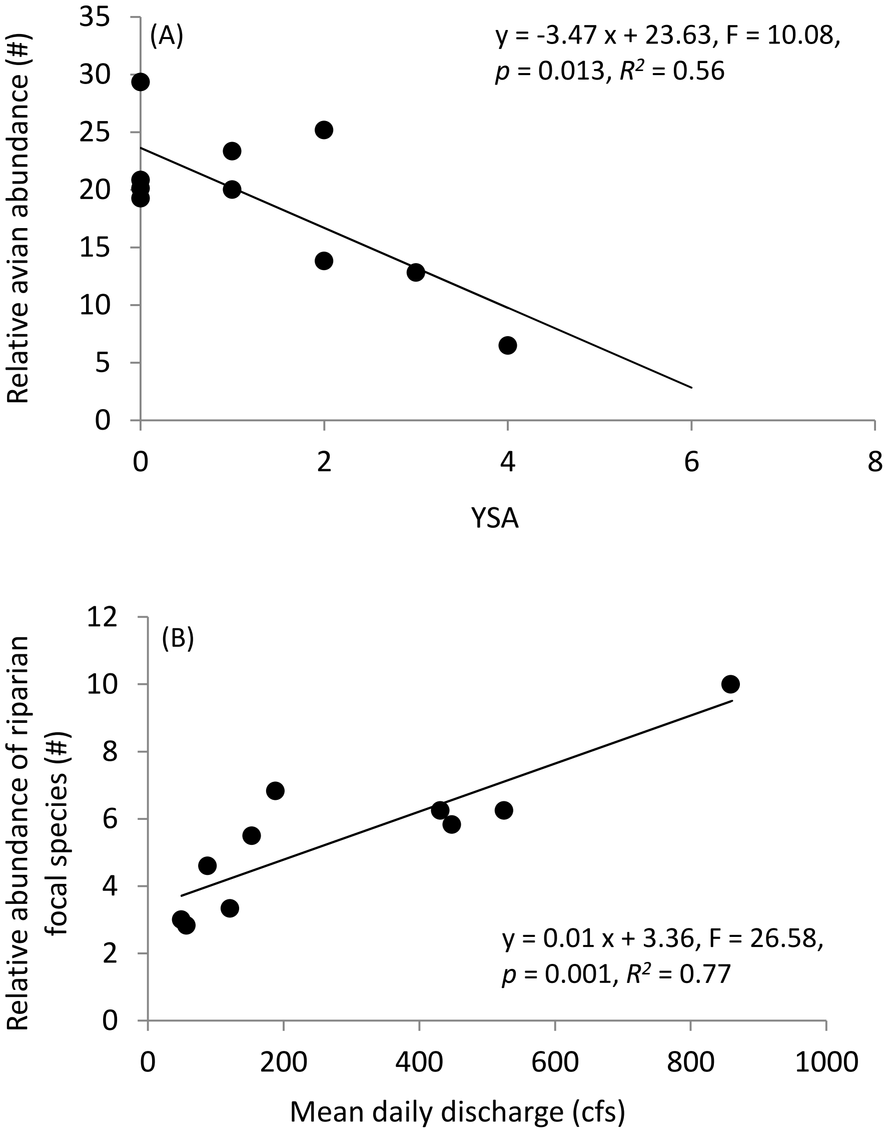


Figure 4-3. Linear relationship between (A) relative avian abundance and years since annual discharge met or exceeded the historic mean (YSA); (B) relative abundance of riparian focal species and mean daily discharge.

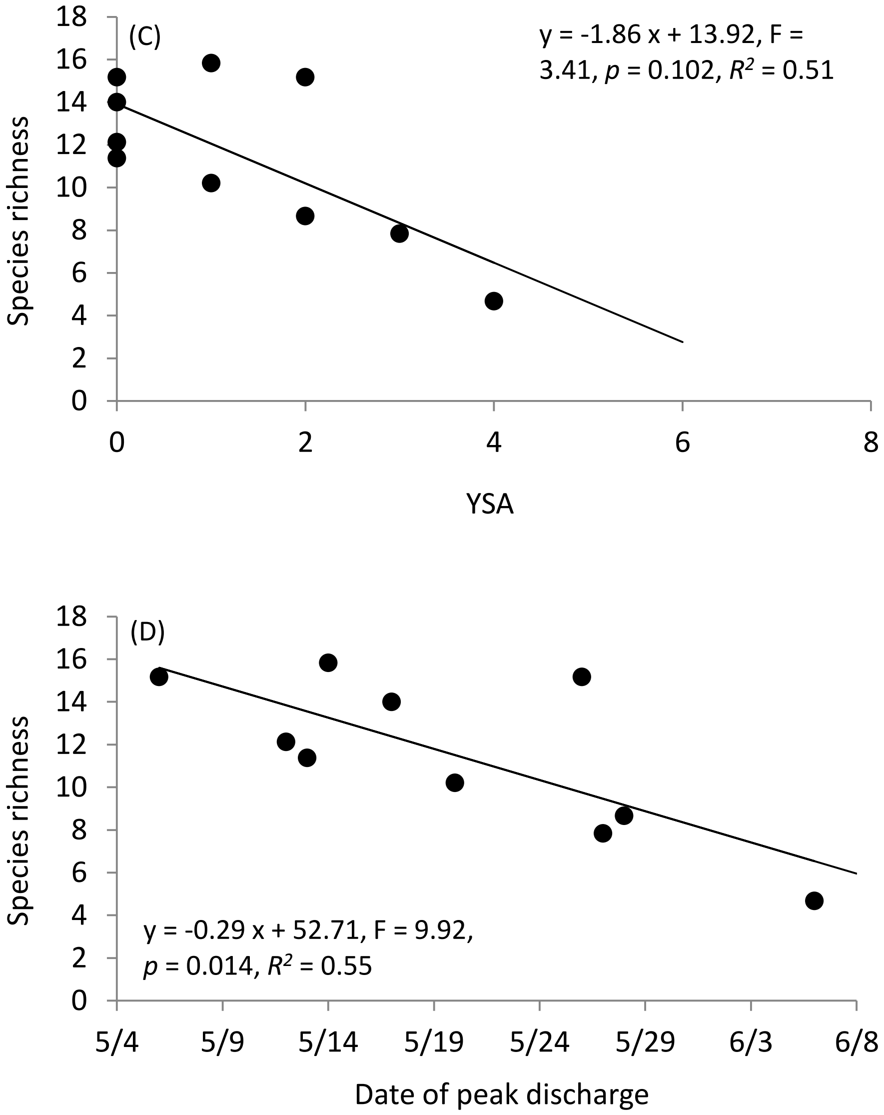


Figure 4-3 continued. (C) species richness and YSA; and (D) species richness and date of peak discharge. All metrics are calculated from area searches conducted between 2007 and 2016 in Poopenaut Valley.

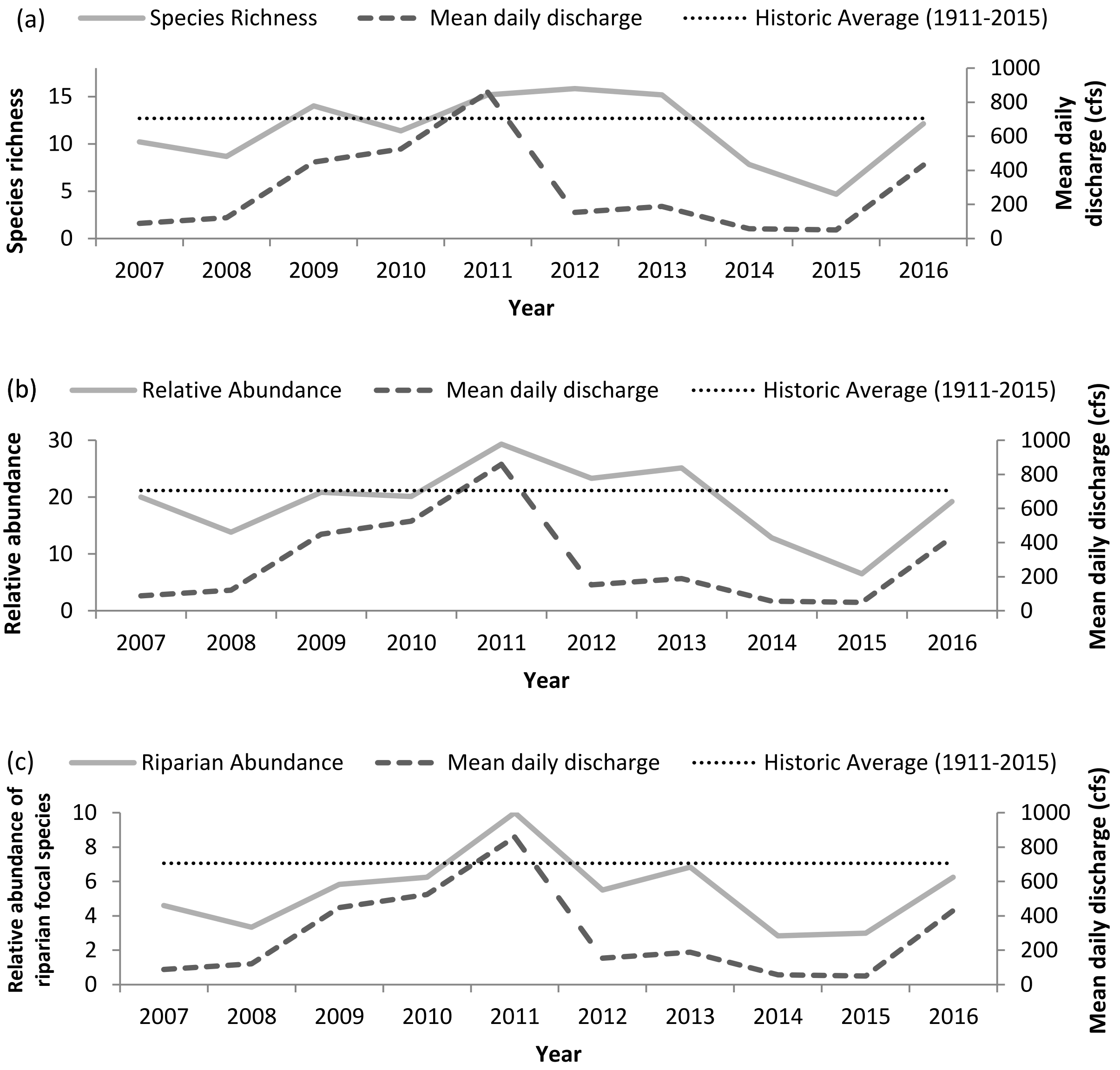


Figure 4-4. Relationship between (a) species richness, (b) relative abundance of all species, and (c) relative abundance of riparian focal species and mean daily discharge across all years (2007 – 2016). Mean daily discharge is the average of all daily averages for the water year.

We observed a reduction in the observed mean of all three metrics of avian abundance and diversity during area search surveys in the years following the Rim Fire. After the fire, we noted reduced relative abundance, species richness, and abundance of riparian focal species during area search surveys. Before the fire, the mean avian abundance was 22.30 ± 4.28 (SD) birds, and after the fire that number dropped to 16.25 ± 3.15 ($t = 15.67$, $p = <0.001$). Mean riparian species abundance was 6.05 ± 2.08 in the years prior to the Rim Fire and 4.03 ± 1.92 after ($t = 8.70$, $p = <0.001$), and species richness dropped from 12.14 ± 2.14 species to 8.97 ± 1.58 ($t = 16.29$, $p = <0.001$).

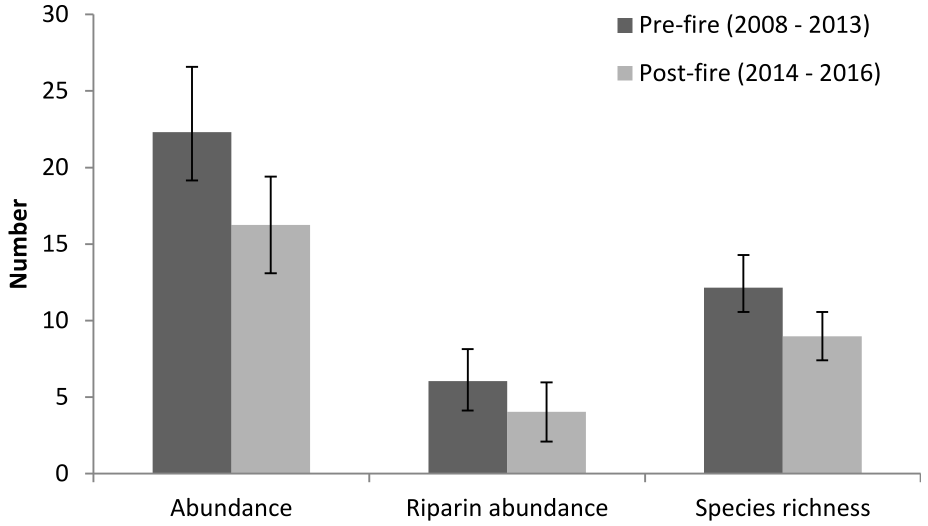


Figure 4-5. Mean relative abundance, mean relative abundance of riparian focal species, and mean species richness observed during Poopenaut Valley area search surveys in the years before (2008 – 2013) and after (2014 – 2016) the Rim Fire.

Point Counts – Poopenaut Valley

During point count surveys conducted in 2016, we recorded a cumulative total of 117 individual birds of 21 different species. During each point count, we detected an average of 19.5 birds of 12.2 species. Due to high river stage on the Tuolumne River preventing access to the north side of the survey area, we sampled the north point twice during the season and the south point four times. Across point count locations, the five most common birds based on relative abundance were Red-winged Blackbird, Song Sparrow, Western Wood-Pewee, Acorn Woodpecker, and Mountain Quail. Two of the species (Acorn Woodpecker and Mountain Quail) were upland species less prevalent during area searches with clear, loud vocalizations that carry well.

Table 4-5. Relative abundance of the five most commonly detected species during 2016 point count surveys based on average number of detections during each survey event.

Common Name	Scientific Name	Relative Abundance
Red-winged Blackbird	*Agelaius phoeniceus*	3.33
Song Sparrow	*Melospiza melodia*	1.50
Western Wood-Pewee	*Contopus sordidulus*	1.50
Acorn Woodpecker	*Melanerpes formicivorus*	1.33
Mountain Quail	*Oreortyx pictus*	1.00

Mean annual discharge was the only independent variable that was supported for inclusion in our proposed models predicting relative avian abundance, abundance of riparian focal species, and species richness (Table 4-6). All three of these indices were greater in years when mean daily discharge was higher (Figure 4-6). However, in all cases, the null model was the best supported model or within 2 AICc units of the best model (Table 4-6, Figure 4-6).

Table 4-6. Retained regression models (ΔAICc ≤ 2) for predicting relative abundance, relative abundance of riparian focal species, and species richness calculated from point count surveys conducted in Poopenaut Valley between 2007 and 2016 with corresponding Akaike Information Criterion for small sample size (AICc) scores, Akaike weights (wi) and variation explained (Adj R2). Null models (i.e., intercept only) are also included. Signs in parentheses indicate the direction of the relationship between predictor and response variables.

Avian response	AICc	Δ AICc	w_i	R^2
Relative abundance				
Mean annual discharge (+)	53.23	0.00	0.50	0.44
Null	54.40	1.17	0.28	-
Relative abundance of riparian focal species				
Mean daily discharge (+)	39.40	0.00	0.66	0.62
Null	43.20	3.80	0.10	-
Species richness				
Null	37.83	0.00	0.51	-
Mean annual discharge (+)	39.33	1.50	0.24	0.32

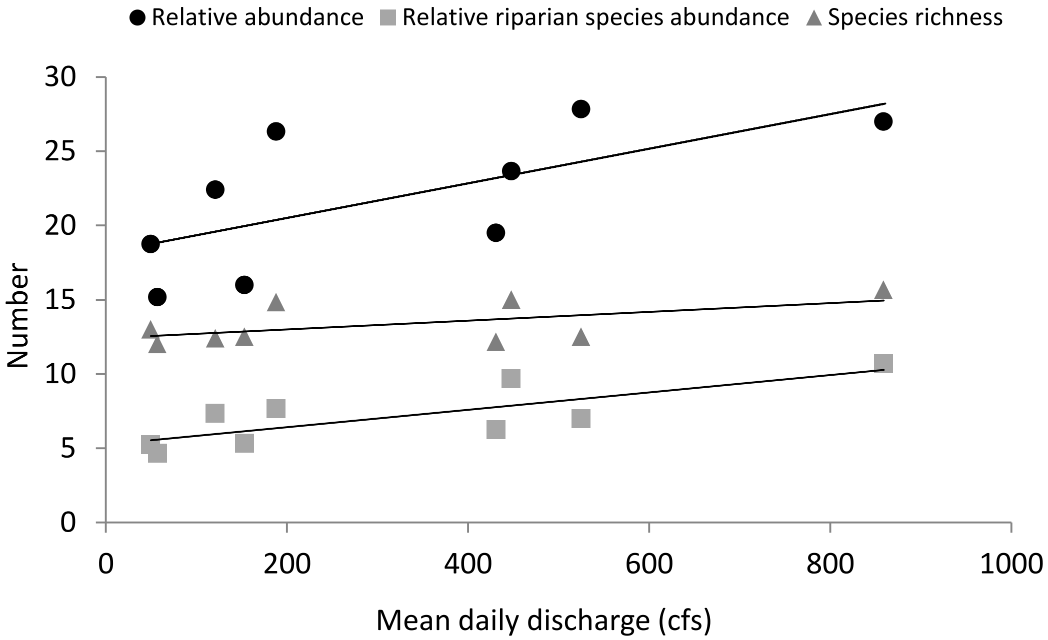


Figure 4-6. Linear relationship between mean daily discharge and relative avian abundance (y = 0.01 x + 18.2; F = 6.59; p = 0.037, R^2 = 0.44), relative abundance of riparian focal species (y = 0.01 x + 5.25; F = 11.20; p = 0.012; R^2 = 0.62), and species richness (y = 0.003 x + 12.41; F = 3.10; p = 0.012; R^2 = 0.32) calculated from point counts conducted between 2008 and 2016 in Poopenaut Valley.

We observed reduced relative abundance, relative abundance of riparian focal species, and species richness measured by point counts conducted in the years following the 2013 Rim Fire. Mean relative abundance decreased from 23.87 ± 4.38 (SD) prior to the Rim Fire (2008 – 2013) to 17.81 ± 2.32 after (*t* = 15.87, *p* = <0.001). Mean relative abundance of riparian focal species dropped from 7.94 ± 1.93 to 5.39 ± 0.80 (*t* = 12.01, *p* = <0.001), and mean species richness decreased from 13.82 ± 1.51 to 12.39 ± 0.54 (*t* = 34.911, *p* = <0.001).

Yosemite Valley Point Counts

Between 2012 and 2016, we observed 3,308 individuals belonging to 129 species while conducting point counts in Yosemite Valley. We found no support for including flow parameters as predictors of avian community composition responses in Yosemite Valley with one exception: relative abundance of riparian focal species was greater in years when peak flow was higher (Figure 4-8; F = 22.27, p = 0.005, $Adj\ R^2 = 0.78$). In all other cases, the null model was the best supported model, indicating that our proposed explanatory variables were not good predictors of avian community composition along the Merced River in Yosemite (Table 4-7). In addition, we observed no significant change between any of the three avian community composition metrics in the years before (2010 – 2013) and after (2014 - 2016) the Rim Fire occurred: Relative avian abundance was 9.68 ± 0.66 (SD) before and 10.49 ± 0.81 after; mean relative abundance of riparian focal species was 3.90 ± 1.03 before and 2.78 ± 0.22 after; and species richness was 7.43 ± 0.08 before and 8.20 ± 0.74 after.

Table 4-7. Retained regression models (ΔAICc ≤ 2) for predicting relative abundance, relative abundance of riparian focal species, and species richness calculated from point count surveys conducted in Yosemite Valley between 2010 and 2016 with corresponding Akaike Information Criterion for small sample size (AIC_c) scores, Akaike weights (w_i) and variation explained (Adj R^2). Null models (i.e., intercept only) are also included. Signs in parentheses indicate the direction of the relationship between predictor and response variables.

Avian response	AICc	Δ AICc	*w_i*	*Adj R^2*
Relative abundance				
Null	20.76	0.00	1.00	-
Relative abundance of riparian focal species				
Annual maximum discharge (+)	20.23	0.00	0.87	0.78
Null	25.11	4.87	0.08	-
Species richness				
Null	19.11	0.00	0.99	-

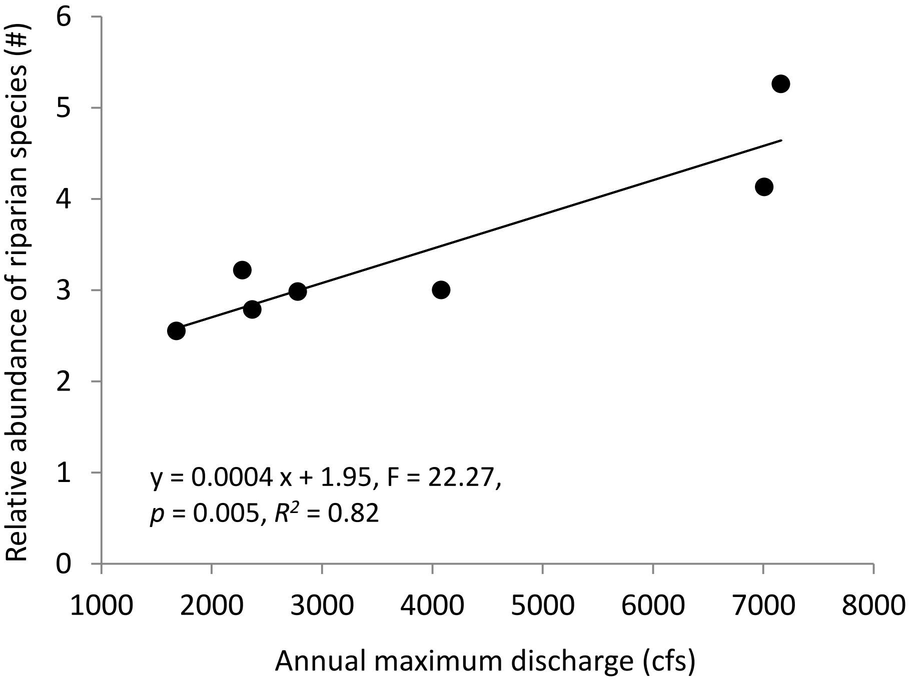


Figure 4-7. Linear relationship between annual maximum discharge and relative abundance of riparian focal species calculated from point counts conducted between 2010 and 2016 in Yosemite Valley.

Target Netting and Tissue Sampling

During the 2016 season, we target netted the four primary riparian focal species (Black-headed Grosbeak, Song Sparrow, Warbling Vireo, and Yellow Warbler) to collect blood, feces, and feather samples for the purposes of studying trophic dynamics in Poopenaut Valley and Yosemite Valley (see Chapter 5 for more details). Banding took place during all three visits to Poopenaut Valley along with two supplementary visits prior to peak flows on 2-3 May as well as after peak flows on 24 July.

We captured a total of 61 individual birds of 17 different species in Poopenaut Valley, including 10 Black-headed Grosbeaks, 11 Song Sparrows, 8 Warbling Vireos, and 4 Yellow Warblers (Appendix A). Prior to 2016, only 56 birds were banded throughout the entirety of the Looking Downstream study. Of the 61 birds we captured, we recaptured 8 individuals at least once (4 Song Sparrows, 3 Warbling Vireo, and 1 Yellow Warbler). While target netting in Poopenaut Valley, we collected 64 blood samples, 51 feather samples, and 21 fecal samples. We fit 33 birds with color bands, including 7 Black-headed Grosbeaks, all 11 Song Sparrows, 7 Warbling Vireos, and 3 Yellow Warblers. During the season, we also re-sighted 11 of the color banded birds (see Spot Mapping).

In addition to supporting the trophic dynamic study and territory mapping, observations of the breeding condition (i.e. the presence of a brood patch or cloacal protuberance) of captured birds made it possible to positively confirm breeding in 12 of the 17 species captured.

Spot Mapping

During the 2016 season, we completed a total of 29 separate spot map surveys focused on our four primary riparian focal species. Nine surveys took place within Area 4, eight within Areas 3 and 5, and two within the northern search Areas (1 and 2), which were generally inaccessible due to flooding. Of the 27 birds color banded during the 2016 season, we could have potentially re-sighted up to 17, (the final 10 color-banded birds were captured after the last formal spot-mapping session of 2016 occurred). Of these 17 birds, we re-sighted and spot-mapped 11 within Poopenaut Valley one or more days after being banded. We re-sighted 4 Warbling Vireos, 1 Yellow Warbler, and 6 Song Sparrows. We also re-sighted one additional Song Sparrow color-banded in 2015, the male RR/RS.

Song Sparrows

During the course of spot mapping, we completed 29 observations of Song Sparrows in which we noted the location, and movements and behaviors of an individual on a given day. Of these observations, 11 were of birds whose identity was unknown. Because many of these individuals were color-banded, we were able to record changes in territory size and the number of individuals occupying the Poopenaut Valley as the season progressed and water levels changed. We were able to identify two consistent areas occupied and defended by the same males (Y/G S/R and T/G R/S; Figure 4-8) and observed a probable female present within both of these areas allowing us to confirm a consistent territory. Of these, Y/G S/R was the most conspicuous and aggressive.

Figure 4-8. Male Song Sparrow with color bands Y/G S/R. This bird was banded on 2 May 2016 and observed throughout the breeding season.

During the first visit to Poopenaut Valley (12 May 2016), while river flow was highest, we made four observations of Song Sparrows. Only two of these were banded this early in the season (Figure 4-9, Appendix A). During this first visit, all individuals were found clustered in a relatively limited area where vegetation was not inundated.

During the second visit, nine individuals were identified, six of which were already color-banded (Figure 4-10). Two more were un-banded birds occupying areas overlapping with a banded bird's territory. We inferred these to be the banded birds' mates by behavior including soliciting copulation, continued presence on a territorial bird's territory, and lack of singing. Because the water level was markedly lower than during the first visit, more vegetation was exposed, and more possible territories were made available, all of which became occupied.

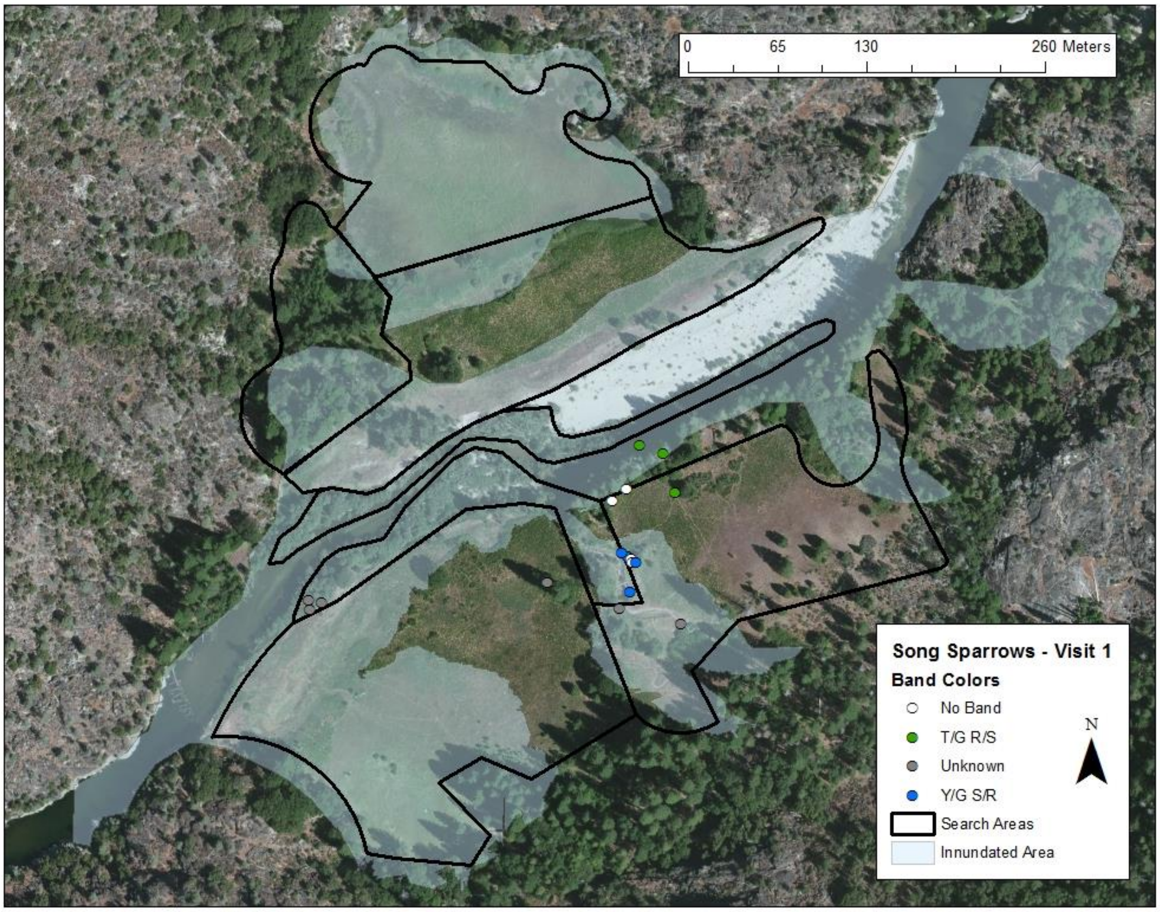


Figure 4-9. Song Sparrows observed during the first spot map survey in Poopenaut Valley conducted on 12 May 2016 while discharge was 7,500 cfs. Approximate area of inundation is delineated in transparent blue. Individual Song Sparrows are indicated by different colored circles.

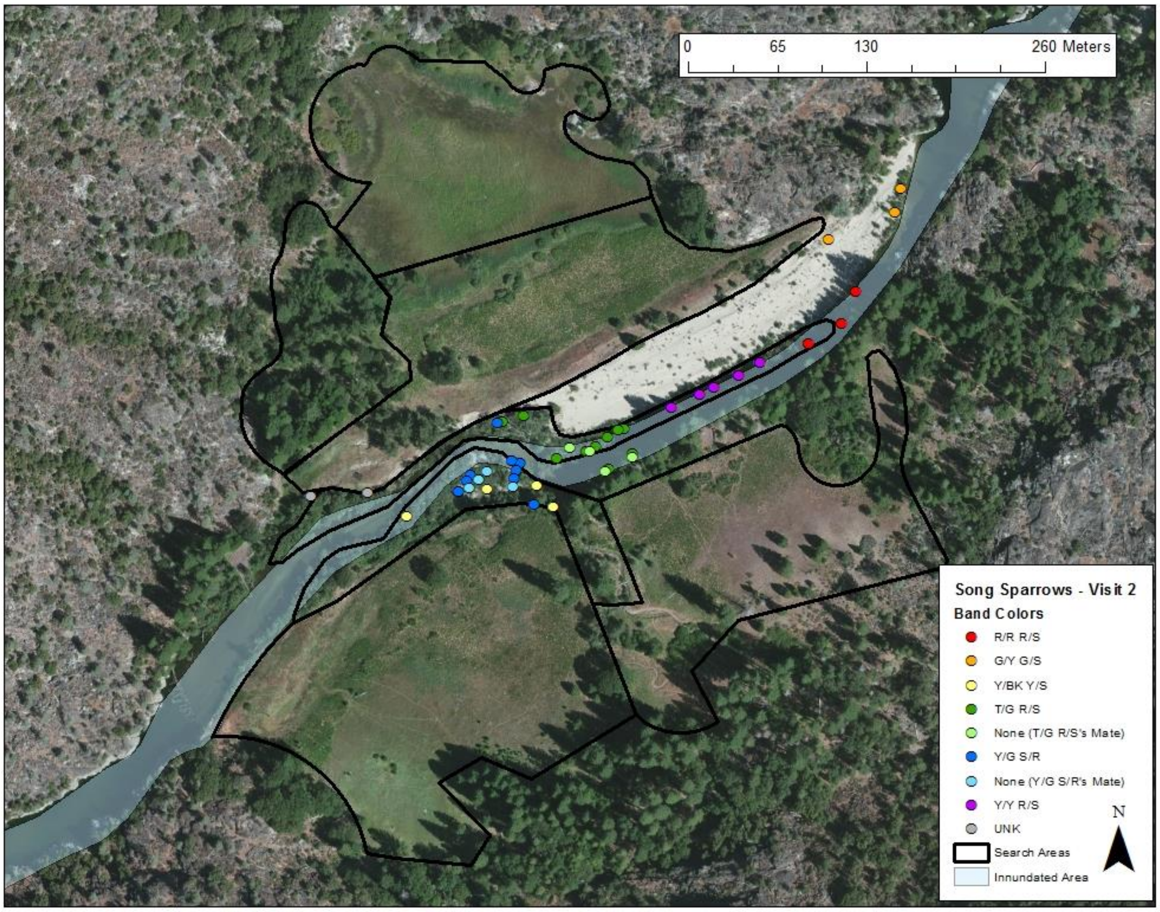


Figure 4-10. Song Sparrows observed during the second spot map survey in Poopenaut Valley conducted on 28 and 29 May 2016 while discharge was 550 cfs. Approximate area of inundation is delineated in transparent blue. Individual Song Sparrows are indicated by different-colored circles.

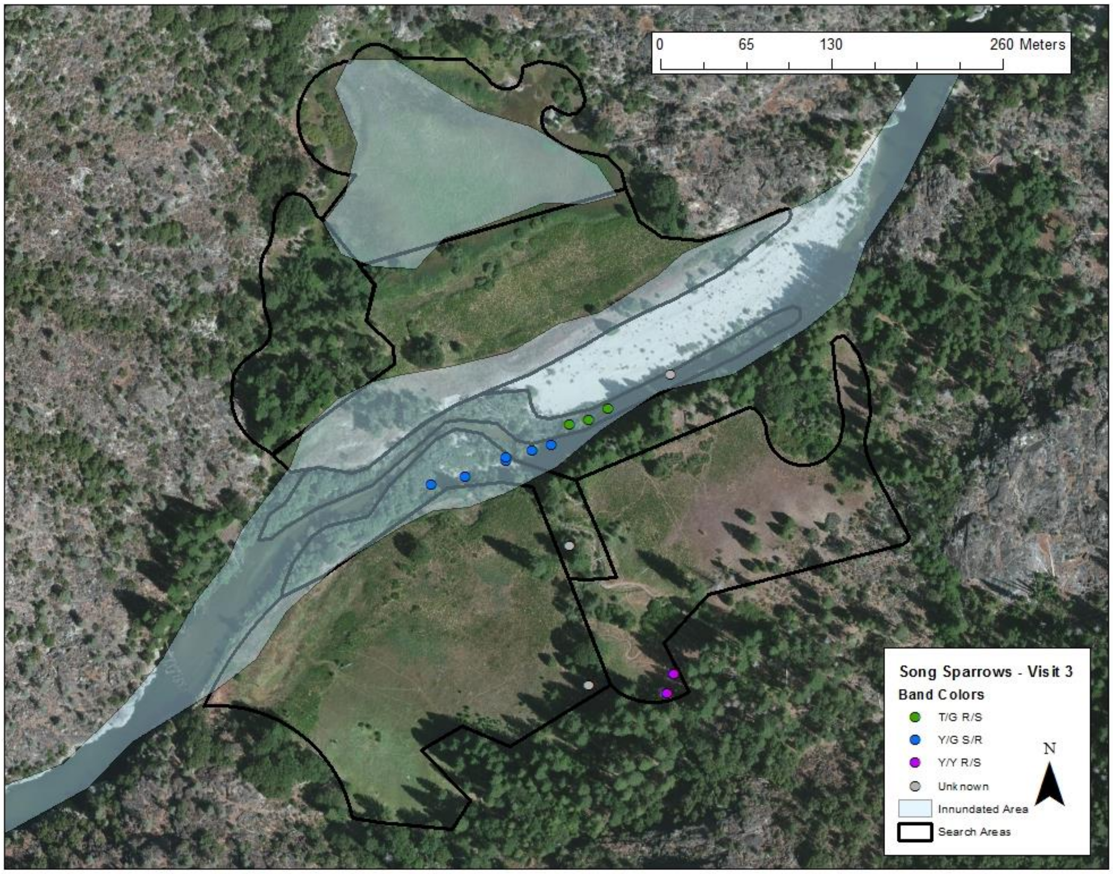


Figure 4-11. Song Sparrows observed during the third spot map survey in Poopenaut Valley on 14 and 15 June 2016 while discharge was at 1,300 cfs. Approximate area of inundation is delineated in transparent blue. Individual Song Sparrows are indicated by different-colored circles.

Figure 4-12. Song Sparrows observed during the fourth spot-map survey in Poopenaut Valley on 29 June 2016 while discharge was 550 cfs. Approximate area of inundation is delineated in transparent blue. Individual Song Sparrows are indicated by different-colored circles.

Yellow Warblers

We made 33 observations of Yellow Warblers where we were able to record the location, movements and behaviors of an individual on a given day (Figure 4-13). Of these, we were able to confirm the band combination (or lack of bands) of the bird observed on 6 occasions. Only one male Yellow Warbler was banded in 2016, and this banded bird was the only male Yellow Warbler observed while spot mapping during the second, third and fourth visits to Poopenaut Valley. We also suspect that a territorial male warbler confirmed to be un-banded on the first spot mapping visit was that same territorial male seen on subsequent visits. The area being occupied by this bird changed during each visit to Poopenaut Valley.

Figure 4-13. Yellow Warblers observed during 2016 spot map surveys in Poopenaut Valley across all four visits.

Warbling Vireos

We made 36 observations of Warbling Vireos where we were able to record the location, movements, and behaviors of an individual on a given day (Figure 4-14). Of these observations, we were able to confirm band colors during six observations, and identified and photographed one more color-banded bird whose band colors could not be fully distinguished (Figure 4-15). This represented four of the six Warbling Vireos color banded during the 2016 field season.

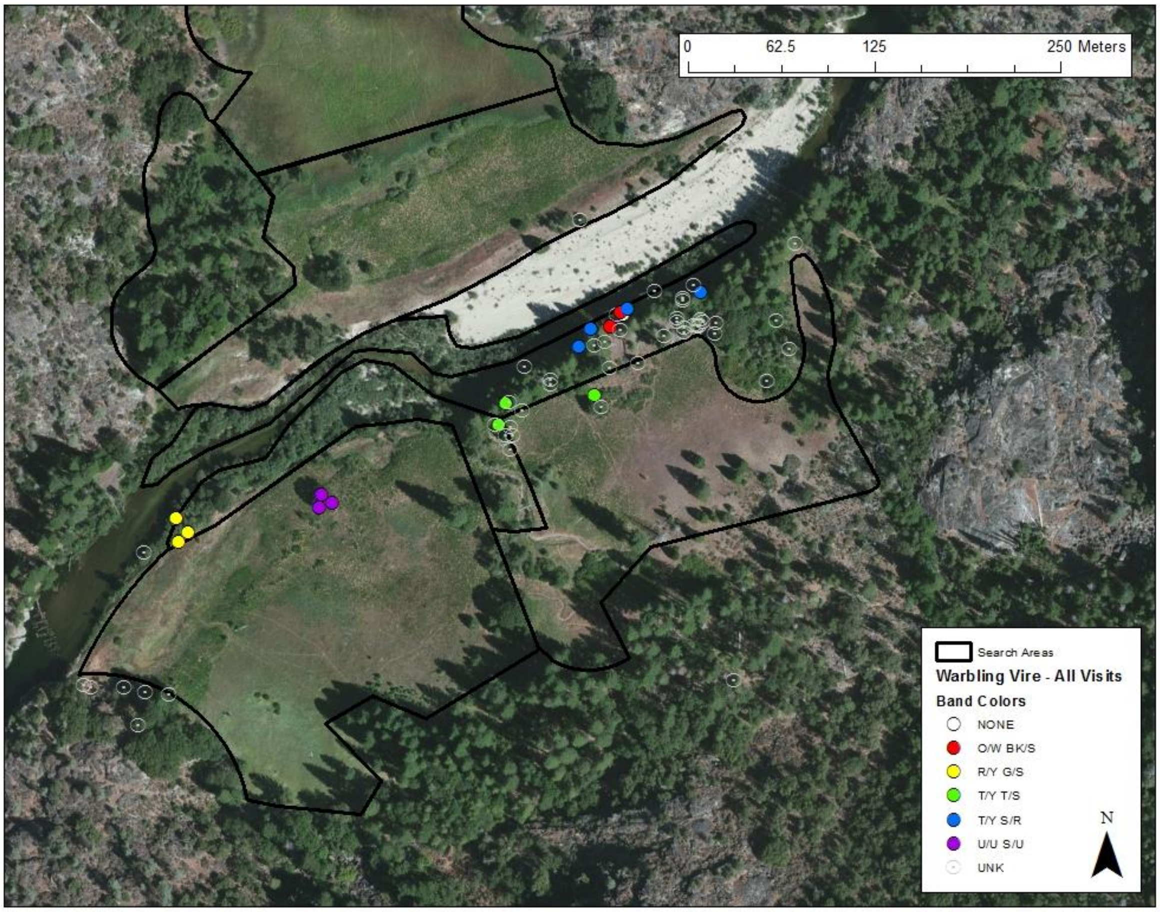


Figure 4-14. Warbling Vireos observed during the 2016 season in Poopenaut Valley.

Figure 4-15. Color-banded Warbling Vireo with indistinguishable color bands.

Black-headed Grosbeaks

During the 2016 field season, we spot mapped 22 Black-headed Grosbeaks (Figure 4-16). We were unable to re-sight any of the four individuals color banded prior to the final spot mapping session. This may be in part because we were unable to begin color banding grosbeaks until the second visit to Poopenaut Valley. We were able to confirm that the bird observed during 5 of our observations either had no band or possessed a silver band from United States Fish and Wildlife. Because these observations were made in distinct, spatially separated locations, we suspect that this represents 4 territories.

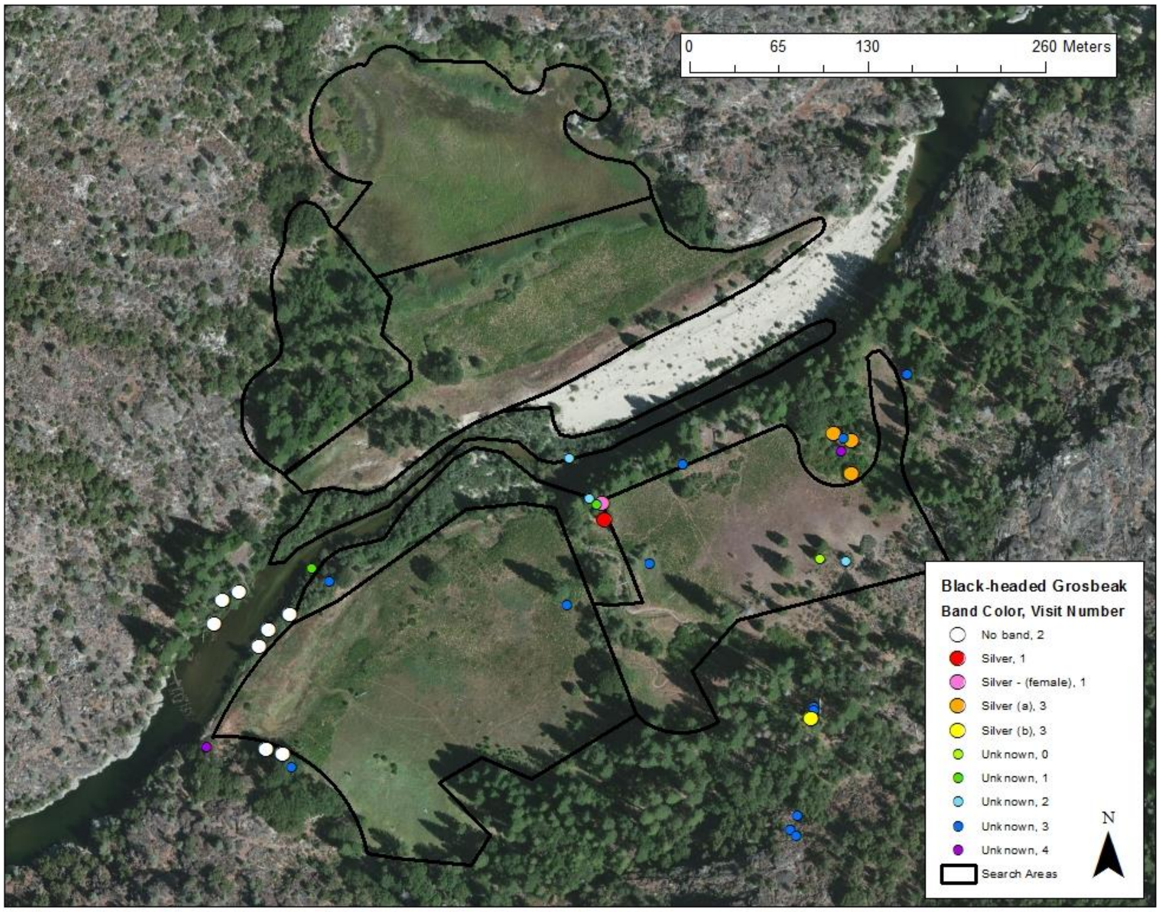


Figure 4-16. Black-headed Grosbeaks observed during 2016 spot-map surveys in Poopenaut Valley.

Nest Searching

We found 14 nests in 2016 (Figure 4-17, Table 4-8). Five of these were nests made by riparian focal species. Because of high flows during much of the early part of the season in Poopenaut Valley, nest searching was limited. The nests were all found during the second and third visits to Poopenaut Valley (Table 4-8). Only one juvenile resident bird was detected until 24 July during the supplementary banding session.

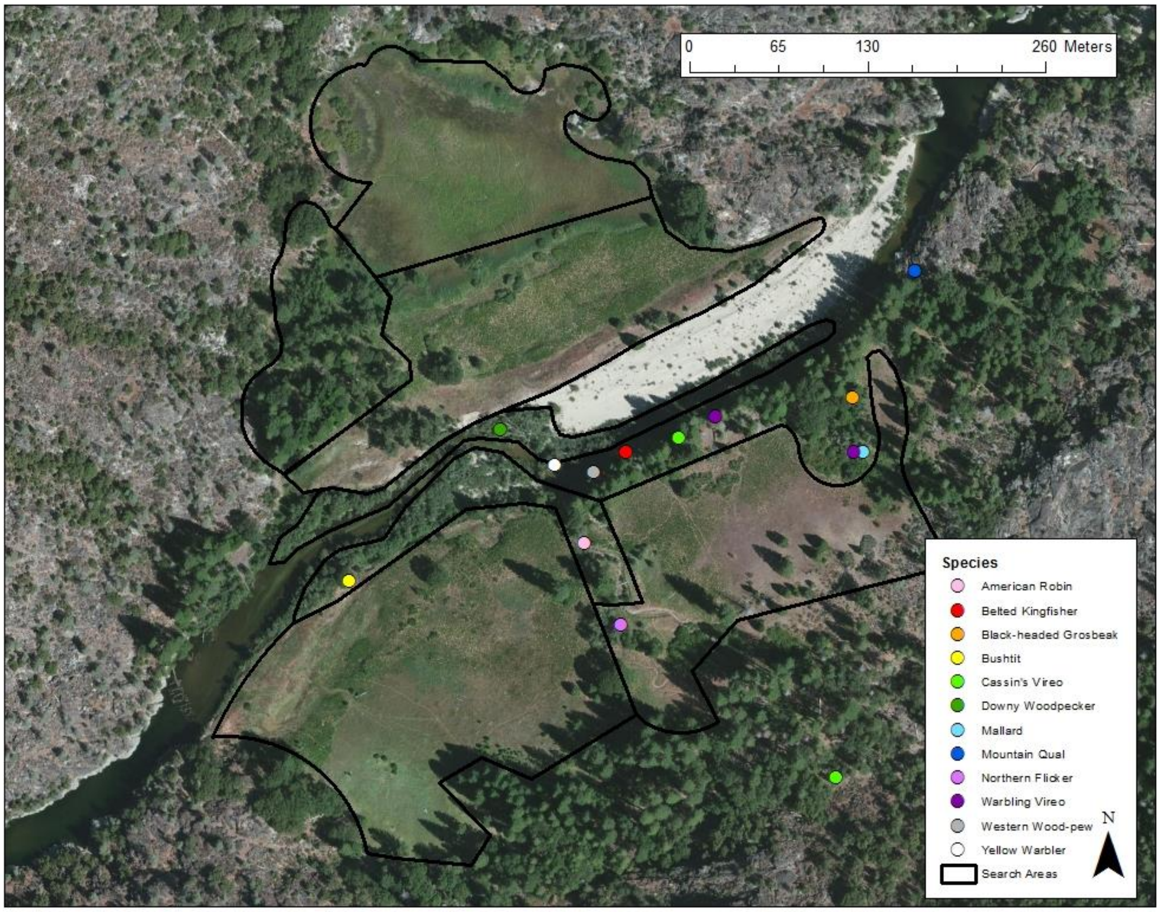


Figure 4-17. Nests found in Poopenaut Valley during 2016.

Figure 4-18. Warbling Vireo nest in Poopenaut Valley.

Table 4-8. Nests found in 2016.

Common Name	Date Found	Stage When Found
American Robin	5/12/2016	Building
Warbling Vireo	5/28/2016	Building
Downy Woodpecker	5/28/2016	Nestling
Western Wood-pewee	5/30/2016	Building
Cassin’s Vireo	6/13/2016	Nestling
Mallard	6/13/2016	Incubation
Warbling Vireo	6/13/2016	Incubation
Mountain Quail	6/13/2016	Incubation
Black-headed Grosbeak	6/13/2016	Building
Bushtit	6/13/2016	Nestling
Northern Flicker	6/14/2016	Nestling
Yellow Warbler	6/14/2016	Nestling
Cassin’s Vireo	6/15/2016	Nestling
Belted Kingfisher	6/15/2016	Nestling

4.4 Discussion

Populations of individual bird species and avian communities shift in response to short-term changes in emergent aquatic prey availability and longer-term changes in environmental conditions including geomorphology, riparian vegetation structure and composition, and water temperature – all habitat features that respond to changes in hydrology (Royan et al., 2013). We sought to describe how breeding birds in Poopenaut Valley respond to changes in the hydrology of the Tuolumne River. We found preliminary evidence that changes in the timing and magnitude of flood events and annual discharge explain a large portion of the variation in abundance, species richness, and breeding behavior of riparian birds. In addition, a wildfire and long-term drought decreased abundance of upland and riparian birds and species richness over the course of our study. Therefore, multiple disturbances influence breeding birds at the individual, population, and community level, and river regulation is an important driving factor.

Mean daily discharge and years since discharge was at or above the historic mean (YSA) were identified as supported predictors of both upland and riparian bird abundance in Poopenaut Valley during the breeding season (Table 4-4). Higher mean daily discharge was associated with greater abundance of riparian and upland birds (Figures 4-3B and 4-4), and overall bird abundance decreased with time since a historically average or above average annual discharge (Figure 4-3A). It would be easy to interpret observed avian responses as a result of drought conditions (i.e., far less than average precipitation) from 2011 to 2015. However, our point count surveys along the unregulated Merced River in Yosemite Valley revealed no such relationship (Table 4-7) despite similar drought and lower than average flow conditions. Together these results indicate an increased effect of river regulation on persistent low-flows and decreased bird abundance in Poopenaut Valley.

Earlier peak flow was associated with increased abundance of all birds, increased abundance of riparian birds, and increased species richness in Poopenaut Valley (Table 4-4, Figure 4-3D), but not in Yosemite Valley (Table 4-7). The response of riparian Song Sparrows to the 2016 experimental flood events may in-part explain this pattern. During the initial flood on 12 May, Song Sparrow territories in Poopenaut Valley were restricted to a small area near the confluence of the Tuolumne River with an ephemeral tributary to the south (Figure 4-9). In a subsequent survey conducted on 27-28 May, 5 more individual Song Sparrows were detected and 9 total territories delineated throughout the riparian vegetation on both sides of the river indicating a positive effect of the initial flood on Song Sparrow abundance (Figure 4-10). However, following a subsequent peak flow that occurred on 14 June, all but four Song-Sparrow breeding territories disappeared and never returned (Figure 4-11). We interpret these results as initial evidence that later flood events that inundate nests and territories negatively affect breeding birds in Poopenaut Valley.

We observed a significant decrease in abundance and richness of upland and riparian bird species occupying Poopenaut Valley in the years following the Rim Fire compared to the years prior to the Rim Fire (Figure 4-5). The Rim Fire reduced riparian plant cover important for nest building and may have decreased invertebrate prey availability leading to subsequent decreases in avian abundance and diversity. However, each of these metrics is also negatively associated with years since average discharge which increased throughout the study period (with the notable exception of 2016). Separating the influence of the Rim Fire from persistent low-flows is therefore not within the scope of this study and requires further inquiry. Multivariate modeling that includes variables relating to both the fire and floods may help discern which of these is most important to bird populations. It is likely that both disturbances play a role in influencing bird abundance and diversity.

Preliminary evidence suggests that bird abundance and diversity in Poopenaut Valley could be enhanced by increased mean daily discharge, decreased time between historically average annual discharge, and earlier peak flows. Floods that occur in late June and annual low-flows are associated with decreased abundance and diversity of birds; however, the results of this study do not allow us to infer anything about how magnitude or timing of floods that occur outside the breeding season influence birds. In addition, we did not assess the influence of flood duration or ramping rates on bird abundance or diversity.

Annual floods shape riparian habitat and drive changes in emergent aquatic insects – an important food source for many bird species. Riparian and aquatic organisms, including birds, are highly-adapted to predictable disturbance regimes and therefore recovery quickly following floods. However, persistent departure from historic magnitude, duration, and timing of flows is likely to reduce the ability of populations and communities to recover. Concomitant changes in climate and regional bird habitat loss will likely interact with river regulation to drive further changes in bird populations and diversity.

Chapter 5. 2015 Bat Studies in Poopenaut Valley

5.1 Introduction

Bats are landscape integrators: they utilize riverine habitat for multiple purposes, are highly mobile, and are sensitive to disturbance. Bats use rivers and riparian habitat as nesting/roosting sites, foraging areas, and migration corridors. Some species such as Yuma myotis specialize in foraging on emergent aquatic insects like mayflies and caddisflies directly over the water. Others, such as Mexican free-tailed bat may primarily forage and roost in upland areas, but are known to forage frequently over rivers when prey availability is high. Many species derive a majority of their food from aquatic sources at certain times of the year and in certain locations. In addition, almost all species of bats rely on rivers or other water bodies to drink, making these areas bat hotspots on the landscape. Bats are highly mobile and migratory. Because of this, bats are believed to be especially sensitive to spatial and temporal shifts in river condition across scales. Therefore shifts in bat activity, community composition, and habitat use over time may be indicative of overall ecosystem function and resistance and resilience to disturbance (including river regulation).

The riparian zone of Poopenaut Valley may be an important landscape feature to bats. Poopenaut Valley is a rare low-elevation meadow (~1,000m. asl) and prior studies suggest that the highest bat species diversity, detection rates, and foraging intensity occur in the park’s lower elevations. Unlike upstream and downstream reaches of the Tuolumne River, the Poopenaut reach is less-confined, resulting in a floodplain meadow that is partially inundated for several months in wet years. The floodplain meadow provides complex habitat to bats including three ephemeral small tributaries with associated riparian forest, willow, and cottonwood forest along the river itself, a seasonal pond, a spring, open meadow, upland mixed-conifer and oak forest, and rock outcrops. Because of the diversity of habitat features and position of Poopenaut Valley on the landscape, it is not entirely surprising that all 17 bat species known to occur within Yosemite National Park have been detected since April 2011. Five species of these are special status species that have experienced state-wide declines (Table 5-1). While population declines are based largely on issues that affect these species outside park boundaries, they serve to highlight the importance of park land as potential refugia, and signal a potentially heightened sensitivity of these species to management activities within the park.

A significant driver of bat foraging activity is availability of invertebrate prey. Insectivorous bats forage on a variety of prey items including both terrestrial invertebrates and emergent aquatic insects. In particular, many species of bats feed on insects belonging to the Orders Ephemeroptera, Diptera, Lepidoptera, and Coleoptera. At certain times of the year when terrestrial invertebrate abundance is low, but emergent aquatic insect abundance is high (i.e., spring and fall), bats can derive a high proportion of their energetic demand from aquatic prey subsidies. In addition, bats can track emergence events and forage preferentially in riparian zones of river reaches where emergence is high.

Flooding is the foremost driver of food web dynamics in aquatic-terrestrial food webs. Disturbance from floods can alter these food web properties through direct and indirect mechanisms. Floods that exert enough energy to disrupt and displace the benthic substrate wash benthic algae, periphyton, stream-conditioned leaf litter, and benthic macroinvertebrates downstream. Recovery is rapid (days to weeks) and recolonizing benthic macroinvertebrates are generally comprised of R-selected generalists like Ephemeroptera and Diptera, preferred prey items of bats. Therefore, we would expect bat activity to be influenced by the timing, magnitude, and duration of floods through shifts in prey availability over time.

This study aims to (1) determine seasonal patterns of bat species present in Poopenaut Valley, (2) quantify bat foraging activity in relation to stream flow, (3) aid in understanding the ecology of the seasonal pond as related to insect availability and stream flow, and most importantly (4) provide recommendations to SFPUC on the timing, magnitude, and duration of water releases from O'Shaughnessy Dam in order to benefit bat assemblages.

A fifth study objective was added in 2014 following the Rim Fire (August and September 2013). The Rim Fire offers a unique opportunity to study the effects of wildfire on bat assemblages inhabiting Poopenaut Valley, as described below.

Table 5-1. Common and scientific names of the seventeen bat species known to occur in Yosemite National Park. Species in bold indicate California species of special concern.

Common Name	*Genus species*
Pallid bat	***Antrozous pallidus***
Townsend's big-eared bat	***Corynorhinus townsendii***
Big brown bat	*Eptesicus fuscus*
Spotted bat	***Euderma maculatum***
Western mastiff bat	***Eumops perotis***
Western red bat	***Lasiurus blossevillii***
Hoary bat	*Lasiurus cinereus*
Silver-haired bat	*Lasionycteris noctivagans*
California myotis	*Myotis californicus*
Small-footed myotis	*Myotis ciliolabrum*
Long-eared myotis	*Myotis evotis*
Little brown bat	*Myotis lucifugus*
Fringed myotis	*Myotis thysanodes*
Long-legged myotis	*Myotis volans*
Yuma myotis	*Myotis yumanensis*
Canyon bat	*Parastrellus hesperus*
Mexican free-tailed bat	*Tadarida brasiliensis*

5.2 Methods

From April 2011 to July 2016 we conducted acoustic bat surveys at two sites in Poopenaut Valley to determine species presence and activity level. We deployed one bat detector on the south side of the Tuolumne River and operated it on a year-round basis to determine seasonal bat patterns in relation to stream flow. We deployed a second bat detector on the north side of the Tuolumne River adjacent to the seasonal pond and, when accessible, operated it to determine the relationship between bat foraging activity and water levels in the adjacent seasonal pond (Figure 5-1). In May 2016 we added a third detector directly adjacent to the Tuolumne river on the south bank in order to assess differences in bat foraging activity and species composition between river and meadow habitat. In addition, we added a detector in Yosemite Valley to serve as a reference. This detector was deployed near the south-east corner of the Camp 6 pond on the north side of the Merced River.

At the two meadow sites, we secured one detector and external battery in a locked metal box at the base of a 20 foot tall metal pole (Figure 5-2). At the top of the metal pole, we mounted an external microphone in a weather-proof metal casing and positioned it horizontally to face the meadow opening (south site) and seasonal pond (north site) in order to increase the detection probability of foraging bats. The microphone for the river detector was attached to a tree approximately 15 meters above the water surface, and the microphone for the Yosemite Valley detector was attached to the branch of a mature willow tree approximately 4 meters above the water surface. We powered each detector with a 6-volt external battery, which was secured in the locked metal box. Each detector recorded sound in the high frequency range continuously during each night between 1900 and 0700 during the first month of survey. For the remaining time period, each detector recorded sound in the high frequency range each night at two different time periods: (1) 1800 - 2300 and (2) 0300 - 0800. Acoustic surveys at the south site occurred from 14 April 2011 to 28 July 2016. Acoustic surveys at the north site occurred from 19 April 2011 to 28 July 2016. Acoustic surveys at the river site occurred from 2 May 2016 to 28 July 2016. Acoustic surveys at the Yosemite Valley site occurred from 12 May 2016 to 2 August 2016. Detectors were scheduled to be checked on a monthly basis, however due to high-volume of bat passes at the Yosemite Valley study location, the detector at this site was checked fortnightly.

We used Pettersson D500x ultrasound recording units coupled with SonoBat™ software for full-spectrum acoustic monitoring and bat echolocation call identification. The Pettersson D500x hardware is built specifically for long-term passive monitoring. SonoBat™ software provides a comprehensive tool for analyzing and comparing high-resolution full-spectrum sonograms of bat echolocation calls. SonoBat™ uses a decision engine based on the quantitative analysis of approximately 10,000 known species recordings from across North America. The software automatically recognizes and sorts calls, then processes the calls to extract six dozen parameters that describe the time-frequency and time-amplitude trends of a call.

SonoBat's call trending algorithm recognizes the end of calls buried in echo and noise as well as establishes trends through noise and from low power signals. We analyzed echolocation call data from each site using the batch process option in SonoBat™. The discriminant probability threshold for each echolocation call was set at 0.90 and the acceptable call quality was set at 0.80. Species were identified by consensus only.

Due to intermittent equipment failure (both sites), bear damage (north site only) and accessibility issues (north site only), continuous monitoring was not conducted during 2012 and 2014, with a large data gap during the summers. Additionally, during December 2012, human error resulted in incorrect recording times at the north site, with the detector recording at a less than optimal time period (i.e. during daylight) for one of the daily monitoring sessions during that month. From 7 December 2012 through 8 January 2013, the detector at the north site recorded from: (1) 0700 – 1300 and (2) 1700 – 2200, effectively reducing detection probability by half. Although no species were detected at the south site during this same period, the detector appeared to be functioning. Total seasonal monitoring effort for each site is shown in Table 5-2.

The Rim Fire burned the north side of Poopenaut Valley 23-24 August 2013 and the south side 10-11 September 2013 (Figures 5-3, 5-4). Both original bat detectors were in burned areas but continued to record throughout this time. The detector at the south site had minimal damage (burnt external microphone cable) whereas the detector at the north side remained undamaged.

In April and May 2016 a high-volume experimental flood occurred under the management of The City of San Francisco Public Utilities Commission. The flood occurred from mid-April through mid-July with peak flows near 6,800 cfs. We monitored the acoustic detectors throughout this time; however, the river detector did not record in the month of May due to battery malfunction.

To complement our long-term acoustic monitoring dataset, we piloted a new study component beginning in the spring of 2016. We mist-netted bats in Poopenaut Valley and in three reaches of the Merced River in Yosemite Valley: near the Camp 6 pond, Swinging Bridge, and Cascade Falls. Surveys were conducted over three separate sampling efforts conducted in May, June, and September 2016. We captured bats in Poopenaut Valley on the nights of May 1st, May 2nd, June 13th, June 14th., and September 16th. In Yosemite Valley we captured bats at the Camp 6 pond location on May 3rd and June 15th, at Swinging Bridge on June 16th and September 17th, and at the Cascade reach on September 18th. Multiple nets were deployed during each sampling effort (5-6 3m high nets) in addition to a single 10m high net. All captured bats were classified to species, physical attributes recorded, and blood (50uL) and hair samples collected. Feces were collected when present in capture bags. Skin biopsy samples were collected from the tails of bats sampled in the first round of sampling in May, however this was insufficient sample for stable isotope analysis, so we discontinued collection after the first round. We plan to use analysis of naturally abundant isotopes of carbon and nitrogen to determine the amount of energy bats derive from an aquatic primary production pathway and trophic position respectively. This work will be finalized in winter 2016.

We used summary statistics and graphic displays to assess differences in bat activity over time and in relationship to changes in hydrology and the Rim Fire. We used Non-parametric multidimensional scaling (NMS) and multi-response permutation procedure (MRPP) analysis to describe differences in community composition by season, month, year, and in relationship to river hydrology.

Figure 5- 1. Acoustic monitoring sites targeting bat species in Poopenaut Valley, Yosemite National Park. Monitoring occurred between April 2011 and July 2016 at two sites: (A) north of the Tuolumne River adjacent to the seasonal pond and (B) south of the Tuolumne River. A third detector (C) was added directly adjacent to the river on the south side in May 2016 and monitored through July 2016.

Figure 5-2. Acoustic bat detector set-ups in Poopenaut Valley (A) north of the Tuolumne River adjacent to the seasonal pond, (B) south of the Tuolumne River, and (C) along the river on the south side. Yosemite Valley location not shown.

Figure 5-3. Aerial image of Poopenaut Valley taken 10 September 2013 showing active burn front of the Rim Fire on the south side of the valley, and the area on the north side of the valley that burned on 23-24 August 2013. The northern area includes the seasonal pond and site of the north bat detector (A). The active burn front eventually reached the bat detector at the south site (B).

Figure 5-4. Poopenaut Valley post-Rim Fire on 23 September 2013. Bat detectors at the north site (A) and the south site (B) were in burned areas. Both detectors were recording during the Rim Fire.

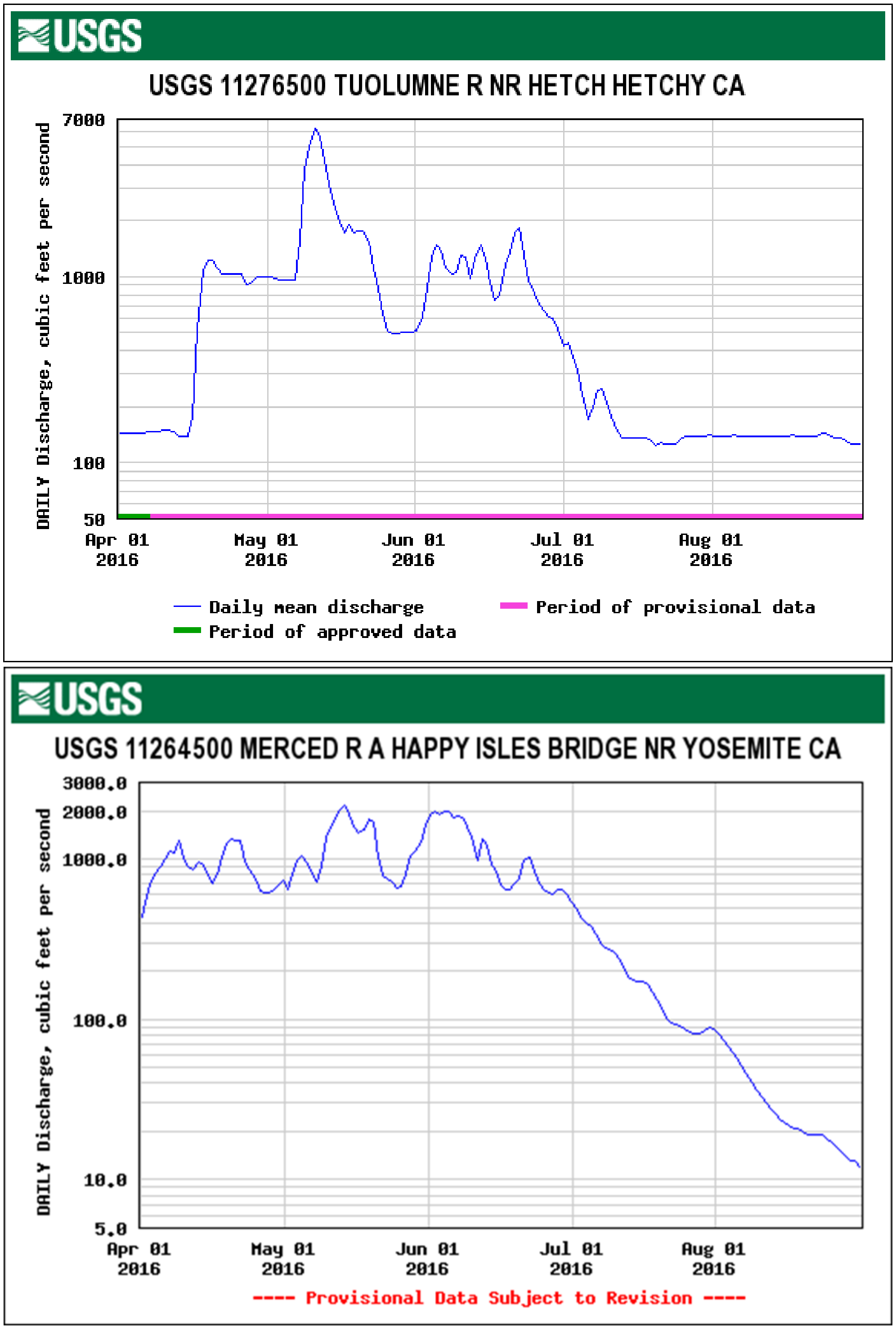


Figure 5-5. USGS hydrographs for the Hetch Hetchy reach of the Tuolumne River (top) and the Happy Isles reach of the Merced River (bottom) from April 1st, 2016 to August 31st, 2016.

5.3 Results

We documented a high diversity of bat species in Poopenaut Valley from spring 2011 through summer 2016. Over this five year monitoring period, we detected all 17 bat species known to occur within Yosemite National Park in Poopenaut Valley every year except 2013 (16); thus, Poopenaut Valley alone is as diverse as the entirety of Yosemite National Park. Over the entire study period the vast majority of detections of low-frequency echolocations are from spotted bats (45%) followed by Mexican free-tailed bat (28%), western mastiff bat (14%), hoary bat (8%), and silver-haired bat (4%) (Figure 5-6). The majority of detections of bats echolocating at a high-frequency are from California myotis (44%) followed by canyon bat (31%), Yuma myotis (19%), and western long-eared myotis (2%) (Figure 5-7).

Five of the 17 detected species are California species of special concern (pallid bat, spotted bat, western mastiff bat, Townsend’s big-eared bat, and western red bat). While some of these species are only represented by a small proportion of the total number of detections, all five have been detected at least once each year since the beginning of the study period with the exception of pallid bat. Although pallid bat was detected at the south site in 2011 and at the north site in 2012, it was not detected at either site in 2013. In 2014, pallid bats were again detected at both sites throughout the summer and then mostly disappeared in 2015. In 2016 pallid bat reappeared at both north and south study locations.

Activity levels of bats seem at first glance idiosyncratic with large differences between months, years, and species (Figures 5-8 and 5-9). In some years, spring is the most active season, in others fall, and in still others summer. In general bat activity levels are highest near the beginning and end of the summer and are lowest in the winter. Free-tailed bats are the only species that have been detected every winter during the study period. Habitat requirements and arrival/departure dates of the eight most frequently detected bat species in Poopenaut Valley are described in Table 5-3.

Species richness was generally highest in August, September, and July each year (16 +/- 1.0 (SD), 15 +/- 2.1, and 14 +/- 2.0 species respectively). Species richness in June varied most from year to year (11.5 +/- 3.5 (SD). Throughout the study period December was the least species rich month (2.7 +/- 1.5) (Figure 5-10).

Preliminary results show that community composition of bat activity in Poopenaut Valley varied by season (Figure 5-11), site (Figures 5-12), and year (Figure 5-13). Using NMS ordination, we described seasonal bat community composition with a two-axis solution representing 69.8% of the total variation (Figure 5-11). Winter bat community composition was most distinct from other seasons, but we also observed significant differences in bat community composition between summer, spring, and fall (Table 5-4) and even between months (unreported data).

Prior to the addition of the 2016 data, we found no significant difference in summer (May-October) community composition between the north and south detector sites (unreported data). However, with the addition of the data collected between May and July 2016, we observed significant differences among all detector locations including the newly added Poopenaut river and Yosemite Valley sites (Figure 5-12). We described summer bat community composition with a three-axis NMS solution representing 80.2% of the total variation. We saw significant differences in community composition by site and in pairwise comparisons between the north detector and both the south detector and Yosemite Valley site (Table 5-5).

Correlated with the timing of the Rim Fire, we observed an increase in bat activity from August 23rd through September 10th. The species that most exhibited this pattern was California myotis which had the highest detection frequency ever recorded for that species (Figure 5-14). Other species, including Yuma myotis, Mexican free-tailed bat, and hoary bat, also exhibited increased activity relative to earlier in the season in 2013. In addition, several species of bats returned in record numbers in 2014 including but not limited to western mastiff bat, canyon bat, California myotis, silver-haired bat, Yuma myotis, and hoary bat (Table 5-3). Finally, the largest shift in summer community composition occurred between 2013 and 2014, correlating with the timing of the Rim Fire (Table 5-5, Figure 5-13).

The study area has been in drought condition since 2012 (Figure 5-15) with actual summer discharge in the Tuolumne River far below the estimated unregulated discharge. Therefore, it has been difficult to assess the effect of river regulation on bat activity. In 2016, we observed remarkable patterns in bat activity correlated with the timing of a large experimental flood that peaked at 6,800 cfs in May. Bat activity began to increase in March and April at both the Poopenaut north and south detector locations with 5-times greater activity at the south site in March and 2-times greater activity in April compared to the north site. In May and June, the detector at the south site continued to record more activity than at the north site, but activity at both sites was reduced (Figure 5-16.A). Then in July, the pattern was reversed and we observed almost ten-times more activity at the north site compared to the south site. The Poopenaut river detector recorded ten-times more bat activity in June than either north or south detector. In July, we observed 15-times more bat activity along the river compared to the south detector site and 1.5-times more bat activity compared to the north site (Figure 5-16.B). In Yosemite Valley, we recorded 600-700 bat passes per night in May and June far eclipsing bat activity levels in the Poopenaut by seven to 200-times! In July, this pattern abruptly ended with average nightly bat activity at fewer than 100 passes per night, lower than recorded at both the Poopenaut north and river sites during the same timeframe (Figure 5-16.C).

We recorded all 17 species of bats known to utilize Yosemite and Poopenaut Valley along the Tuolumne River in both June and July, 2016. During the same time period we observed a maximum of 14 species at the north site (June), 13 species at the south site (July), and 14 species at the Yosemite Valley site (July). Over the entire year (January to July), we observed 15 species at each of the north and south sites, and from May to July we observed 16 species in Yosemite Valley (Figure 5-17). In 2016, long-legged myotis was absent from Poopenaut north and Yosemite Valley, pallid bat was absent from Poopenaut north and south, and fringed myotis was absent from Poopenaut north.

Accessibility issues at the north site and equipment failure at both sites prevented continuous monitoring over the 5 year survey period. While the detection rates take effort into account, we collected much less data over certain periods of time. For example, at the north site during summer 2011, the detector operated only five days during June, July, and August (Table 5-2). As a result, seasonal comparisons between years and sites will become more meaningful when additional data are collected over the coming years.

Table 5-2. Total seasonal monitoring effort from acoustic bat detectors at two sites in Poopenaut Valley from 14 April 2011 to 28 July 2016. Spring is March-May, Summer is June-August, Fall is September-November, and Winter is December-February. In addition the monthly monitoring effort for the two newly deployed detectors along Poopenaut River and in Yosemite Valley are presented. The first number indicates total number of days that the detector was operational; the second number in parentheses indicates the percentage of operational days out of all days elapsed in that season/month.

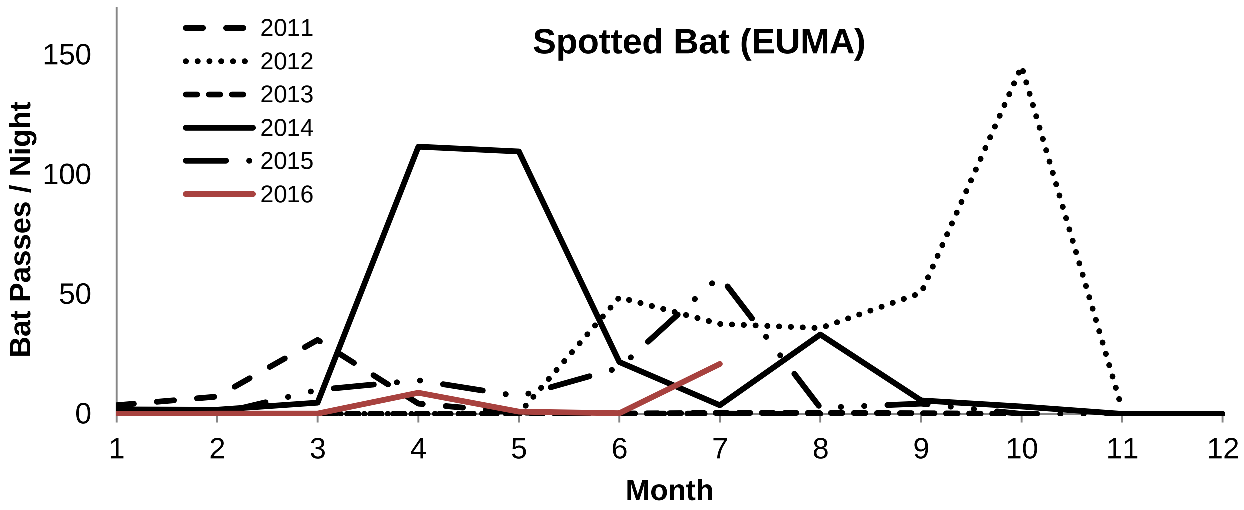
	2011			2012				2013			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
North	42 (46%)	5 (5%)	48 (53%)	70 (78%)	92 (100%)	88 (96%)	74 (81%)	57 (63%)	92 (100%)	92 (100%)	12 (13%)
South	14 (15%)	18 (20%)	82 (90%)	90 (100%)	90 (98%)	92 (100%)	88 (97%)	87 (95%)	90 (98%)	91 (99%)	22 (24%)

	2014				2015				2016		
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
North	53 (58%)	59 (68%)	36 (46%)	92 (100%)	78 (100%)	91 (100%)	70 (86%)	92 (100%)	91 (100%)	92 (100%)	57 (100%)
South	34 (37%)	55 (75%)	68 (76%)	92 (100%)	78 (100%)	34 (37%)	59 (24%)	62 (67%)	75 (82%)	92 (100%)	57 (100%)

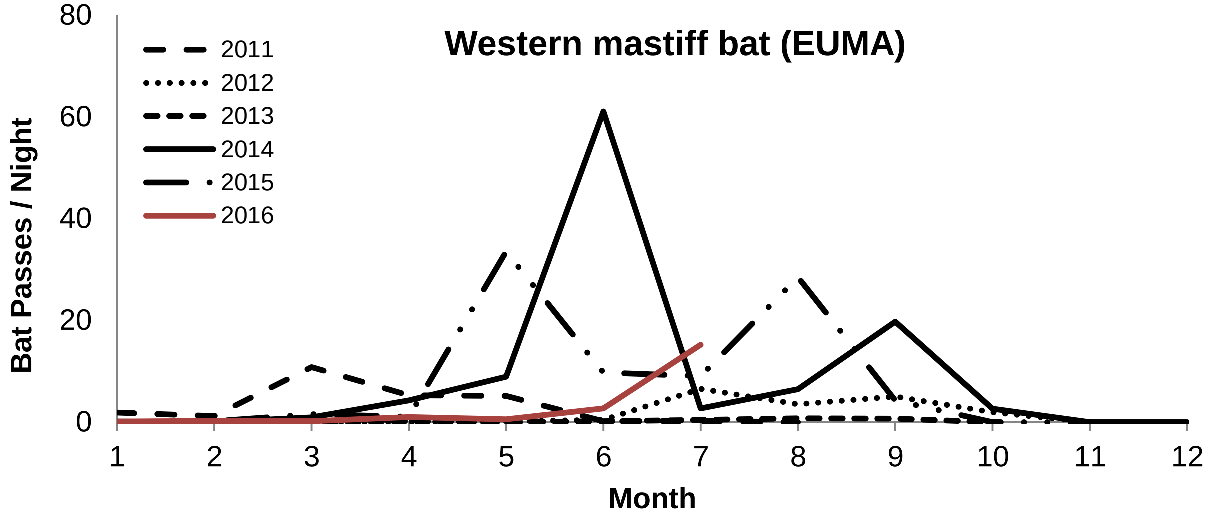
	2016		
	May	June	July
River	0 (0%)	28 (93%)	9 (32%)
Yosemite	4 (13%)	6 (20%)	11 (40%)

Table 5-3. Occurrence, habitat requirements, arrival/departure dates, and bat detections by season of the eight most frequently detected bat species in Poopenaut Valley from 14 April 2011 to 28 July 2016. Arrival/departure dates represent when each species was first/last detected each year. Some species were present year-round. The vertical axis on graphs is the number of bat detections/number of recording nights averaged between the north and south detectors.

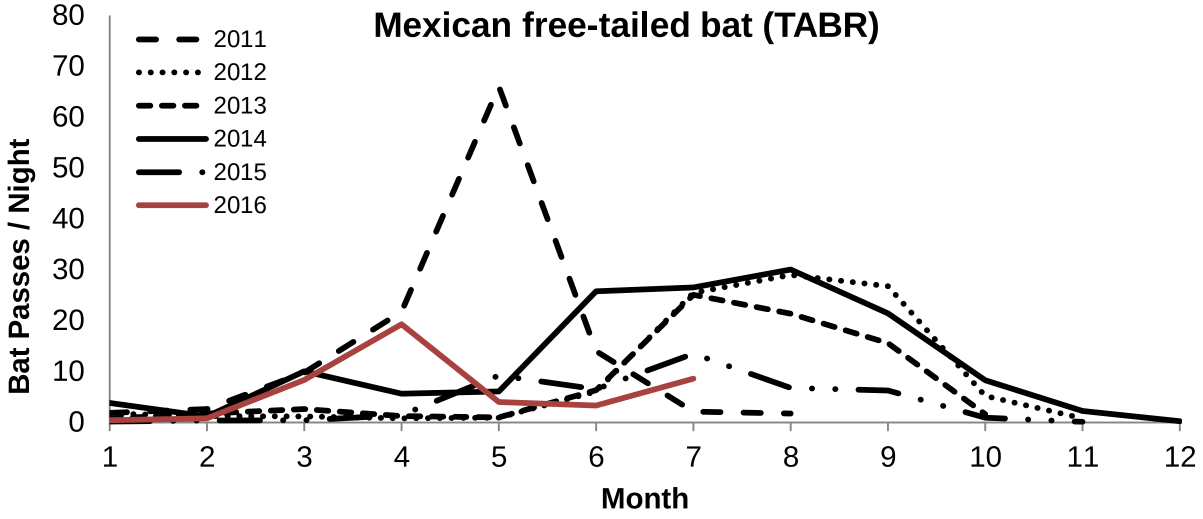
SPOTTED BAT		
Occurrence/habitat	Widely distributed throughout Sierra Nevada, with records > 3000 m. Occurs in habitats ranging from desert scrub to montane coniferous forests	
Feeding type/food source	Forages in a wide variety of habitats,5-15 m off the ground, primarily for moths	
Roosting structure	Uses crevices in rock faces for roosting and reproduction	
Seasonal movements	Makes local movements in some areas, from high elevations in summer to lower elevations in fall. Little is known about the California populations; may be yearlong residents, or migratory.	
2011-2016	**NORTH**	**SOUTH**
Average Arrival	April–May	April–May
Average Departure	September–November	August–September



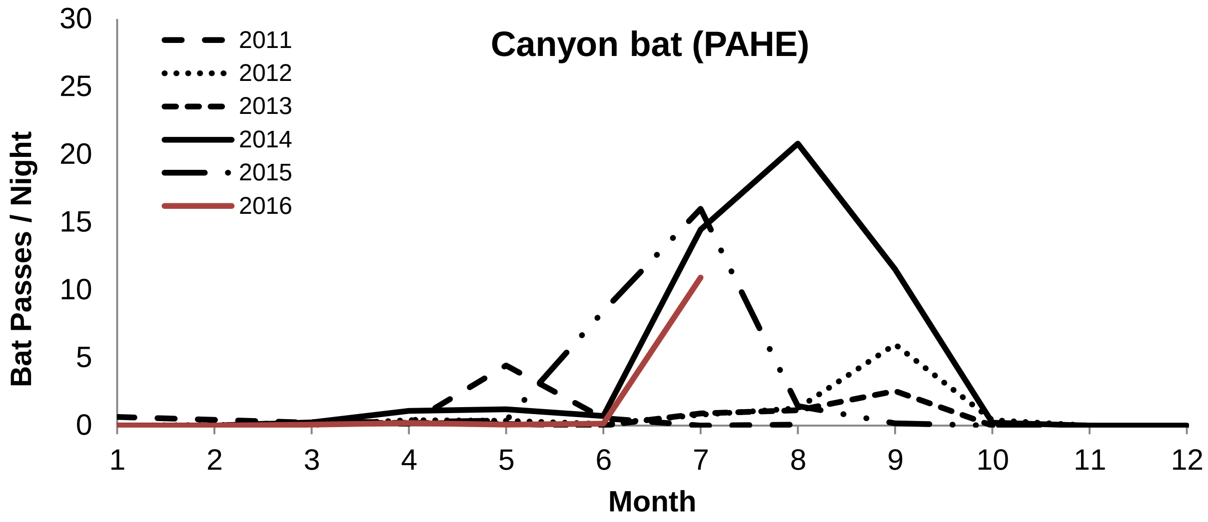
WESTERN MASTIFF BAT		
Occurrence/habitat	Found in a variety of habitats to > 3000 m in elevation. From desert scrub to chaparral to oak woodland and into the ponderosa pine belt.	
Feeding type/food source	Detected most often over meadows and other open areas, but will also feed above forest canopy; sometimes to high altitudes (1,000 feet)	
Roosting structure	Roosts primarily in crevices in cliff faces and occasionally trees	
Seasonal movements	Unknown	
2011–2015	**NORTH**	**SOUTH**
Average Arrival	January–April	April–May
Average Departure	October–December	September–October



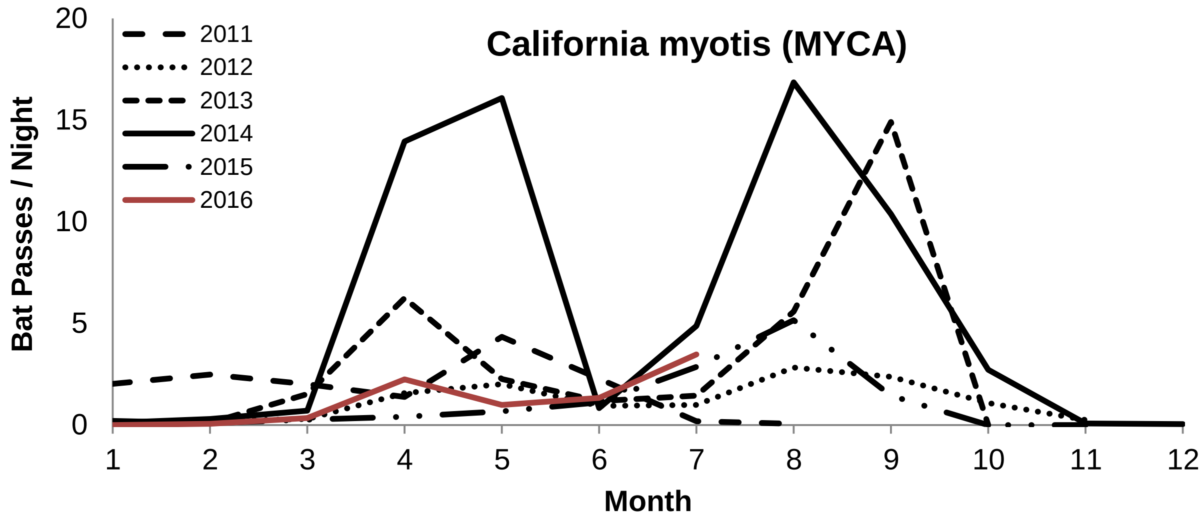
MEXICAN FREE-TAILED BAT		
Occurrence/habitat	Uncommon in high Sierra Nevada but found throughout California. Found in all habitats including mixed conifer forest, but open habitats such as woodlands, shrublands, and grasslands preferred.	
Feeding type/food source	Forages high, 100 feet above ground.	
Roosting structure	Roosts in caves, mine tunnels, crevices, and buildings.	
Seasonal movements	In California, makes local movements to and from hibernacula or short migrations attitudinally.	
2011–2015	**NORTH**	**SOUTH**
Average Arrival	Year-round	Year-round
Average Departure	Year-round	Year-round


Mexican free-tailed bat (TABR)

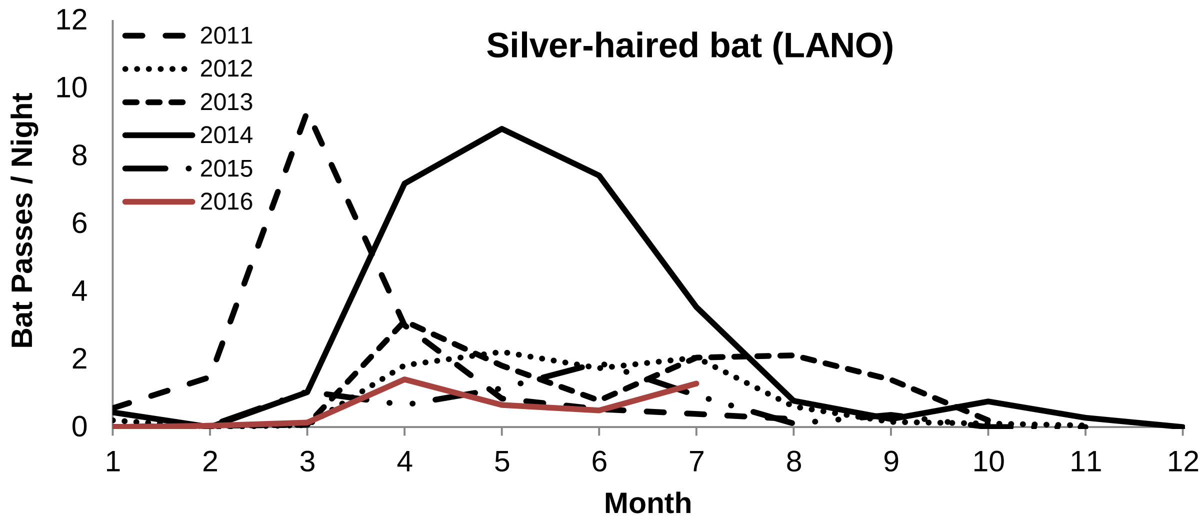
CANYON BAT		
Occurrence/habitat	Wide range including desert, grassland, woodland, and mixed conifer forests. Yearlong resident in California	
Feeding type/food source	Feeds at low to moderate heights over water, rocky canyons, and along cliff faces.	
Roosting structure	Roosts in rock crevices, mines, caves, and buildings.	
Seasonal movements	Yearlong resident in California. May make local movements.	
2011–2015	**NORTH**	**SOUTH**
Average Arrival	March	April
Average Departure	October-November	September-October



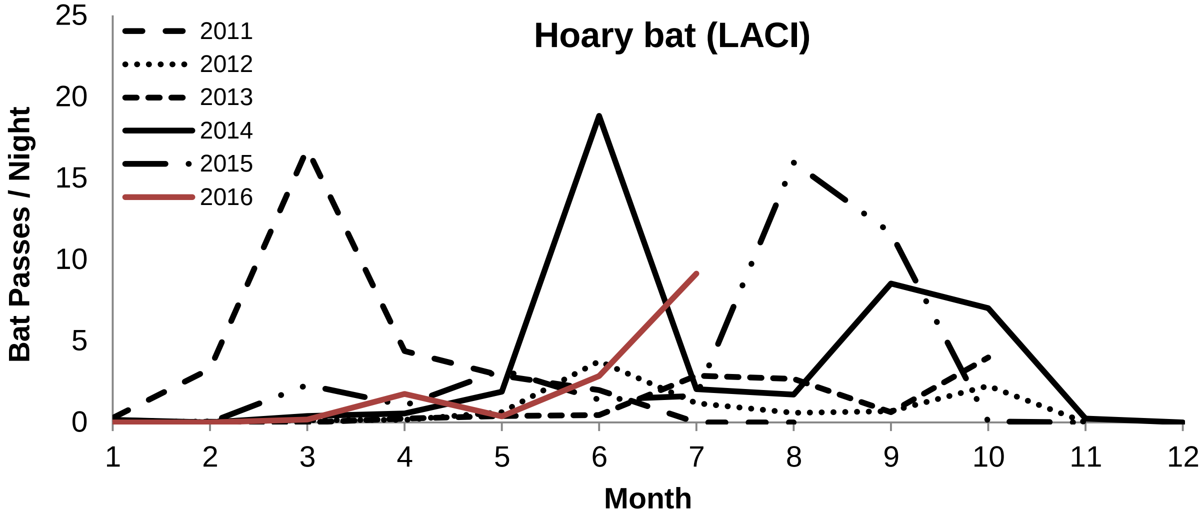
CALIFORNIA MYOTIS		
Occurrence/habitat	Broad distribution over western North America, most abundant at mid-elevations. Found in almost every habitat.	
Feeding type/food source	Forages in canopy and along riparian corridors on insects and moths.	
Roosting structure	Uses crevices in wide variety of natural and anthropogenic structures.	
Seasonal movements	Individuals can be active in winter, even in below freezing temperatures.	
2011–2015	**NORTH**	**SOUTH**
Average Arrival	January–March	January–April
Average Departure	September–October	September–November



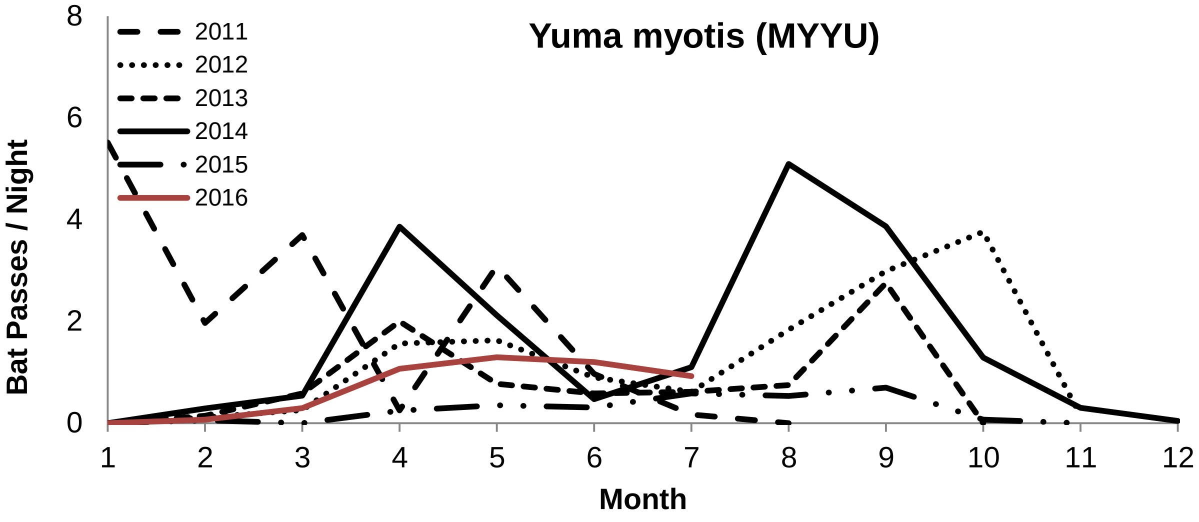
SILVER-HAIRED BAT		
Occurrence/habitat	Broad distribution concentrated in northern part of CA.	
Feeding type/food source	Forages above canopy, in forest clearings, and in riparian zone along water courses for wide variety of insects and moths	
Roosting structure	Roosts in trees	
Seasonal movements	Migratory	
2011–2015	**NORTH**	**SOUTH**
Average Arrival	January	January–February
Average Departure	September	September



HOARY BAT		
Occurrence/habitat Feeding type/food source Roosting structure Seasonal movements	The hoary bat is the most widespread North American bat. Habitats include cottonwood riparian habitat, forested areas, and woodlands. Feeds primarily on moths. Roosts in dense foliage of medium to large-size trees Migrates between summer and winter ranges, probably over long distances. During spring and fall, large groups are encountered, occasionally in unusual locations. Females precede males in the northward spring migration, which occurs from Feb - May. Fall migration occurs Sep - Nov.	
2011–2015	**NORTH**	**SOUTH**
Average Arrival	February–April	January–April
Average Departure	September–October	September–October



YUMA MYOTIS		
Occurrence/habitat	Usually occurs below 8,000 feet in elevation. Optimal habitats are open forests and woodlands with sources of water over which to feed. More highly associated with water than any other species.	
Feeding type/food source	Forages over open, still, or slow-moving water and above low vegetation in meadows for emergent insects (midges, mayflies, caddis flies) and moths.	
Roosting structure	Roosts in buildings, caves, or crevices.	
Seasonal movements	Probably makes local or short migrations to suitable hibernacula. Individuals that spend summer at high elevations probably move downslope.	
2011–2015	**NORTH**	**SOUTH**
Arrival	February–March	March–April
Departure	September–October	September–November



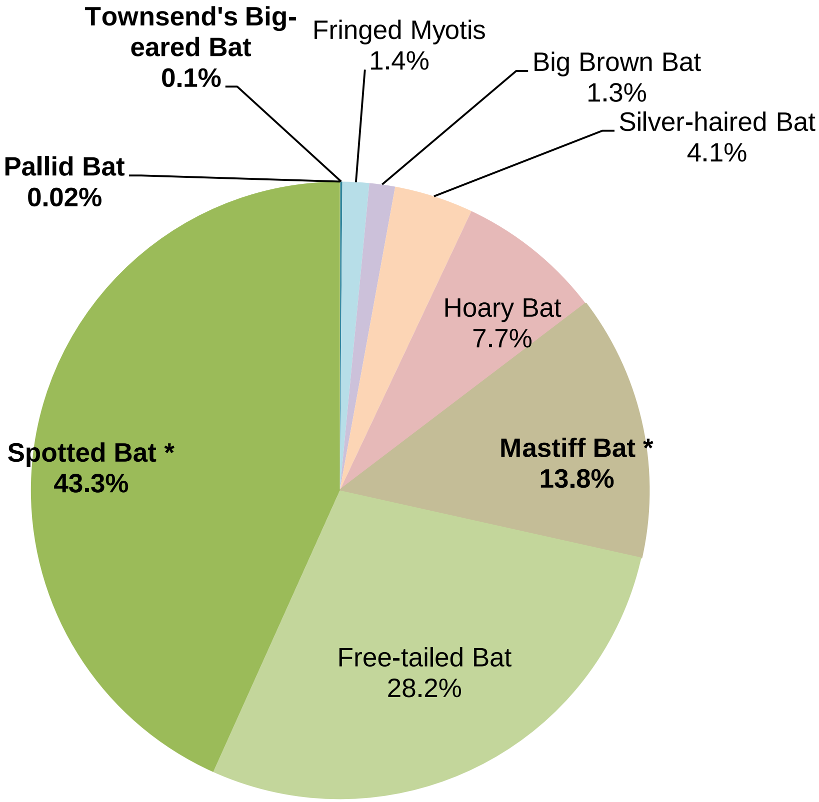


Figure 5-6. Proportion of all detections between April 2011 and July 2016 belonging to each species (low-frequency calls). *Spotted bat and mastiff bat emit calls that are at very low frequency and are audible to the human ear. These two species are the easiest to detect with an acoustic sensor.

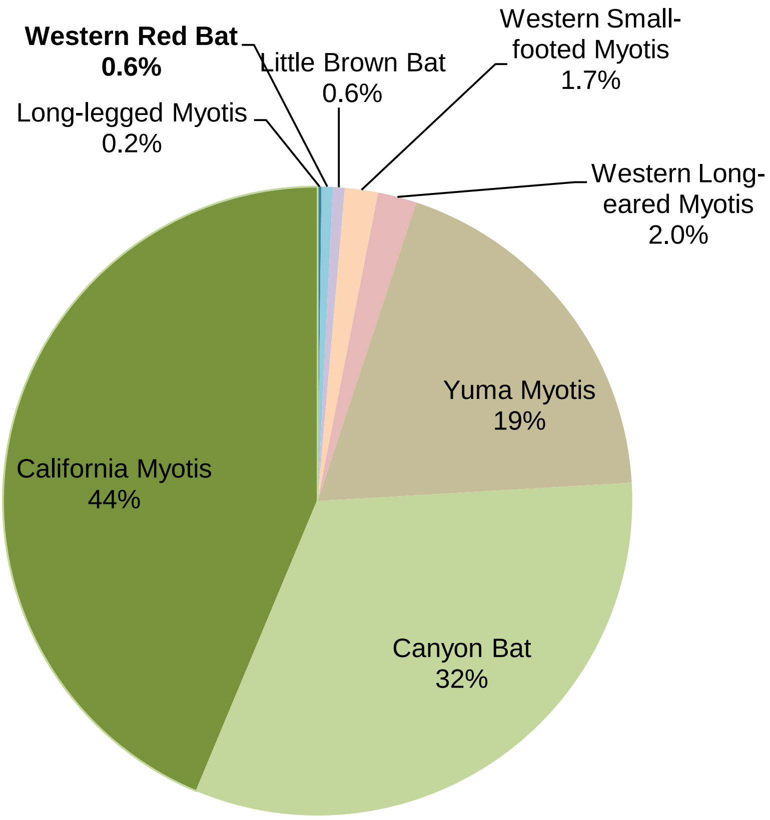


Figure 5-7. Proportion of all detections between April 2011 and July 2016 belonging to each species (high-frequency calls).

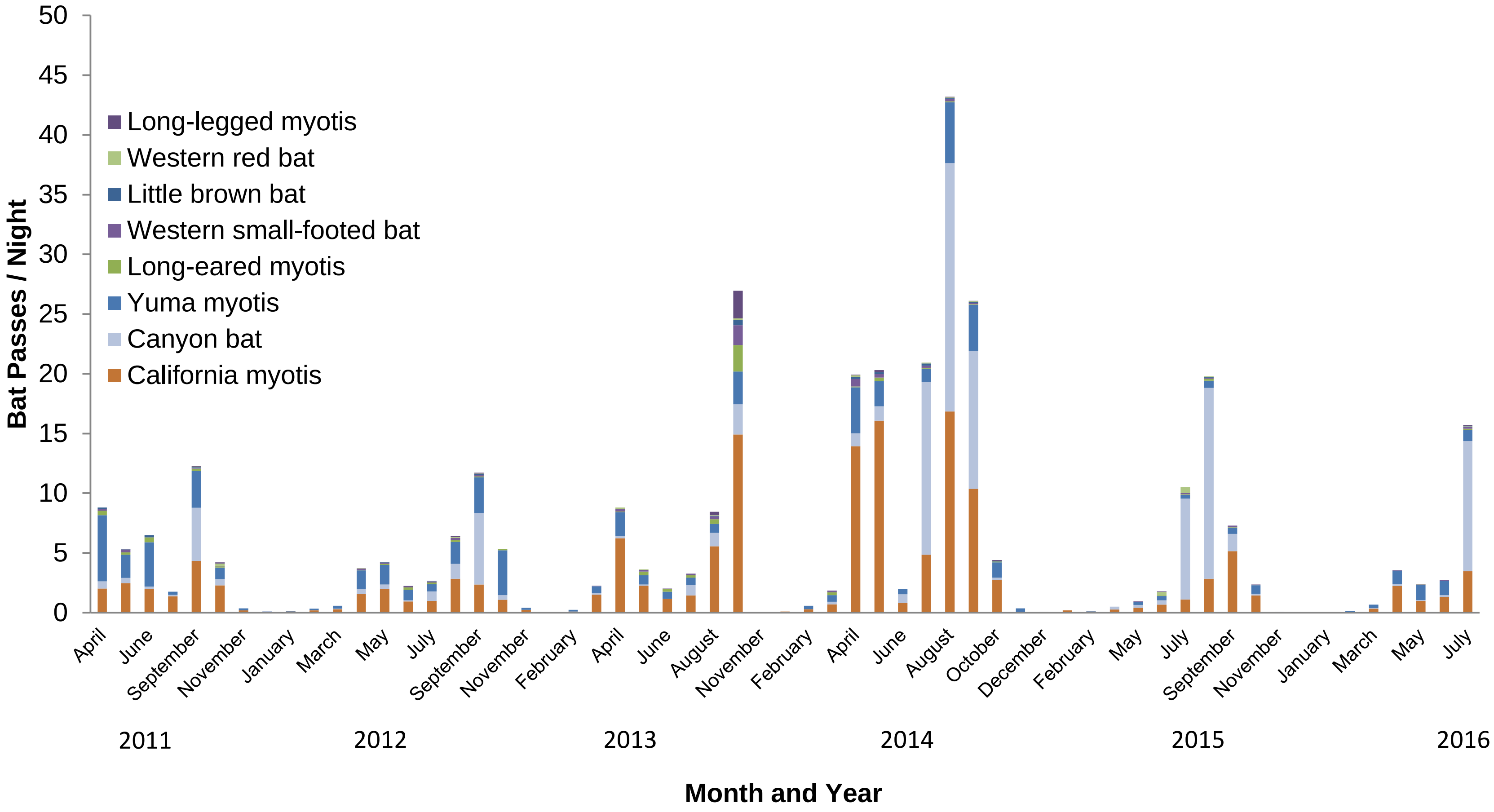


Figure 5-8. Bat detections by month of 8 species that echolocate at a high frequency. Passes per night are calculated as the average between the north and south detectors from 14 April 2011 to 28 July 2016. The vertical axis is number of bat passes normalized by the number of recording nights that month.

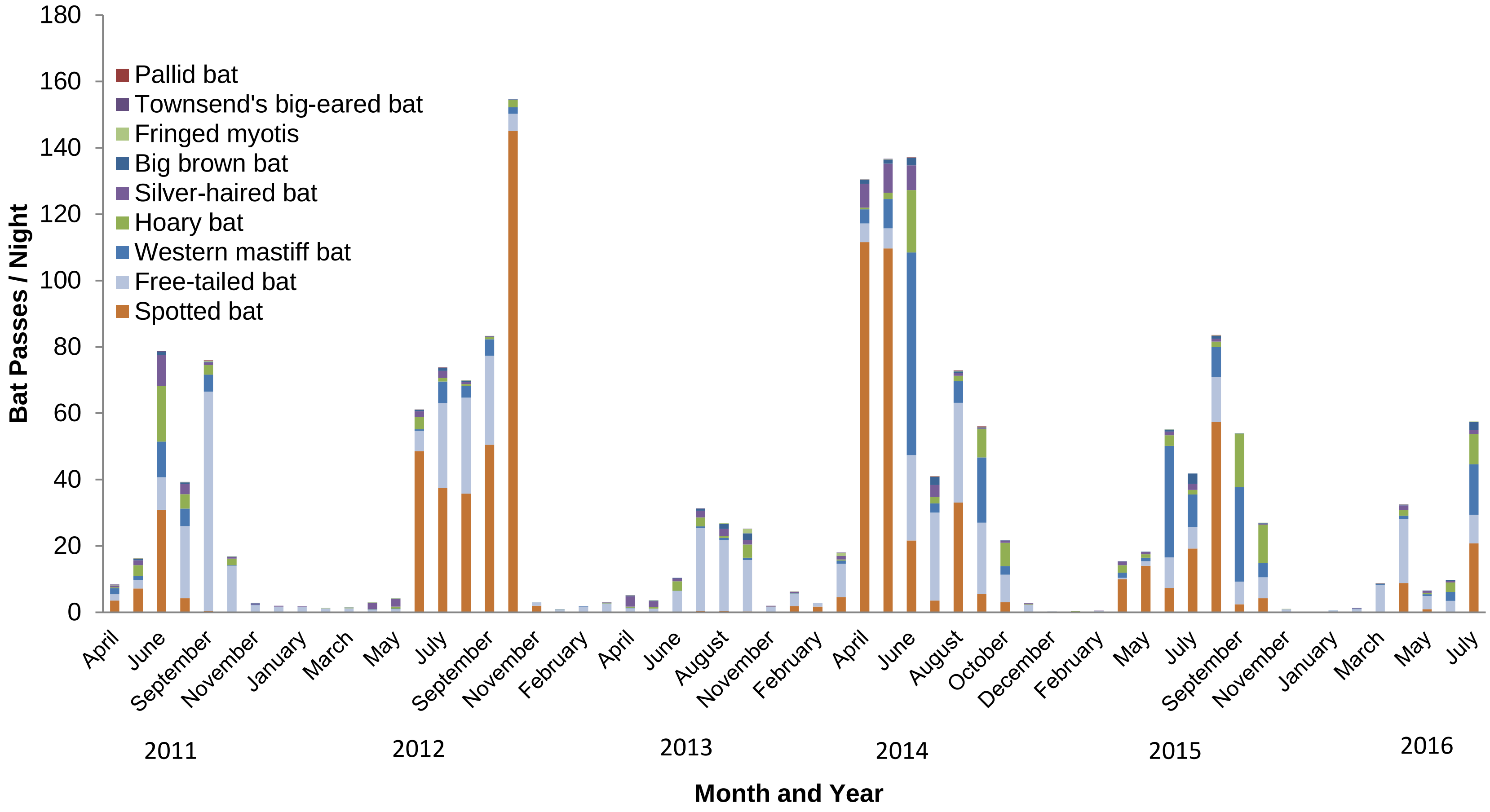


Figure 5-9. Bat detections by month of 9 species that echolocate at a high frequency. Passes per night are calculated as the average between the north and south detectors from 14 April 2011 to 28 July 2016. The vertical axis is number of bat passes normalized by the number of recording nights that month.

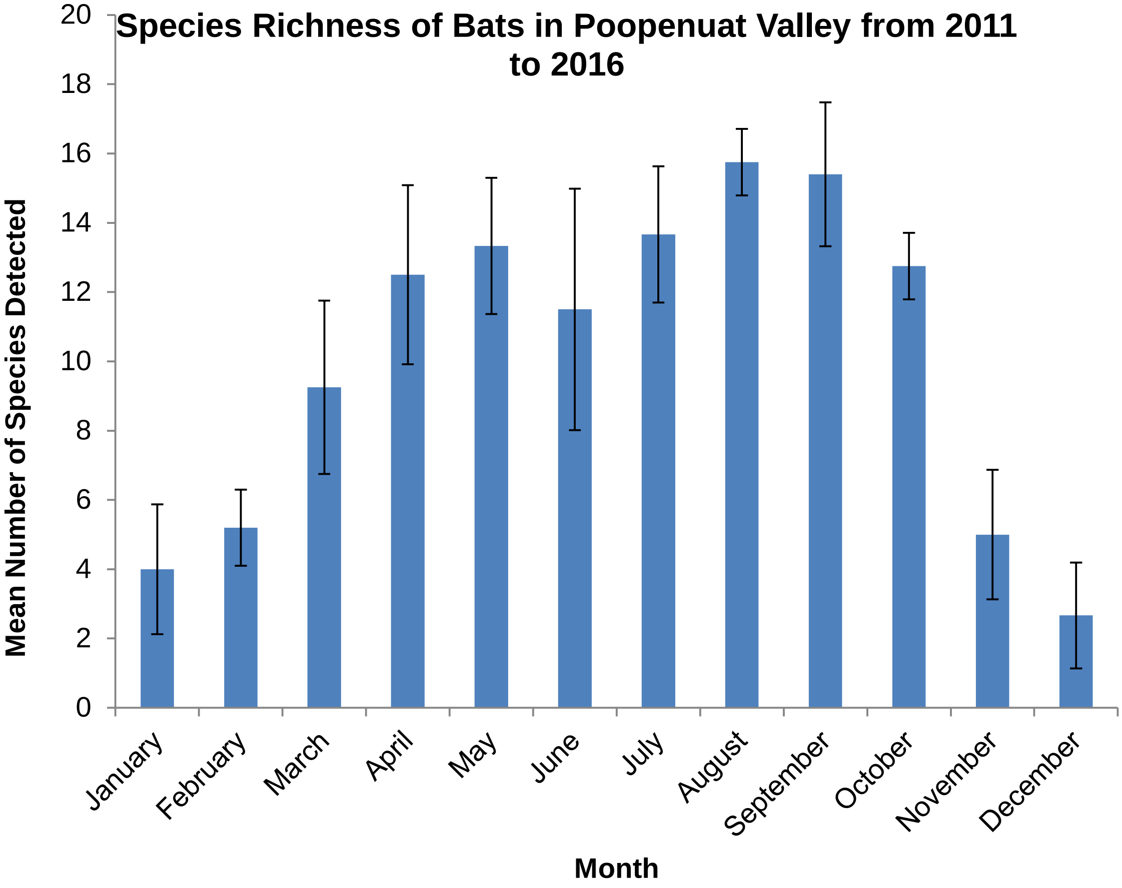


Figure 5-10. Bat species richness detected in Poopenaut Valley at both detector sites. Mean is presented per month from 2011-2016. Error bars represent standard deviation.

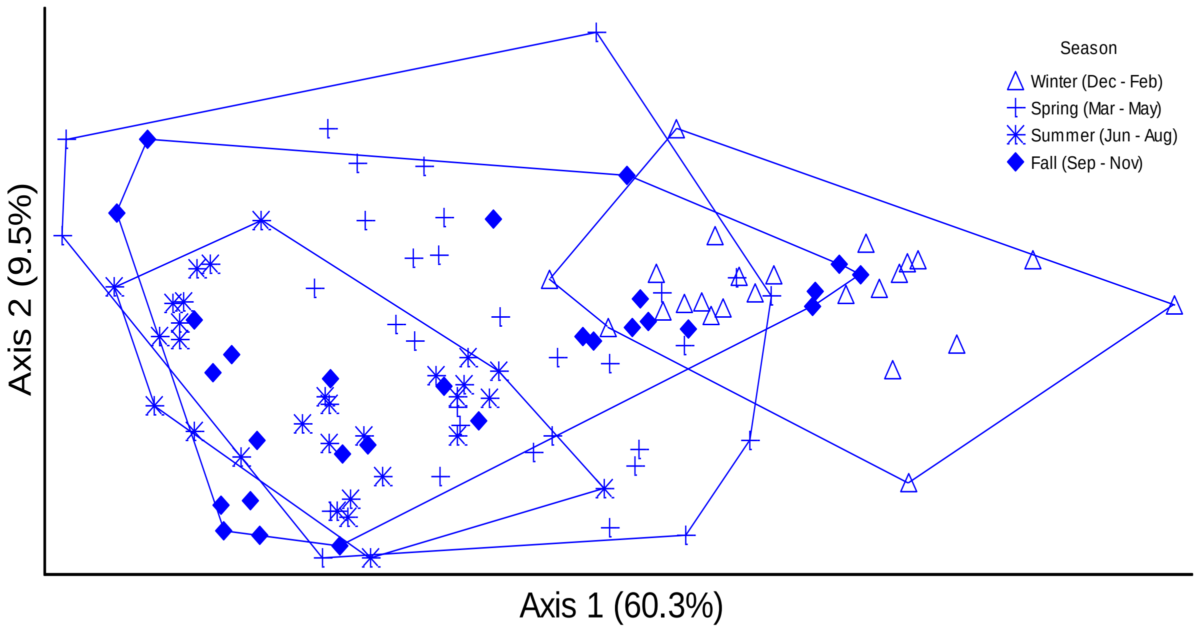


Figure 5-11. Non-parametric multidimensional scaling (NMS) representation of bat activity community composition in Poopenaut Valley from 2011 to 2016. Distances are Sorenson (Bray-Curtis). A two-dimensional solution was recommended (stress = 10.4). Symbols represent community composition for each month. Hulls represent seasons. Community composition of bat activity is significantly different between seasons with winter being the most distinct (see Table 5-4).

Table 5-4. Differences in bat activity community composition from April 2011 to July 2016 between north and south detector sites and between seasons determined by multi-response permutation procedure (MRPP). Significance at the α < 0.05 level is represented by *. A Bonferoni correction was applied to pairwise comparisons (α = 0.05 / 6 = 0.008). Significance at the α < 0.008 level is represented by **.

Source	Bat Community Composition	
	A	*p*
<u>Acoustic survey location</u>	0.00	0.025*
<u>Season</u>	0.12	0.000*
Winter vs. Spring	0.10	0.000**
Winter vs. Summer	0.20	0.000**
Winter vs. Fall	0.08	0.000**
Spring vs. Summer	0.06	0.000**
Spring vs. Fall	0.02	0.002**
Summer vs. Fall	0.03	0.001**

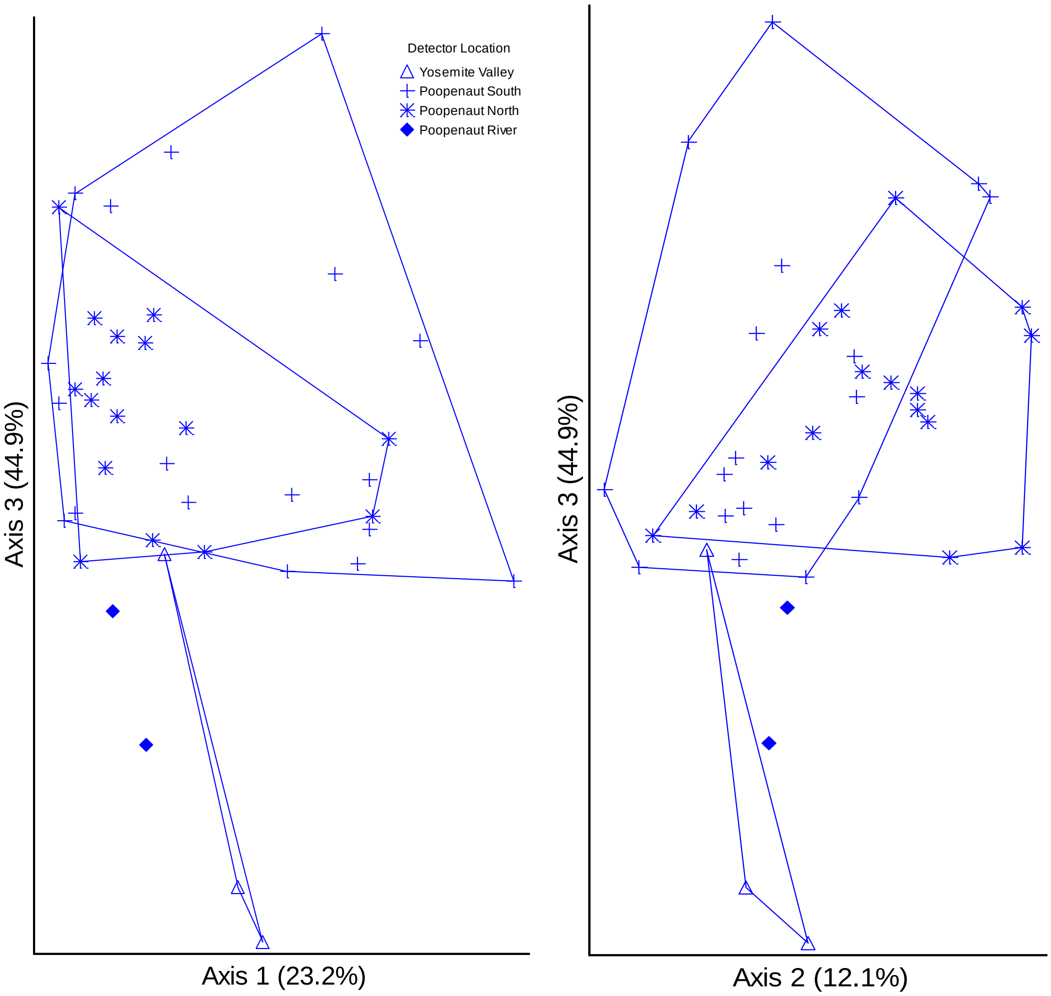
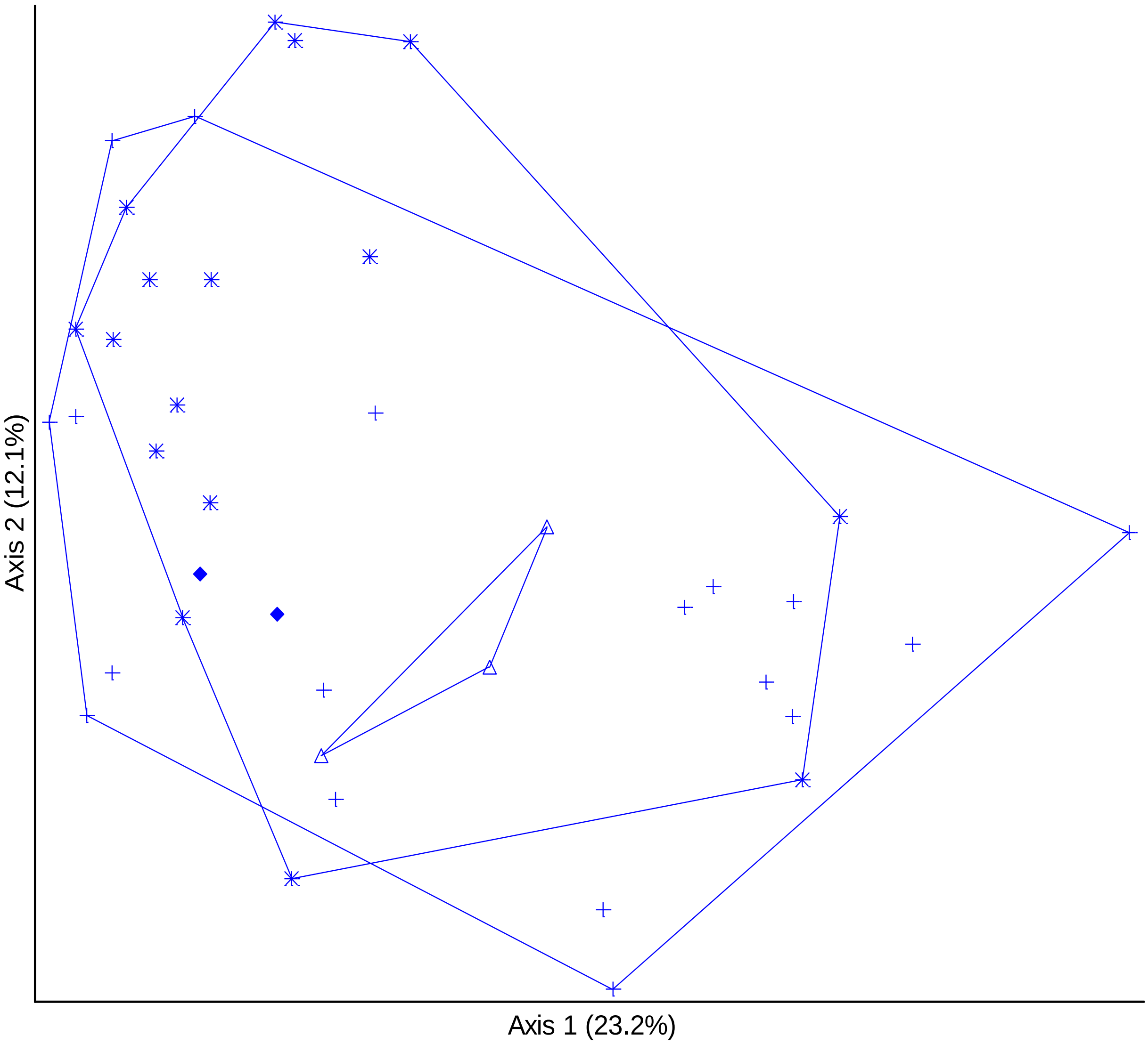


Figure 5-12. Non-parametric multidimensional scaling (NMS) representation of bat activity community composition in Poopenaut Valley and Yosemite Valley in 2016. Only non-winter months are represented (May – October). Distances are Sorenson (Bray-Curtis). A three-dimensional solution was recommended (stress = 8.9). Symbols represent community composition for each month. Hulls represent study sites. Community composition of bat activity is significantly different between sites with Yosemite Valley and Poopenaut River sites being the most distinct (see Table 5-5).

Figure 5-12 continued.



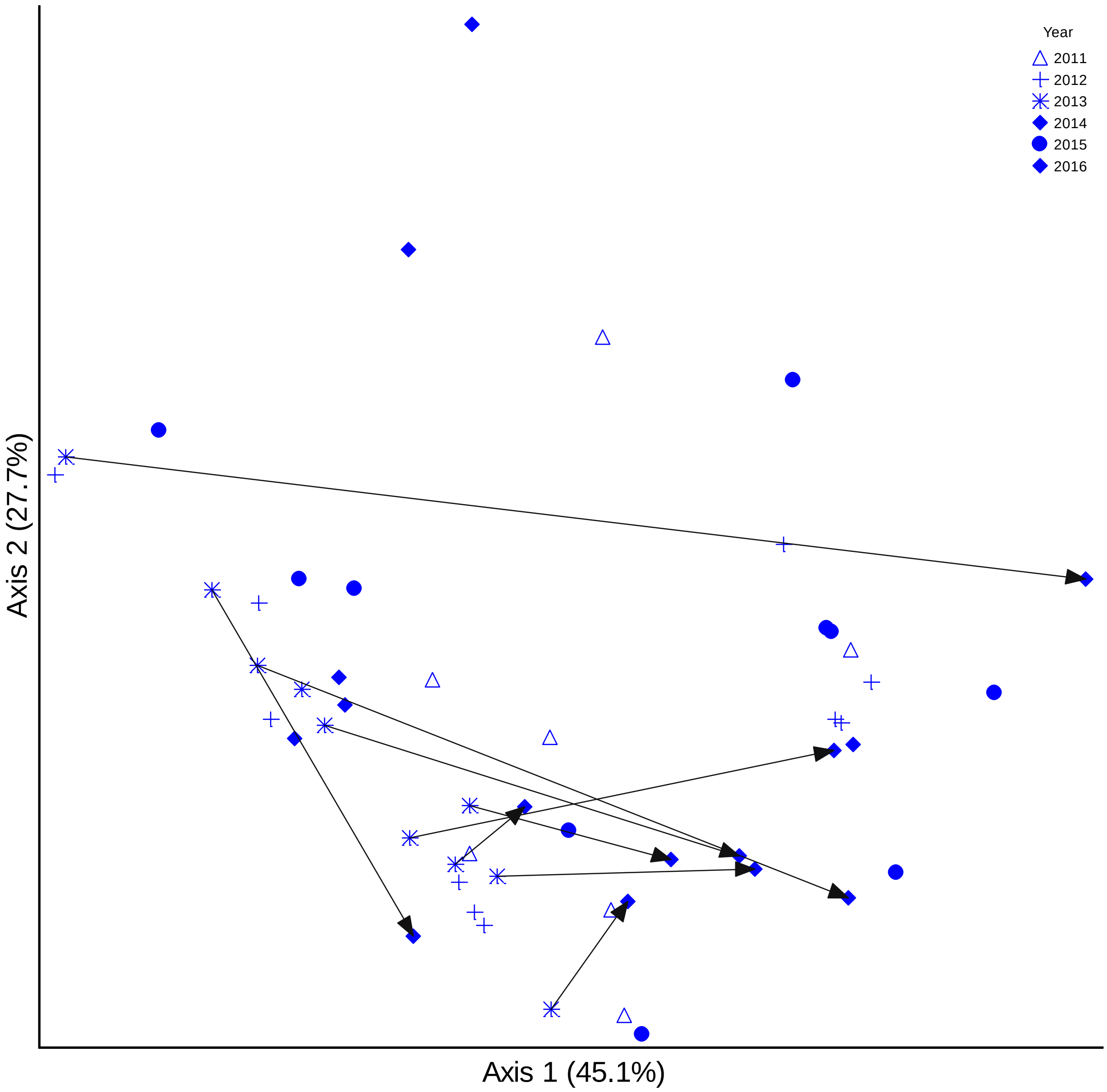


Figure 5-13. Non-parametric multidimensional scaling (NMS) representation of bat activity community composition in Poopenaut Valley from 2011 to 2016. Only non-winter months are represented (May – October). Distances are Sorenson (Bray-Curtis). A three-dimensional solution was recommended (stress = 8.9). Symbols represent community composition for each month. Vectors represent distances (in community space) between monthly community composition in 2013 and 2014. Community composition of bat activity is significantly different between years with 2013 and 2014 being the most distinct (see Table 5-5).

Figure 5-13 continued.

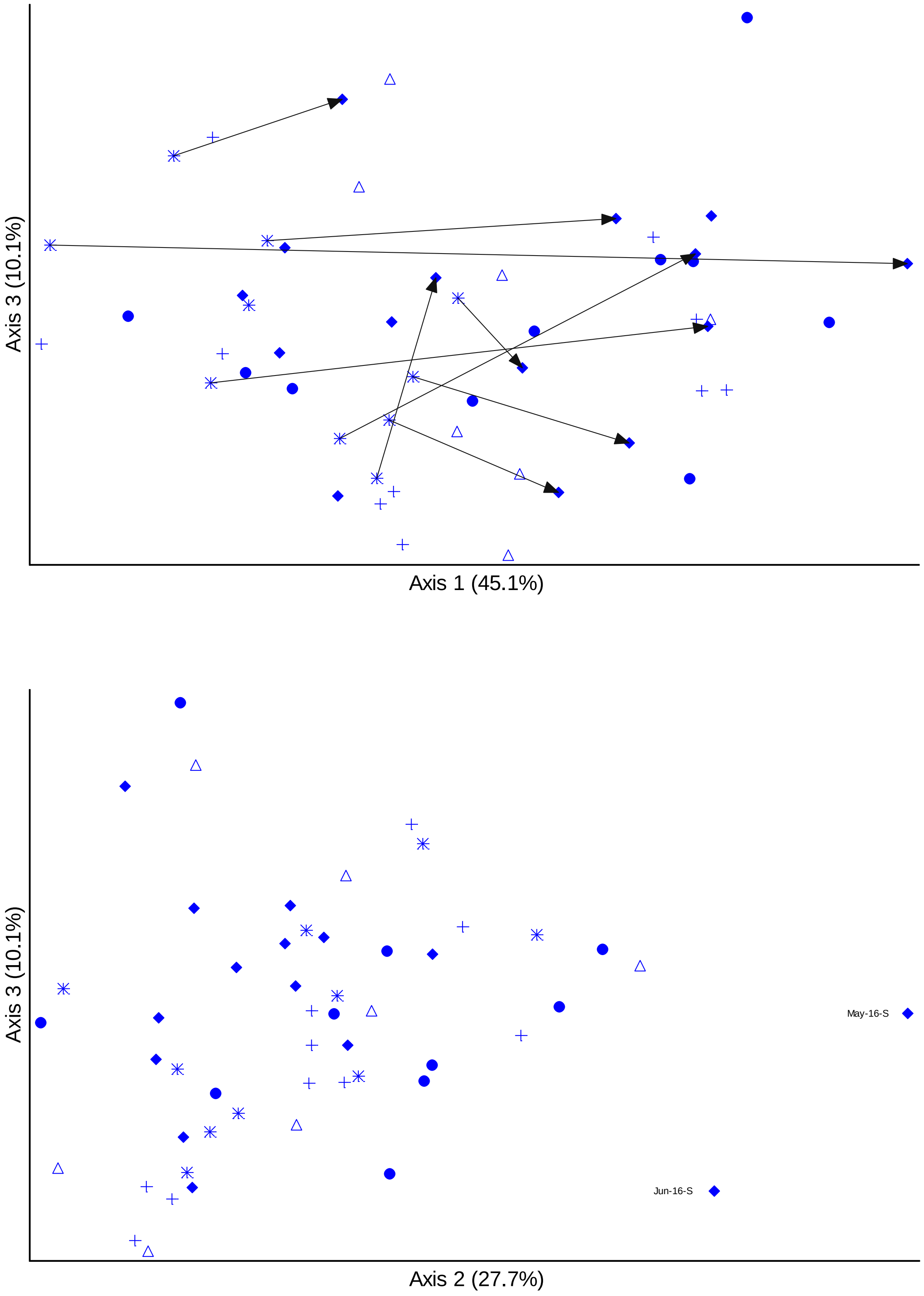


Table 5-5. Differences in non-winter (May – October) bat activity community composition from April 2011 to July 2016 between study sites and years determined by multi-response permutation procedure (MRPP). Significance at the α < 0.05 level is represented by *. A Bonferoni correction was applied to pairwise comparisons (α = 0.05 / 6 or 15 = 0.008 or 0.003). Significance at the α < 0.008 / 0.003 level is represented by **.

Source	Bat Community Composition	
	A	*p*
Acoustic survey location	0.09	0.000*
South vs. North	0.04	0.005**
South vs. River	0.05	0.029
North vs. River	0.08	0.009
South vs. Yosemite	0.05	0.013
North vs. Yosemite	0.09	0.003**
River vs. Yosemite	0.08	1.000
Year	0.05	0.004*
2011 vs. 2012	0.00	0.411
2011 vs. 2013	0.05	0.034
2011 vs. 2014	0.01	0.210
2011 vs. 2015	0.00	0.363
2011 vs. 2016	0.02	0.224
2012 vs. 2013	0.03	0.089
2012 vs. 2014	0.04	0.053
2012 vs. 2015	0.01	0.252
2012 vs. 2016	0.03	0.145
2013 vs. 2014	0.11	0.000**
2013 vs. 2015	0.06	0.012
2013 vs. 2016	0.02	0.134
2014 vs. 2015	0.02	0.141
2014 vs. 2016	0.07	0.009
2015 vs. 2016	0.00	0.465

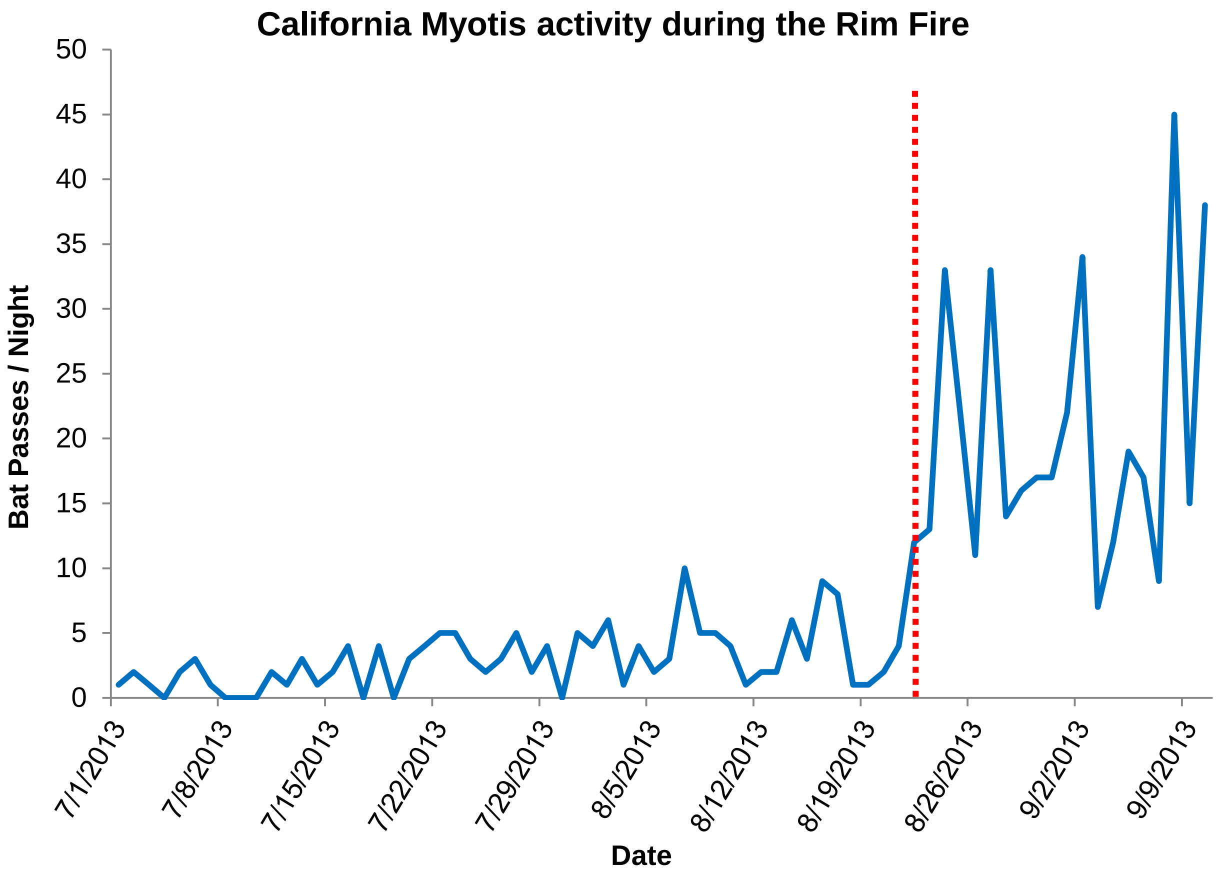


Figure 5-14. Bat detections by night of California myotis from 1 July to 10 September, 2013. Data is presented for the north-side detector only. The vertical red line represents the arrival of the Rim Fire which burned on the north side of the river from 23 August to 24 August and on the south side from 9 September to 10 September, 2013.

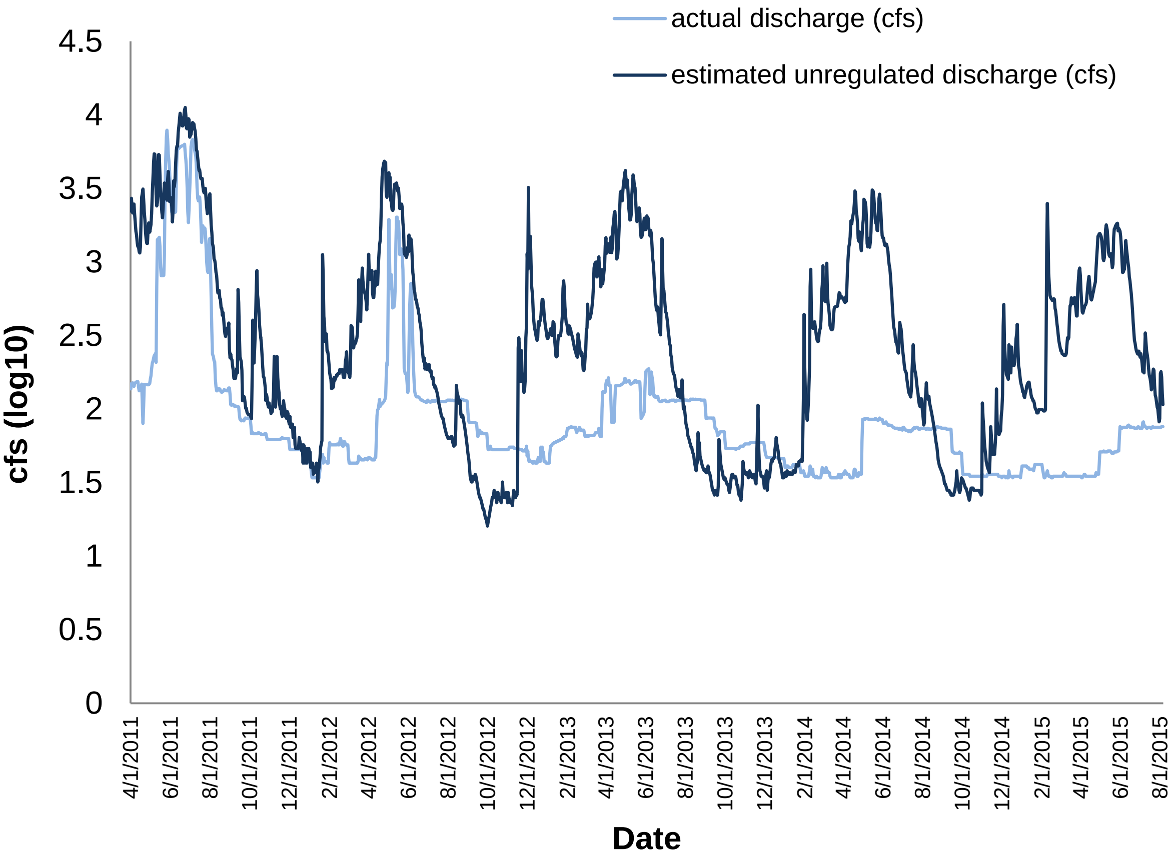


Figure 5-15. Discharge in cfs from April 2011 to April 2015 for the Hetch Hetchy reach of the Tuolumne River. Data from the USGS.

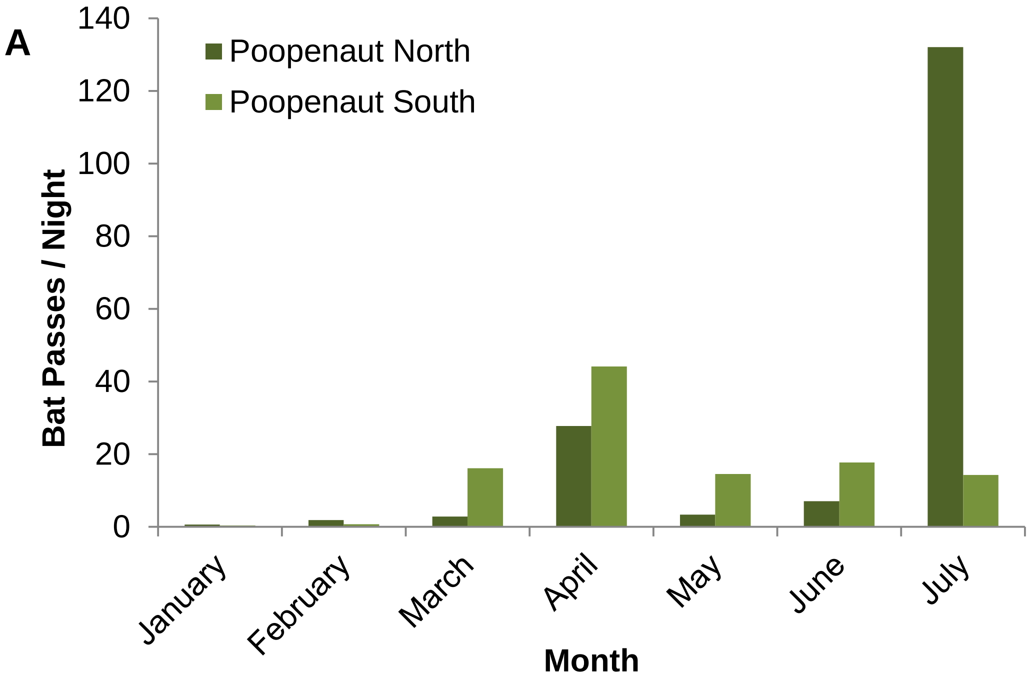
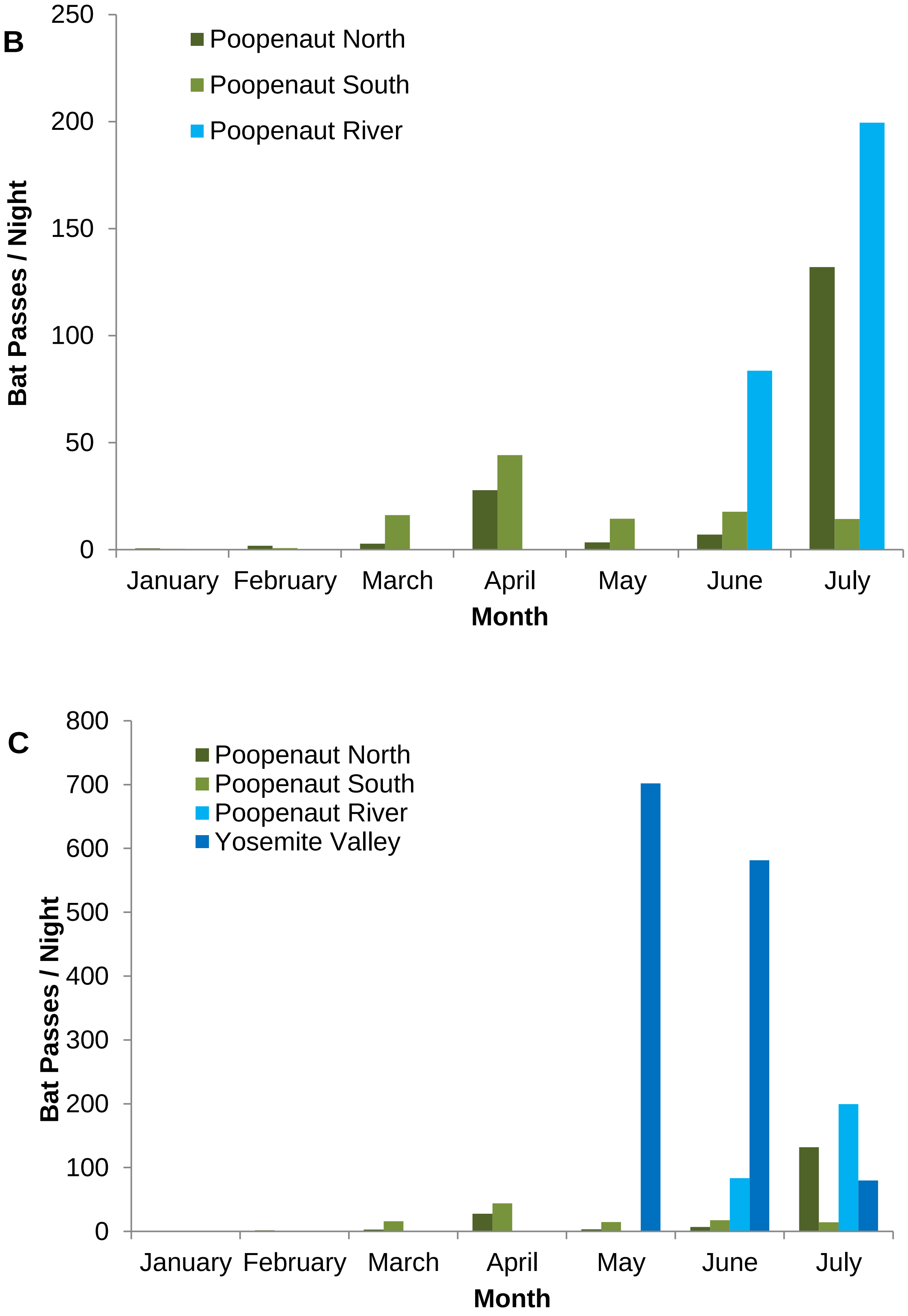


Figure 5-16. Number of bat passes per night for each study location from January to July 2016. A) Compares only Poopenaut north and Poopenaut south. B) Displays comparison with the Poopenaut river study location. C) Displays bat activity in Yosemite Valley during the same time frame.

Figure 5-16 continued.



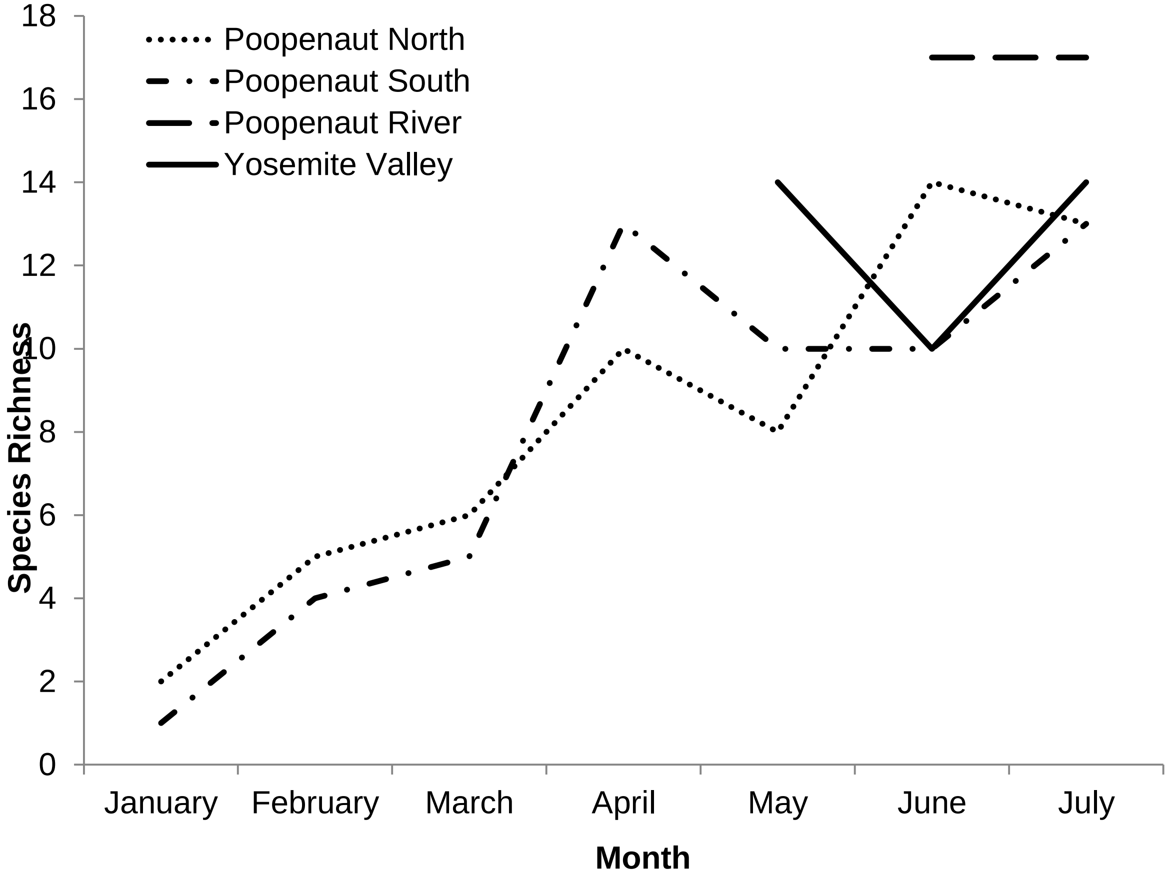


Figure 5-17. Species richness at the four study locations monitored in 2016 by month. The Poopenaut River location was only monitored successfully in June and July while the Yosemite Valley location was monitored successfully May to July. All 17 species of bats known to occur in Yosemite Valley and Poopenaut Valley were detected in both June and July at the Poopenaut river location.

5.4 Discussion

This study has identified an impressive biodiversity of bat species inhabiting Poopenaut Valley, with at least one species, the Mexican free-tailed bat, present year-round. We documented five special status species, two of which are the first (spotted bat) and third (western mastiff bat) most frequently detected species throughout the study period. We detected patterns in bat activity levels and community composition across seasons, study sites, and years that correlate with the timing of the Rim Fire (2013) and an experimental flood (2016). The addition of two new study sites in 2016 – one directly adjacent to the Tuolumne River in Poopenaut Valley and one near the Camp 6 pond in Yosemite Valley – greatly enhanced our ability to attribute shifts in bat activity and species composition to changes in river regulation.

Decreased bat activity in the winter is likely attributable to lower ambient temperature as well as reduction in prey availability. Many species of bats migrate to warmer areas in the winter where they are able to forage throughout the year, while others hibernate and undergo torpor for some portion of the year. Persistent activity of Mexican free-tailed bat (among others) seems to indicate at least some year-round insect prey availability in Poopenaut Valley, and concomitant surveys by Holmquist and Schmidt-Gengenbach (2013) identified a substantial increase in the abundance of benthic black flies (Diptera) and mayflies (Baetidae) in the fall and winter. While both terrestrial invertebrate and emergent aquatic insect abundance is generally highest in the summer within a temperate climate regime, emergent aquatic insects may be a primary source of food for bats in the fall and winter when relative abundance of terrestrial invertebrates declines. Whether and to what extent the winter bat community relies on aquatic prey items is beyond the scope of this study, but represents an interesting avenue for further research. This is especially true because winter discharge into the Tuolumne River and water temperature downstream of Hetch-Hetchy reservoir is greater than is expected under an unregulated scenario (Figure 5-15). Both of these conditions should affect emergent aquatic insect availability and therefore bats.

Annual and monthly shifts in bat activity and community composition may be attributable to changes in abundance of emergent aquatic prey as bats can travel long-distances to forage and track prey availability. Certainly Holmquist and Schmidt-Gengenbach (2013) have recorded greater abundance of both terrestrial and aquatic insects in Poopenaut Valley in “wet” years compared to “dry” years, and significant fluctuations of riparian, riverine, and pond-dwelling invertebrates at the population level between months and years.

We observed an increase in bat activity during the Rim Fire compared to the summer months leading up to the fire in 2013. Data indicated California myotis to be the most affected and was detected in record numbers during the Rim Fire. Other smaller species of bats that prefer cluttered canopy like hoary bat, Yuma myotis, and canyon bat also increased in activity levels during the Rim Fire. This pattern suggests that smaller species of bats may have been driven upstream ahead of the fire, either passing through Poopenaut Valley and continuing up river, or seeking refuge in the floodplain meadow. It is also possible that bats were drawn to the area to feed on aerial insects confused by the fire; however we did not see large increases in activity levels for larger higher-flying bats that are more likely to fly long distances to forage on aerial insects.

A large increase in bat activity and shift in bat community composition in 2014 compared to 2013 suggests that the Rim Fire may have had inter-annual effects on bats. The Rim Fire shifted invertebrate assemblages directly through mortality of plant-associated taxa, indirectly via habitat loss or restructuring, and via emigration of mobile organisms from the area (Holmquist and Schmidt-Gengenbach, 2013). In the short term (weeks to months following the Rim Fire) there may have been a reduction in invertebrate prey. However over a longer time period (one year) invertebrate abundance may have increased. For example, in their study of the 2002 McNally Fire in the Sierra Nevada, Buchalski et al. (2013) observed that bats may exhibit some resiliency to landscape scale fire in mixed-conifer forests of California, and some species preferentially select burned areas for foraging, perhaps facilitated by reduced clutter and increased post-fire availability of prey and roosts. Due to the absence of a reference site in 2013 and 2014, it is difficult to discern with any certainty whether the temporal patterns in bat activity that correlate with the timing of the Rim Fire are a result of the fire. It is likely that multiple factors are interacting to affect bat activity.

The addition of two new detectors – one directly adjacent to the Tuolumne River in Poopenaut Valley and one near the Camp 6 pond in Yosemite Valley – greatly enhanced our understanding of bat activity and community composition in Poopenaut Valley. With the river acoustic detector we recorded all 17 species of bats known to occur in Yosemite and Poopenaut Valley in both June and July. No other detector recorded all 17 species within that same timeframe, suggesting that a more diverse array of bats utilize the river corridor than adjacent pond or meadow habitat. Further, we found significant differences in bat community composition among study sites, suggesting that pond, meadow, and river habitat each attract a distinct cohort of bats. Further inquiry into patterns at the population level will be useful to tease out exact mechanisms driving the differences we see.

We observed distinct patterns in bat activity that may correspond to spatial hydrologic patterns. Bat activity at both the north and south sites increased in April, decreased in May and June correlating with the flood, and jumped to record highs for the Poopenaut north site in July. In addition, activity levels were higher at the Poopenaut river site in both June and July than ever recorded for the north and south locations. Taken together, this pattern may indicate a proclivity of bats for inundated conditions as we saw greater activity on the south side of the river in the spring when the small stream running near the detector was full, greater activity on the north side in July when the pond still had water in it even though the tributaries were dry, and the most activity along the river throughout.

We predicted that the experimental flood would lead to a short-term decrease in the abundance of emergent aquatic insects – and therefore bat activity – due to scouring of the river leading to mortality and drift of benthic aquatic insects. However, we also anticipated a relatively quick recovery of benthic invertebrate populations with concomitant increases in bat activity in the months following the flood. Preliminary evidence supports our prediction. We observed a decrease in bat activity at the north and south locations around the same time as the flood, then a sharp increase in bat activity over water (i.e., the river and pond) in June and July. Concurrently, bat activity in Yosemite Valley was highest in May and June and decreased significantly in July – the opposite pattern. Although the Merced River also flooded around the same time as the Tuolumne River, the magnitude of the flood was much lower (2,000 cfs) and the descending limb more gradual. Therefore, the flood conditions in Yosemite may not have had the same power to temporarily extirpate benthic invertebrates. Other factors including differences in pond hydrology between the Camp 6 pond in Yosemite and the north-side pond in Poopenaut Valley also may have contributed to this pattern and deserve further inquiry.

We added two new study components in 2016. The addition of two new detectors greatly enhanced our ability to detect shifts in bat activity, population, and community dynamics in response to regulated hydrology. Extending this component to future years will continue to enhance our understanding and more importantly infer causal environmental drivers of bat ecology and ecosystem integrity in Poopenaut Valley.

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Appendix A. Summary of birds captured during target-netting in Poopenaut Valley, 2016

Age Code Key: HY = Hatch Year, SY = Second Year, AHY = After Hatch Year, ASY = After Second Year, U = Unknown

Color Band Key: BLU = Blue, BK = Black, G = Green, O = Orange, R = Red, S = Silver (USGS-BRD numbered aluminum band), T = Turquoise, W = White, Y = Yellow, X = no band in that position on the leg

Capture Date	Capture Time	Capture Type	Band Number	Species Name	Age	Sex	Color Combo (left leg)	Color combo (right leg)	Sample Taken?	Re-sighted ?
14-Jun-16	6:30	New	120296771	American Robin	SY	F			Y	
14-Jun-16	8:00	New	120296772	American Robin	AHY	M			Y	
2-May-16	10:10	New	Unbanded	Anna's Hummingbird	U	M			N	
2-May-16	10:10	New	Unbanded	Anna's Hummingbird	SY	M			N	
15-Jun-16	10:20	New	Unbanded	Anna's Hummingbird	SY	M			N	
3-May-16	6:50	New	184141702	Black-headed Grosbeak	ASY	M			Y	
3-May-16	6:50	New	184141703	Black-headed Grosbeak	SY	M			Y	
3-May-16	6:50	New	184141704	Black-headed Grosbeak	SY	F			Y	
29-May-16	9:00	New	184141713	Black-headed Grosbeak	SY	M	BL/BK	R/S	Y	
15-Jun-16	5:40	New	184141714	Black-headed Grosbeak	SY	M	R/Y	S/BL	Y	
15-Jun-16	6:40	New	184141715	Black-headed Grosbeak	ASY	M	W/BLU	BLU/S	Y	
15-Jun-16	9:00	New	184141716	Black-headed Grosbeak	AHY	F	R/Y	Y/S	Y	
24-Jul-16	6:20	New	184141722	Black-headed Grosbeak	HY	U	W/R	BLU/S	Y	
24-Jul-16	6:50	New	184141723	Black-headed Grosbeak	AHY	F	BK/S	BLU/Y	Y	
24-Jul-16	10:40	New	184141724	Black-headed Grosbeak	ASY	M	W/S	BLU/BK	Y	
3-May-16	8:50	New	184141705	Bullock's Oriole	ASY	M			Y	
29-May-16	9:30	New	185128984	Cassin's Vireo	SY	F			Y	
3-May-16	6:50	New	254048308	Cassin's Vireo	AHY	U			Y	
14-Jun-16	9:40	New	254048314	Cassin's Vireo	SY	M			Y	
1-May-16	20:10	New	Unbanded	Common Poorwill	U	U			Y	
24-Jul-16	6:00	New	253048418	House Wren	ASY	U			N	
24-Jul-16	10:20	New	256048121	House Wren	U	U			Y	
24-Jul-16	10:20	New	257048022	House Wren	HY	U			Y	
2-May-16	9:30	New	263019805	House Wren	AHY	M			Y	
24-Jul-16	9:00	New	185128986	Lazuli Bunting	HY	U			Y	
24-Jul-16	10:20	New	185128987	Lazuli Bunting	AHY	F			Y	
24-Jul-16	10:40	New	185128989	Lazuli Bunting	HY	M			Y	
16-Jun-16	7:50	New	263019813	MacGillivray's Warbler	ASY	M			Y	
29-May-16	7:40	New	263019810	Orange-crowned Warbler	SY	U			Y	
24-Jul-16	8:30	New	263019817	Orange-crowned Warbler	HY	U			Y	
24-Jul-16	9:10	New	263019818	Orange-crowned Warbler	HY	U			Y	
3-May-16	9:10	New	263019807	Pine Siskin	AHY	M			Y	
3-May-16	9:10	New	263019806	Pine Siskin	AHY	U			Y	
2-May-16	6:20	New	225130783	Song Sparrow	AHY	M	Y/G	S/R	Y	Y
2-May-16	7:50	New	225130784	Song Sparrow	AHY	M	T/G	R/S	Y	Y
3-May-16	8:00	New	225130785	Song Sparrow	AHY	M	G/Y	G/S	Y	Y
3-May-16	8:30	New	225130786	Song Sparrow	AHY	M	Y/G	T/S	Y	
12-May-16	10:10	New	225130788	Song Sparrow	AHY	F	R/R	R/S	Y	Y
12-May-16	10:10	New	225130789	Song Sparrow	AHY	M	Y/Y	R/S	Y	Y

30-May-16	9:30	New	225130791	Song Sparrow	AHY	M	Y/BK	Y/S	Y	Y
24-Jul-16	6:00	New	Color Only	Song Sparrow	HY	U	O/Y	R/X	Y	
24-Jul-16	6:50	New	Color Only	Song Sparrow	HY	U	Y/X	R/BK	Y	
24-Jul-16	9:40	New	Color Only	Song Sparrow	HY	U	W/X	T/O	Y	
24-Jul-16	10:20	New	Color Only	Song Sparrow	HY	U	T/X	O/G	Y	
2-May-16	8:30	New	184141701	Spotted Towhee	SY	F			Y	
29-May-16	9:00	New	184141712	Spotted Towhee	ASY	M			Y	
2-May-16	6:50	New	254048305	Warbling Vireo	AHY	U	Y/T	T/S	Y	Y
2-May-16	7:40	New	254048306	Warbling Vireo	AHY	M	R/Y	G/S	Y	Y
3-May-16	6:50	New	254048307	Warbling Vireo	AHY	U			Y	
3-May-16	6:50	New	254048309	Warbling Vireo	SY	U	T/Y	S/R	Y	Y
29-May-16	8:40	New	254048312	Warbling Vireo	AHY	M	O/W	BK/S	Y	Y
14-Jun-16	7:10	New	254048313	Warbling Vireo	AHY	M	R/BK	S/T	Y	
24-Jul-16	7:30	New	254048319	Warbling Vireo	SY	U	R/Y	O/S	Y	
24-Jul-16	8:00	New	255048220	Warbling Vireo	HY	U	T/O	R/S	Y	
13-May-16	9:20	New	225130790	Western Tanager	AHY	M			Y	
24-Jul-16	10:20	New	185128988	Western Wood-Pewee	HY	U			Y	
14-Jun-16	8:30	New	264019812	Western Wood-Pewee	AHY	F			Y	
13-May-16	6:50	New	263019809	Yellow Warbler	AHY	M	T/G	R/S	Y	Y
29-May-16	10:00	New	263019811	Yellow Warbler	AHY	F	BK/O	R/S	Y	
16-Jun-16	11:11	New	263019814	Yellow Warbler	ASY	F			Y	
24-Jul-16	9:40	New	263019819	Yellow Warbler	HY	U	O/R	T/S	Y	
30-May-16	9:30	New	225130782	Song Sparrow	AHY	M	R/Y	G/S	Y	
29-May-16	7:40	Recapture	225130784	Song Sparrow	AHY	M	T/G	R/S	Y	
13-May-16	-	Recapture	225130789	Song Sparrow	AHY	M	Y/Y	R/S	N	
24-Jul-16	6:30	Recapture	225130791	Song Sparrow	AHY	M			Y	
29-May-16	7:40	Recapture	254048305	Warbling Vireo	AHY	M	Y/T	T/S	Y	
14-Jun-16	6:20	Recapture	254048305	Warbling Vireo	AHY	M	Y/T	T/S	Y	
30-May-16	7:30	Recapture	254048306	Warbling Vireo	AHY	M	R/Y	G/S	Y	
13-May-16	6:10	Recapture	254048309	Warbling Vireo	AHY	M	T/Y	R/S	Y	
30-May-16	6:20	Recapture	263019809	Yellow Warbler	AHY	M	T/G	R/S	Y	
14-Jun-16	6:40	Recapture	263019809	Yellow Warbler	AHY	M	T/G	R/S	Y	