Yosemite National Park

Division of Resources
Management and Science

Looking Downstream

2017 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 understand better 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.

The 2017 water year was well above average, with near-record levels of snow water content above about 2,600 meters (8,500 feet) in the watershed above Hetch Hetchy Reservoir. The 1 April and 1 May snow-water equivalents from snow courses in the Hetch Hetchy watershed were measured at 186% and 155% of the 1 April average, respectively. Total water year precipitation measured at Hetch Hetchy was 164.8 cm (64.87 inches), representing 185% of average and the second largest amount since 1910. Water releases from O'Shaughnessy Dam reached a maximum discharge on 24 February 2017 at 11,000 cubic feet per second (cfs), in response to large precipitation events associated with atmospheric rivers. Spring runoff began on 21 April 2017, and peaked on 22 June 2017 at 6,210 cfs, as measured above Hetch Hetchy Reservoir. During the spring runoff, maximum dam releases of 9,680 cfs occurred on 24 June 2017. Early-season precipitation and high discharge dam releases caused the pond on the north side of Poopenaut Valley to remain inundated for more than eight months. In the meadows adjacent to the river, groundwater levels were within 30 cm of the ground surface for 14 consecutive days (the minimum hydrologic requirement for a wetland 5 out of every 10 years) or more at wells 2, 3, and 8. By this standard, a portion of Wetland 5 was saturated for 85 contiguous days, the longest duration that we have yet observed in Poopenaut Valley, and a portion of Wetland 7 was saturated for 64 contiguous days.

Poopenaut Valley vegetation communities appear to be displaying some response to changes in water releases from O'Shaughnessy dam, during years with low water releases, but not high water releases. Wetland vegetation prevalence, as shown by the wetland index metric, appears to be correlated with changes in snow water equivalent on the 1 April date among monitoring years. Percent native vegetation does not appear to correspond with changes in water releases or snow water equivalent, but appears to be fluctuating and potentially slightly declining over time. Monitoring efforts suggest that low water releases are unfavorable for wetland vegetation communities in Poopenaut Valley. Vegetation responses detected during monitoring years could be due to other factors, such as a 4-year drought in 2012-2015, the Rim Fire in 2013, and an unusually high water year in 2017.

The near record snowpack from the winter of 2016/2017 in the Tuolumne River watershed led to incredibly wet conditions in Poopenaut Valley in the spring. Willow vegetation, which provided preferential nesting habitat for riparian focal species in drier years, was nearly completely inundated for the duration of the 2017 bird breeding season. This forced birds up out of the riparian corridor and into nesting substrates that may not be a first choice in drier years.

Flooding was associated with near-average diversity of bird species breeding in Poopenaut Valley. Species richness as measured by area search surveys was slightly above average in 2017 compared to other years. However, species richness as measured by point count surveys was below average. This implies that good habitat for breeding was available for many species, but some species recorded in previous years may not have found suitable breeding habitat in 2017.

An impressive biodiversity of bat species inhabits Poopenaut Valley, with at least one species, the Mexican free-tailed bat, present year-round. Out of five special status bat species documented, two are the first (spotted bat) and second (western mastiff bat) most frequently detected species throughout the study period. 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. The addition of two new detectors – one directly adjacent to the Tuolumne River in Poopenaut Valley and one in Yosemite Valley – greatly enhanced our understanding of bat activity and community composition in Poopenaut Valley. With the river acoustic detector, we consistently recorded more species of bats known to occur in Yosemite, suggesting that a more diverse array of bats utilize the river corridor than adjacent pond or meadow habitats. Further, we found significant differences in bat community composition among study sites, suggesting that pond, meadow, and river habitats each attract a distinct cohort of bats. 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. These results suggest that bats may prefer inundated conditions.

The addition of the food web component of our study allowed us to measure bird and bat dependence on aquatic productivity directly. We found that the birds we sampled relied heavily on aquatic primary production, deriving 40% to 84% of their energetic demand from an aquatic-energetic pathway. Bats in this study relied even more heavily on aquatic primary production, deriving 52% to 98% of their energetic demand from an aquatic-energetic pathway. This suggests that birds and bats selectively prey on emergent aquatic insects *and* that those insects primarily feed on benthic algae. Birds and bats that relied more heavily on an aquatic energetic pathway generally fed at a higher trophic position, suggesting that aquatic-to-terrestrial food webs leading to birds and bats are more complex than terrestrial food webs, include more predators or omnivores, and are perhaps more resistant or resilient to disturbance. Together these results indicate that the birds and bats captured in riparian systems rely disproportionately on food webs supported by photosynthesis occurring within rivers and streams, therefore emphasizing the importance of intact aquatic ecosystem processes to these communities.

Chapter 1. Introduction

The primary goals of the Looking Downstream project are 1) to fill in information gaps by collecting baseline information on the hydrology, vegetation, birds, 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 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, 2016).

As in prior years, our 2017 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, 2017). This status report presents the other subjects in Chapters 2 through 5. This report details findings from our 2017 research in Poopenaut Valley.

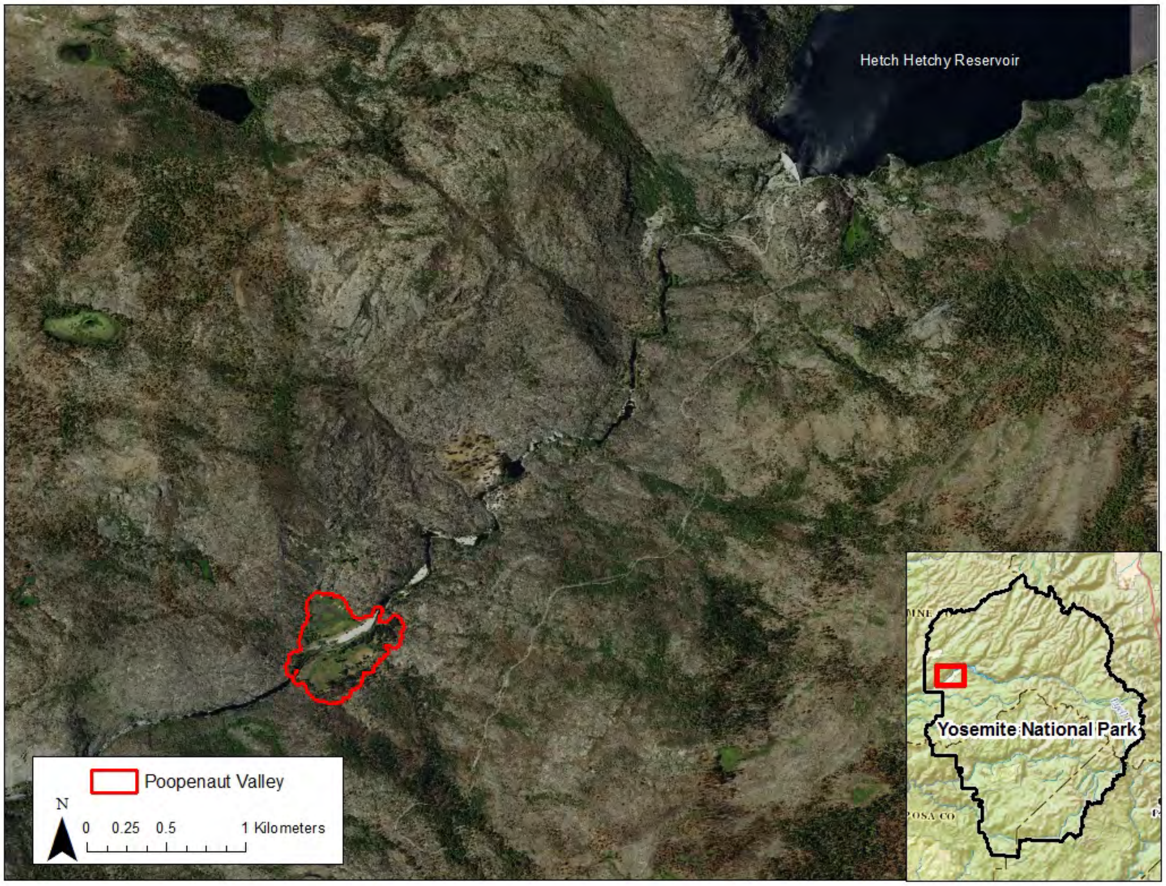


Figure 1-1. Location of Poopenaut Valley, a roughly one-km2 floodplain meadow complex (red polygon) located along the Tuolumne River 5.5 km downstream of Hetch Hetchy Reservoir within Yosemite National Park, California.

Chapter 2. 2017 Hydrology studies in Poopenaut Valley

2.1 Introduction

Hydrology studies in Poopenaut Valley in 2017 consisted of continued monitoring of water levels in the Tuolumne River, tributary streams, the seasonal pond on the north side of the river, and groundwater levels within wetlands and meadows adjacent to the river. 2017 was characterized by an above-average year of snowpack and multiple large winter precipitation events.

2.2 Overview of the 2017 water year

The 2017 water year was well above average, with near-record levels of snow water content above about 2,600 meters (8,500 feet) in the watershed above Hetch Hetchy Reservoir. The 1 April and 1 May snow water equivalents from snow courses in the Hetch Hetchy watershed were measured at 186% and 155% of the 1 April average, respectively (Table 2-1).

Total water year precipitation of 164.8 cm (64.87 inches) was measured at Hetch Hetchy (Station 043939 HETC1, WRCC). This amount is 185% of average, and the second largest amount since 1910 when considering years with complete precipitation records in this dataset.

Spring runoff began on 21 April 2017, as determined using the maximum negative cumulative deviation from annual average flows at the USGS gage #11274790 in the Grand Canyon of the Tuolumne River upstream of Hetch Hetchy Reservoir. Spring runoff peaked at this gage on 22 June 2017 at 6,210 cubic feet per second (cfs) (Figure 2-1). The releases into the Tuolumne River below Hetch Hetchy registered the spring runoff start on 1 May 2017 using the same calculation method.

Snow Course	Course #	Elevation (m)	Apr 1st Average (cm)	April 1 2017 (cm)	May 1 2017 (cm)
Dana	157	2987	76.5	162.6	175.3
Rafferty	158	2865	82.6	179.1	-
New Grace	368	2713	118.4	-	-
Tuolumne	161	2621	56.6	123.2	121.9
Wilma	163	2438	109.0	209.6	224.8
Paradise	167	2332	98.0	196.9	-
Vernon	169	2042	54.9	95.3	59.7
Beehive	171	1981	56.4	53.3	6.4
Lower Kibbie	173	2042	61.5	85.1	54.6
			% April 1st Average	**186%**	**155%**

Table 2-1. Summary snow water content for snow courses in the Tuolumne River watershed within Yosemite National Park, 2017.

Figure 2-1. Photograph of Poopenaut Valley on 21 June 2017, during peak spring runoff, showing extensive inundation of wetland and riparian habitats.

2.3 Hydrological observations in Poopenaut Valley

Figure 2-2 depicts flood inundation extents, including the extent mapped on 28 June 2017 during river flows of approximately 8,120 cfs. Releases this year reached their maximum value on 24 February 2017 at 11,000 cfs, and occurred in response to large precipitation events associated with atmospheric rivers. During the spring, maximum releases of 9,680 cfs occurred on 24 June 2017.

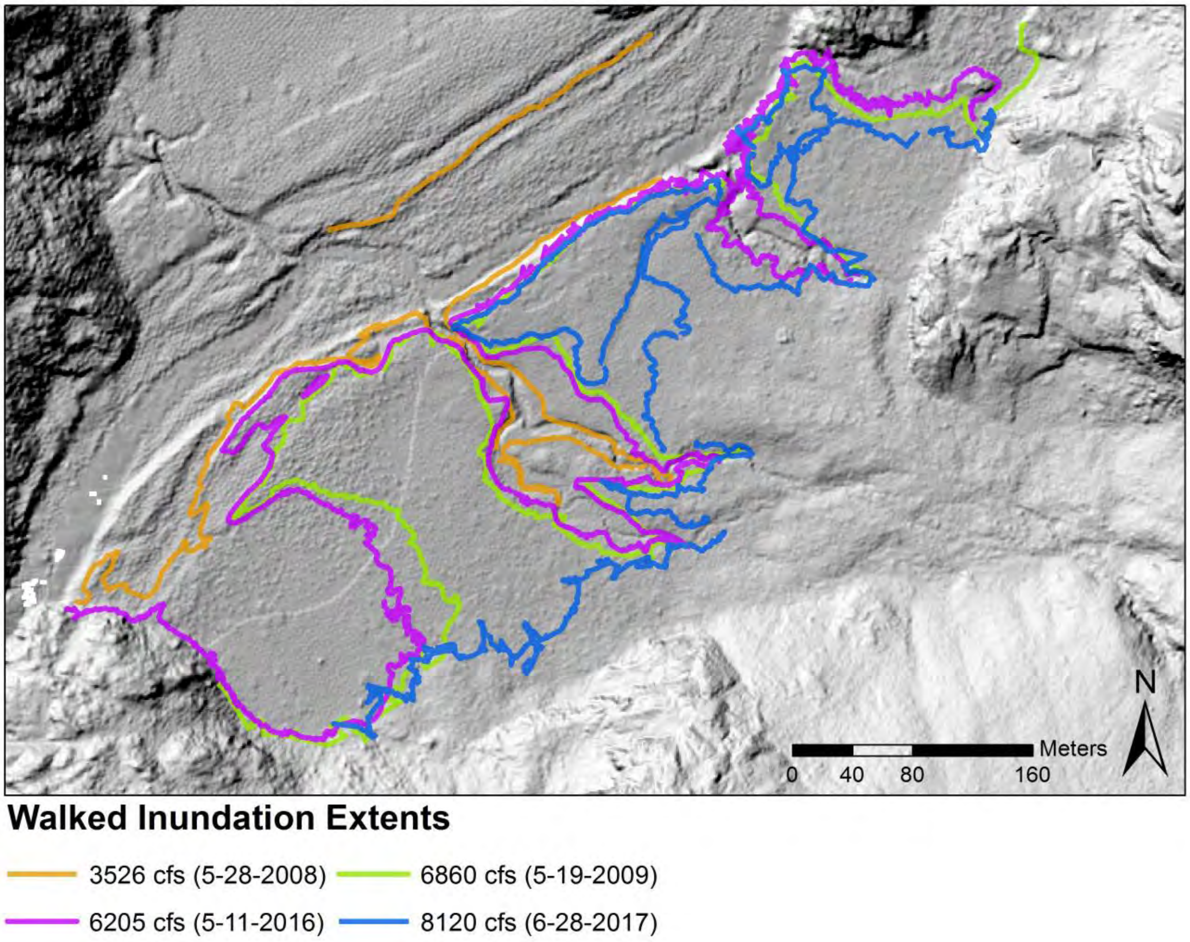


Figure 2-2. Map of inundation extents on the south side of Poopenaut Valley at four river discharge levels, including flows of 8,120 cfs that occurred on 28 June 2017.

The current network of hydrological instrumentation in Poopenaut Valley is shown in Figure 2-3. All sensors located in the tributaries were partially buried by sand-sized particles deposited during the winter and spring. The stage plate at the Tuolumne Upstream Gage was bent over from high river flows. However, all sensors remained functioning and in place throughout the 2017 water year.

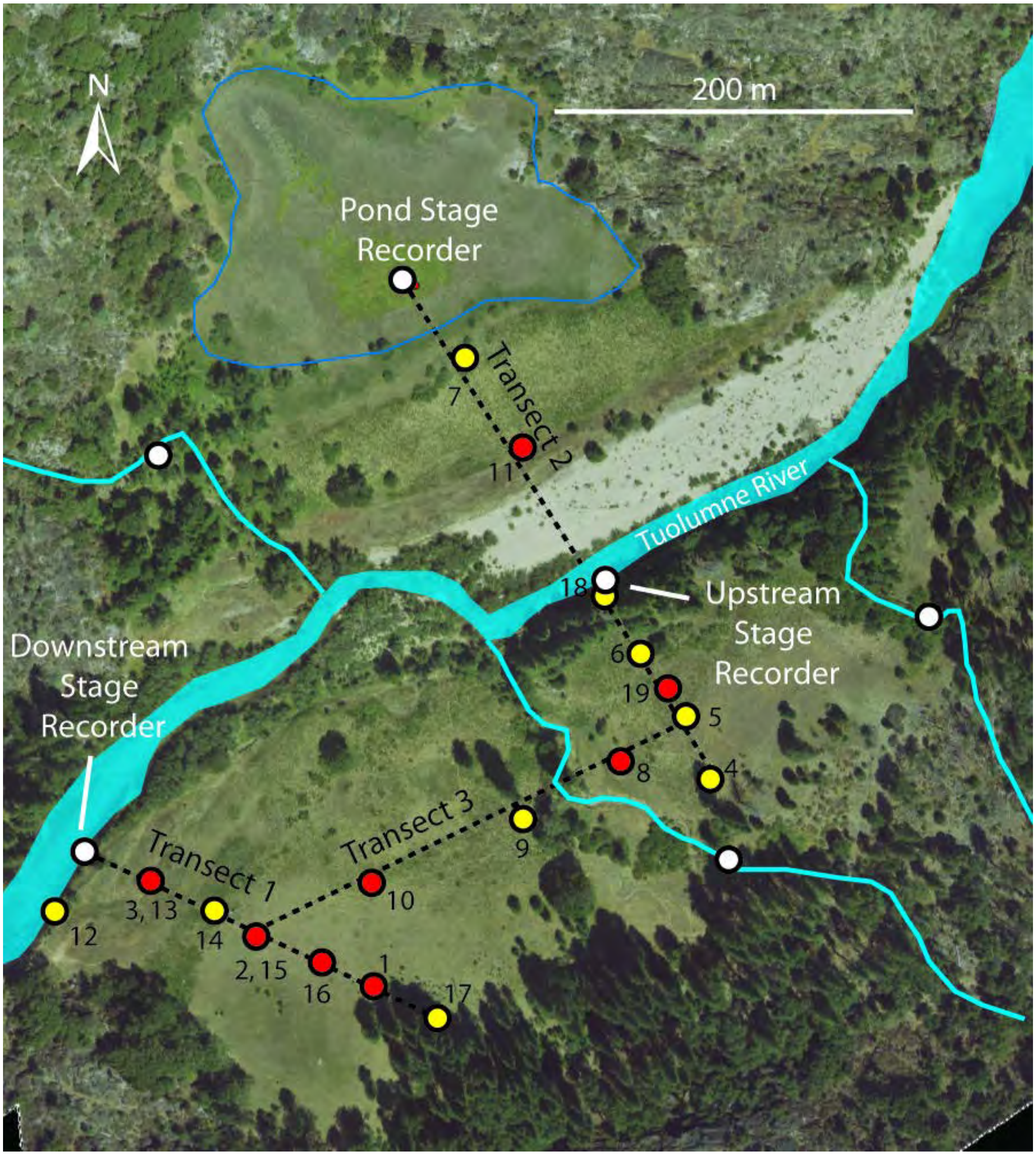


Figure 2-3. Poopenaut Valley water level monitoring locations. White dots indicate stage recorders in surface waters (Tuolumne River, tributaries, and seasonal pond). Red dots indicate existing groundwater monitoring wells. Yellow dots indicate former groundwater monitoring wells removed in October 2011.

The high levels of precipitation and high river releases this WY caused the pond on the north side of Poopenaut Valley to remain inundated for most of the winter, spring, and summer. The water level logger in the pond first registered water on 10 December 2016 (Figure 2-4).

From this point on, the pond remained wet past August of 2017, a total time of more than eight months. The first pond-filling event occurred before a direct connection between the Tuolumne River and the pond was established. Connection occurred when river stage at the Tuolumne Upstream stage recorder increased over ~1013.5 meters. This indicates that the pond first filled from direct precipitation, without a surface connection to the river, but then was filled repeatedly by river flows throughout the rest of the year.

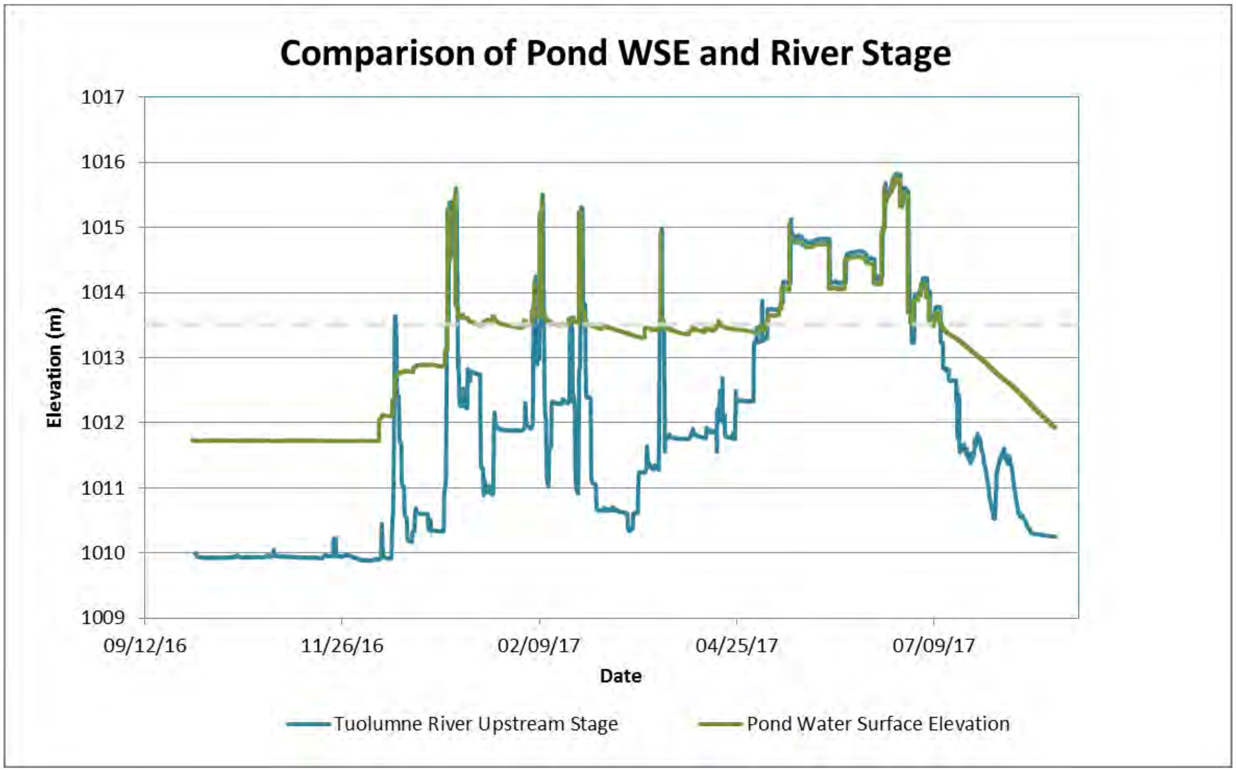


Figure 2-4. Graph of the North Pond water surface elevation and the water levels in the Tuolumne River as measured by the upstream stage logger in Poopenaut Valley.

The high flow releases from Hetch Hetchy also resulted in elevated groundwater elevations in Poopenaut Valley (Figure 2-5). Data from water level loggers located in wells throughout Poopenaut Valley indicate that groundwater levels in many parts of the valley were < 30 cm from the ground surface for at least 14 contiguous days in the spring of 2017. As shown in Table 2-2, a portion of Wetland 5 was saturated by this standard for 85 contiguous days, and a portion of Wetland 7 was saturated for 64 contiguous days.

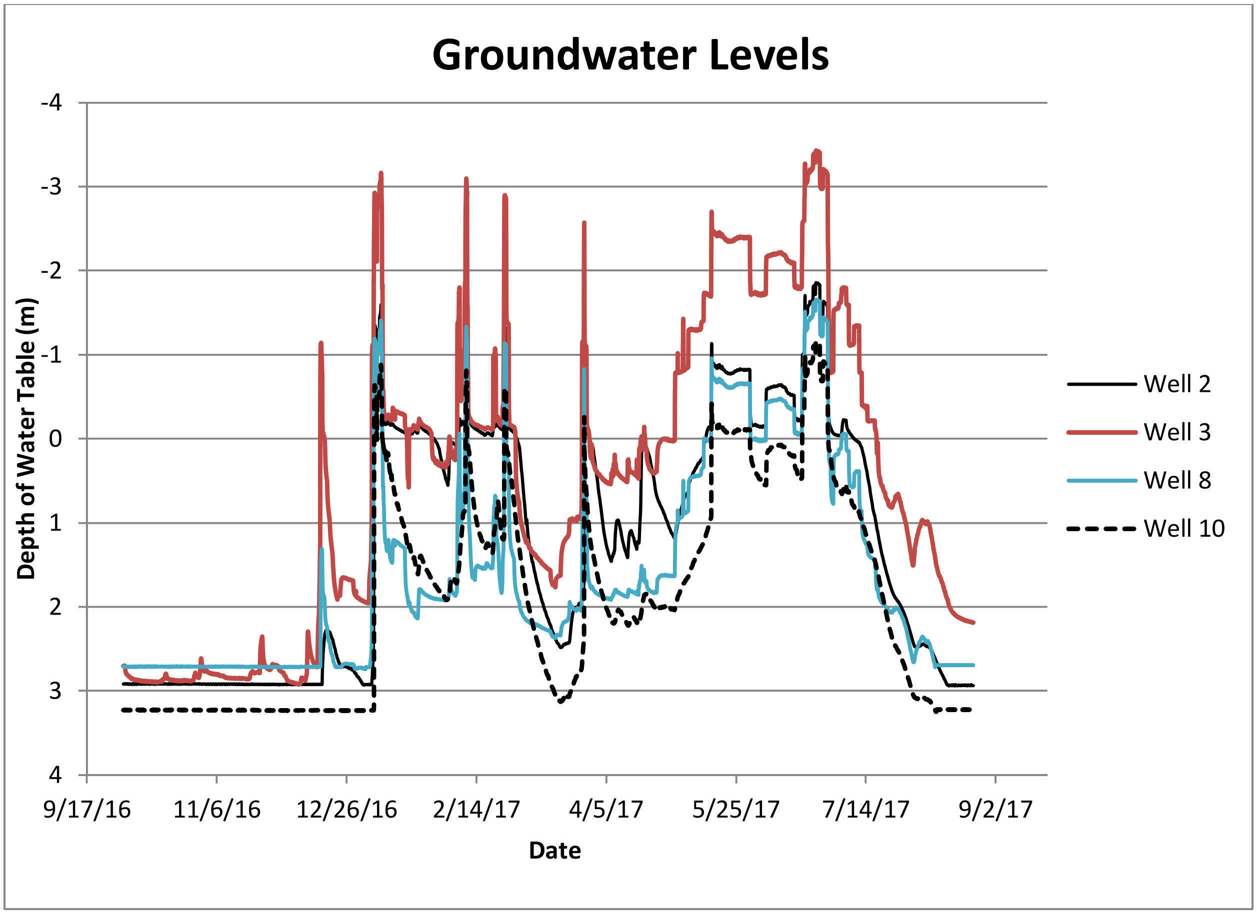


Figure 2-5. Groundwater levels as measured as distance from ground surface. Negative values indicate that water levels were above ground.

Well #	**2**		**10**		**3**		**8**	
Wetland Location	Wetland 7		Wetland 7		Wetland 5		Wetland 8	
	End Date	Period (days)	End Date	Period (days)	End Date	Period (days)	End Date	Period (days)
	1/31/17	26.4	5/31/17	15.8	3/1/17	26.2	6/30/17	48.6
	3/3/17	27.7			7/18/17	85.3		
	7/13/17	64.4						

Table 2-2. Periods in 2017 when groundwater elevations were within 30 cm of the surface for more than 14 contiguous days. The "End Date" is the last day of that period of elevated groundwater levels, and "Period" is the total number of days when groundwater was elevated. The well number is in the top row, followed by the wetland in which it is located.

Chapter 3. 2017 Vegetation Studies in Poopenaut Valley

3.1 Introduction

The vegetation in Poopenaut Valley is comprised of herbaceous wetland and upland meadows intermixed with dense riparian trees and shrubs. 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 wetland 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 in) of the ground surface for a period of 14 consecutive days during the growing season, 5 out of every 10 years (USACE, 2012).

Through hydrologic assessments and modeling, hydrologists have recommended flow models and have a good sense of the physical response (e.g. soil saturation, water table level, soil moisture retention) to different flow magnitudes and durations. 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. While soil physical and chemical properties may change more quickly under an altered flow regime, measurable vegetation responses may take much longer before they reflect the effects of such hydrology. Accordingly, assessment of the biological response to water releases requires a longer monitoring period. Additionally, different plant species will likely respond in different ways to changes in flow regime. Hence, measuring the biological response requires a longer time period and assessment of vegetation response to changes in flow by plant hydrologic regime. In this chapter, we examine overall vegetation response to streamflow releases.

3.2 2017 Vegetation Monitoring

To monitor potential changes to the vegetation communities of Poopenaut Valley we developed a draft monitoring strategy in 2017 (Appendix A), to better document specific monitoring goals and objectives, and identify quantifiable biological metrics of interest. This draft monitoring strategy is subject to further refinement, based on the outcome of additional monitoring and analysis. For example, in the draft monitoring strategy, we plan to identify threshold values for comparison with our quantifiable metrics of interest, to estimate whether vegetation communities in Poopenaut Valley are in acceptable ecological condition. We aim to assign data-driven thresholds in 2018, after further analysis of monitoring results, which should allow us to understand variability in meadow vegetation and hydrology within Poopenaut Valley.

We re-delineated 16 wetlands in 2017 in Poopenaut Valley that had been previously delineated in 2007, 2009, and 2012. Wetland delineation originally occurred in 2007, with refinement to the boundaries in 2008 and 2009. Comparison of repeat wetland delineations to the original 2007 delineation could illustrate broad-scale changes throughout the delineated area, if present. Including, but also beyond, the delineated wetlands, we mapped and described dominant vegetation communities using the Yosemite floristic classification system (NatureServe 2007), which included a survey of invasive and rare plants.

Vegetation monitoring in Poopenaut Valley in 2017 consisted of reading 20 permanent transects. We initially established permanent vegetation monitoring in 2008 to detect fine-scale changes in plant communities, such as composition and cover, in response to annual variations in temperature and available water. Nine permanent monitoring transects were originally installed in 2008, which were dispersed throughout the area. In 2015, we identified the need to increase the sample size of transects in order to achieve greater monitoring sensitivity that would allow us to better detect statistically significant changes in vegetation communities. In 2016, we installed eight new transects, and in 2017, we installed an additional three transects, which brought the total number of transects to 20. This increased sample size allows for better detection of changes in vegetation that are more representative of the entire meadow and wetland sampling area. In our monitoring strategy, we've created a monitoring plan which 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, 2016 and 2017.

During 2017 field data collection, we experienced challenges sampling the area due to water inundation, and an abnormally high water year in the Tuolumne River watershed and Central Sierra that was almost double the average of snow water equivalent (CDEC, 2017). For example, on 1 April snow water equivalent (SWE) was for the Tuolumne River watershed was 186% of average and SWE for the Central Sierra was 163% of average (Table 3-1, CDEC, 2017). Because of exceptionally wet conditions, we chose to monitor later in the summer (mid-July-Mid August and one week in September), which is later than when we typically monitor (in July). Prolonged water inundation in Poopenaut Valley also served to stunt plant phenology, thus delaying our monitoring efforts, which allowed us to measure plants at maturity.

Our objectives for 2017 included: 1) Consultation with monitoring design and statistical analysis experts to further improve sampling design and increase statistical power to detect ecological change, 2) Streamline data collection efforts to focus on vegetation attributes most sensitive to changes in streamflow, 3) Read existing 17 transects including existing photo points, and install and read 3 new transects to achieve a sample size of 20 transects total, in order provide a better representation of all sampling areas, and establish new photo points to improve sample size, and 4) Re-delineate wetlands (as is called for every five years) to compare to previous delineations, and clarify delineation methodology.

3.3 Methods

Study design improvements

In spring 2017, we consulted with vegetation monitoring design and statistical analysis experts Peggy Moore and J.R. Matchett from USGS and Marie Denn, Aquatic Ecologist from the National Park Service-Pacific West Region to improve our sampling design to increase sensitivity to detect ecological change. Previously, our analyses considered the transect as the sampling unit, taking a point intercept at every 1 m; however, this gave us a relatively small sample size overall (*n*=20) with less sensitivity to detect change. These experts suggested that we utilize the point as the sampling unit (there are 42-93 points per transect depending on length) to significantly increase our sample size. To improve our sampling design and increase statistical power, we chose to take a point intercept every 4m along each transect (*n*=337), in order to maintain spatial independence of sampling points. Weixelman and Riegel (2012) found that at least 3.6 m spacing was sufficient to ensure that sampling points were spatially distributed and not auto-correlated within Sierra Nevada meadows.

We also examined all vegetation attributes collected in the monitoring protocol and looked for redundant, subjective, or insensitive attributes that we might eliminate from future sampling to streamline data collection. Through additional research, we discovered that plant species frequency data is relatively insensitive to acute changes in river flow regime while plant cover and composition are much more sensitive (Merritt et al. 2009). Given the substantial investment of time and resources to collect frequency data we decided to eliminate it from future data collection efforts to allow us to focus on attributes such as vegetation cover, composition, proportion of native vs. non-native, and the wetland index of the site. Height was also eliminated because we discovered that it yielded inconsistent data and was highly dependent on time of year sampled, water year, and observer. Height can be a measure of plant productivity but monitoring productivity is not a priority of our management objectives. Additionally, productivity could be measured by more objective methods such as residual biomass monitoring. These changes are reflected in the updated field data collection protocol (Appendix B).

Data collected on each vegetation monitoring transect includes a point intercept reading every meter, where a varying number of nested frequency plots were randomly placed along transects, and read from 2008-2016. In 2017, we chose to continue reading point intercepts, but discontinue reading nested frequency plots along transects.

Point intercept methodology gives us vegetation cover and overall composition data (often expressed as relative cover, where less common species are often underrepresented), while frequency gives us more detailed vegetation composition data. For each point, we record all plant species intercepted. This method is simple and repeatable and is appropriate for monitoring dominant vegetation over large areas (Elzinga et al., 2006). This method also has the advantage of being comparable to other meadow systems.

Frequency is one of the easiest and fastest methods available for monitoring vegetation in that 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 that 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. Another disadvantage of this method is that that the data collected in one location is not comparable to another location. For these reasons, we chose to omit frequency from continued monitoring efforts after 2016. However, these data can be collected intermittently, if needed.

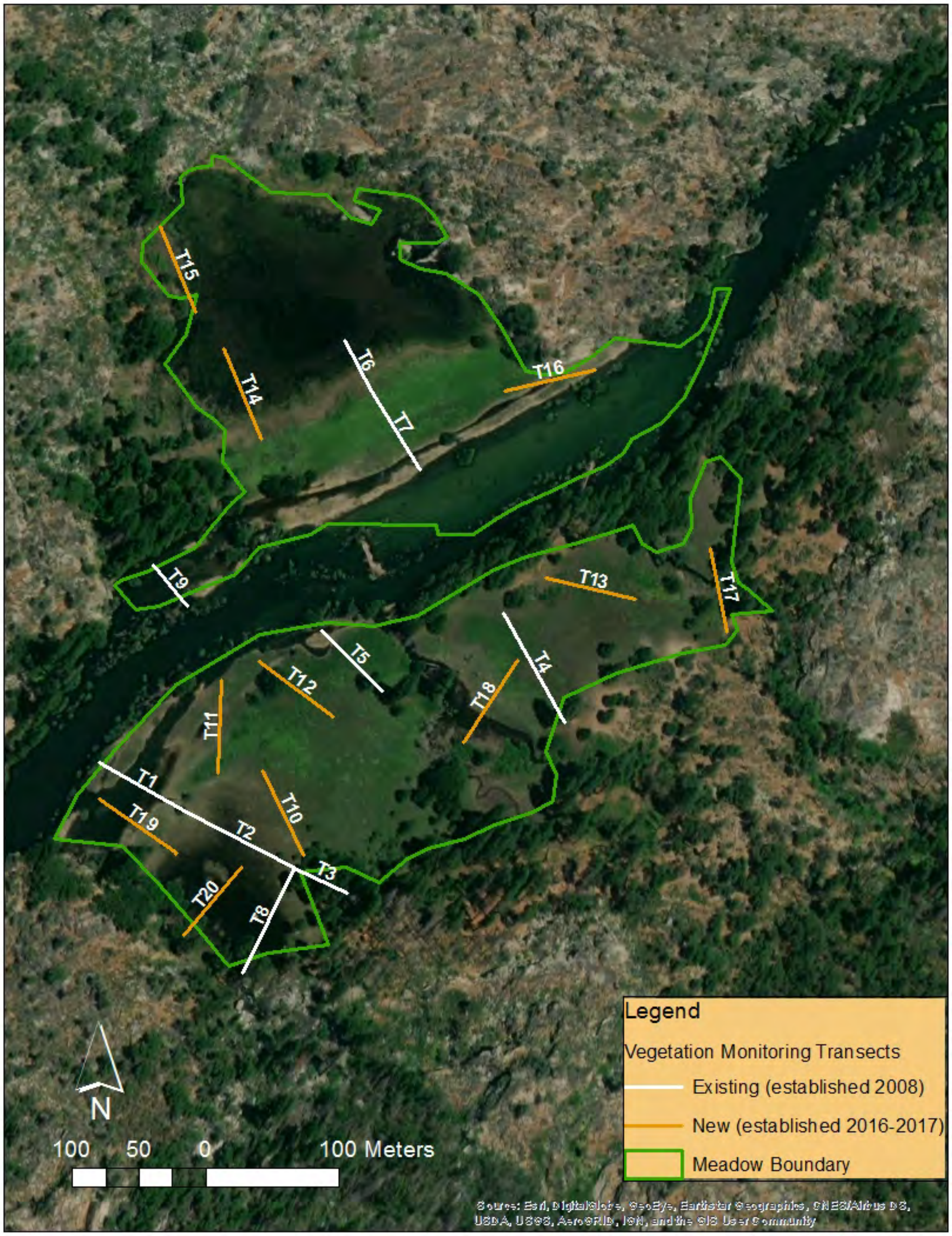
Field Data Collection

Using the consultation and research conducted in spring 2017, we implemented changes to the study design in summer 2017 by increasing the sample size and spatial dispersion of vegetation transects. These additional transects will provide for a more robust dataset and allow increased sensitivity to detect changes in vegetation composition or cover in relation to changes in river flow. In 2016 we had randomly generated an additional three monitoring transects in the North Pond monitoring area but were not able to cross the river and install them at that time, so these transects (T14,15,16) were installed and read in 2017. We also read the existing 17 permanent transects. Fieldwork occurred over a period of three weeks from the end of July-middle of August. The North Pond was still inundated in August due to the exceptionally wet water year. Due to exceptionally wet conditions, we chose to wait until September to return for an additional week to read transects located in the North Pond area (Figure 3-1).

Transects established in 2008 vary in length depending on the location of river cross section rebar, and were strategically placed, often to coincide with groundwater wells. All transects established in 2016-2017 are 70m in length, and were randomly placed, to allow for improved spatial representation of the sampling area (Figure 3-2, Appendix B). We collected photo points at both ends of each transect and at general vantage points to capture detailed and landscape-level photos.

Figure 3-1. Sampling vegetation near the pond on the north side of Poopenaut Valley, September 2017.

Additionally, we observed several alive adult Willow (*Salix spp.*) and Black Cottonwood (*Populus trichocarpa*) individuals that had snapped trunks or had been uprooted and fallen over (Figures 3-3, 3-4). We presume that the high volume flows in 2017 contributed to these conditions, likely by battering willows with floating logs or other debris. Generally, the willow stands had many standing dead individuals or individuals with substantial dieback. However, we recognize that the effects of previous drought years and the 2013 Rim fire, among other factors, could have also contributed to these conditions. To monitor the condition of these riparian trees, we established additional photo points to track changes in riparian vegetation condition over time.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 3-2. Map depicting vegetation monitoring transects read in 2017 (*n*=20, black lines) in Poopenaut Valley. Green lines indicate meadow boundaries.

Figure 3-3. Left- Uprooted Black Cottonwood (*Populus trichocarpa*), 2017. Right- Example of Shining Willow (*Salix lasiandra var. lasiandra*, formerly *S. lucida)* with snapped trunk.

Figure 3-4. Left- Willows on north side of Tuolumne River 2007. Right-Willows on north side of Tuolumne River August 2017. Note that this photo was taken much closer to willows than photo from 2007.

Wetland Delineation

Wetlands in Poopenaut Valley were originally delineated in 2007 using the jurisdictional wetland criteria and wetland delineation methodologies defined by the US Army Corps of Engineers (USACE; Environmental Laboratory 1987), but also included areas defined as wetlands by the Cowardin system (Cowardin et al., 1979). In 2008 and 2009, the USACE released supplements to the 1987 handbook, including one specifically for Western Mountains (USACE, 2008), hence boundaries were further refined, and it was confirmed that delineated boundaries and parameters had not changed based on this supplement.

Re-delineation of wetlands occurs on a 5-year mapping interval, which started in 2007. In 2012, we re-delineated wetlands 1-9 using handheld GPS units to determine if wetland boundaries had shifted substantially. Wetlands 10-16 were not re-delineated due to time constraints and/or the logic that these wetlands were bounded by another wetland (i.e. wetlands 1-9, so if it changed we would know from that delineation), or by the river. 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 short timeframe. There was a margin of error due to the inaccuracies of the GPS unit so where boundary shifts were 1-5 m, we kept the 2007 boundary to represent the delineation. To minimize observer error, we carefully documented the plant species used to determine wetland boundaries.

In August of 2017, we re-delineated all 16 wetlands to determine if wetland boundaries have shifted substantially since 2012, or in some cases 2007, when they were last delineated. We remapped any wetland boundary shifts greater than 5m and filled out USACE wetland determination data forms for vegetation and hydrologic indicators. While these forms were filled out in the original 2007 delineation, we found that filling them out helped us to document and evaluate changes we were seeing and helped us to draw new wetland boundaries. We also created a clear, quantitative and repeatable wetland re-delineation protocol (see Wetland Re-Delineation Protocol in Appendix C), as we found that the 2012 re-delineation field protocol was somewhat unclear, subjective and difficult to repeat.

Data analysis

We identified unknown plant species from collected specimens and categorized all species data collected by their wetland status and native status. Botanical nomenclature (plant species names) follows *The Jepson Manual: Vascular Plants of California, Second Edition* (Baldwin et al. 2012). Wetland indicator status, or wetland indicator category (WIC), values are determined using the USACE National Wetlands Plant List for the Western Mountains, Valleys, and Coast Region (Lichvar et. al., 2016).

We entered field data into a geodatabase for storage of monitoring data and subsequent statistical analysis. We performed all statistical analyses using R Software (R Core Team, 2016). We developed an R script to establish repeatable statistical methods for detecting change in quantitative metrics of vegetation composition over time in relation to changes in river flow.

We analyzed data for two quantifiable metrics of interest identified in our monitoring strategy; 1) wetland index (WI), based on wetland indicator category (WIC) of plant species and 2) percent cover of native vegetation. To detect change over time, we analyzed metrics using a repeated-measures analysis of variance (RM ANOVA), to test for differences between sampling years and post-hoc paired t-test comparisons (alpha value of 0.1). We eliminated samples not repeated each sampling year, and did not apply multiple test correction.

Wetland Indicator Category (WIC)

For vegetation transect monitoring data, we assigned a WIC for plant species recorded at each point intercept located 4m apart along the 20 monitoring transects we sampled. Wetland vegetation are considered to be hydrophytic species that include those listed as obligate (OBL), facultative wetland (FACW), or facultative (FAC) species, which correspond to a given species frequency of occurrence in wetlands. Non-wetland vegetation are considered drier species that do not frequently occur, or do not occur in wetlands, such as facultative upland (FACU) and obligate upland (UPL). We also assigned categories of “Not listed” (NL) when species were not listed in Lichvar et. al. (2016). Plant species with a designation of NL were given a WIC from Lichvar et. al. (2014), or were assigned a WIC based on professional judgement, which included determination of WIC of co-dominant species located at the same point intercept location and landscape position. Plants not identified to species (lacking flowers, fruit, and/or other diagnostic features) were not assigned a WIC and were eliminated from the wetland analysis. An exception was vegetative Carex and Juncus species (vegetative sedge and rush species), which were assigned a WIC of FAC, indicating a 33-66% occurrence in wetlands, since these species are hydrophytic.

Plant wetland indicator categories are defined as:

OBL: greater than 99% occurrence in wetlands,
FACW: between 66% and 99% occurrence in wetlands, and
FAC: between 33% and 66% occurrence in wetlands.
FACU: species occasionally found in wetlands (1-33% estimated probability);
UPL: species usually do not occur in wetlands (greater than 99% probability)
NI: species for which insufficient information was available to determine an indicator status
NL: species not listed in National Wetland Plant List (Lichvar et. al., 2016).

Wetland Index (WI)

We developed a wetland species prevalence index (WI) in 2014 to synthesize the prevalence of each wetland indicator category (WIC) into one metric. This approach has been used to assess differences among or changes in plant communities such as examining environmental gradients, evaluating wetland restoration or creation success, or monitoring potential groundwater impacts (e.g., Stromberg et al., 1996; Campbell et al., 2002; Dwire et al., 2004; Spieles, 2005).

We calculate a 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 point intercepts of each category divided by the total number of point intercepts in the transect:

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

where WI is the wetland index, and P is the number of point intercepts.

Wetland index values are then averaged across all transects to obtain an overall WI. The first nine transects were placed subjectively and the 11 new transects placed randomly so we cannot draw inference to the entire meadow due to the subjective placement of the first nine. However, we can track how the transect WI has changed over time and with the addition of the 11 random transects could make tentative inference to Poopenaut Valley as a whole. A wetland index (WI) value of ≤ 3 is indicative of predominantly wetland plant species and conditions, whereas a WI value of ≥3 is indicative of predominantly upland plant species and conditions.

Wetland index (WI) values and percent native cover values, which use the transect as the sampling unit, represent all monitoring years within the sampling period (2008-2017) that had the same transects sampled (2008, 2010, 2011, 2013, 2014, 2017). Results from 2016 were excluded from analysis because transects within the North Pond area were not read due to inundation. Transect 9 was excluded from this analysis because it was only sampled in 2008, 2014, and 2017. These exclusions gave us an even sample size across the last 9 years. For 2017 data only, analyzing by using the point as the sampling unit, points taken at every 4 m from all 20 transects (9 original and 11 new ones) were included in the analyses.

Percent Native Cover

To evaluate the mean percent cover of native vegetation, and whether percent native cover is changing over time, we calculate the mean percent cover of native vegetation by of all sampling points (point intercepts) for comparison among sampling years:

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

We included all plants identifiable to the species level, where we could determine nativity, in this calculation. The only exception to this was vegetative Carex sp. and Juncus sp., which we assigned a nativity of “native.” We do not have any non-native Carex or Juncus species in Yosemite or the surrounding area, thus we felt comfortable assigning them a “native” status.

3.4 Results

Wetland Index (WI)

Among monitoring years, the mean WI value was 3.11, based on using transect as the sampling unit, where values ranged from a low of 3.04 in 2011 to a high of 3.29 in 2014 (Fig. 3-

5, Table 1). In 2017, the mean WI value was 3.14, based on using transect as the sampling unit, and 3.12 when using point as the sampling unit. These two values are very similar, where the point sampling unit approach appears to produce a WI value that indicates a slightly higher prevalence of wetland vegetation. Regardless, a WI value of ~3 indicates a prevalence of mainly facultative (FAC) species (those occurring in wetlands 33- 66% of the time), indicating mesic soil moisture conditions. Years with the lowest WI values (2008, 2010, 2011, 2017) appeared to correspond with the wetter water years for the sampling period (Table 3-1).

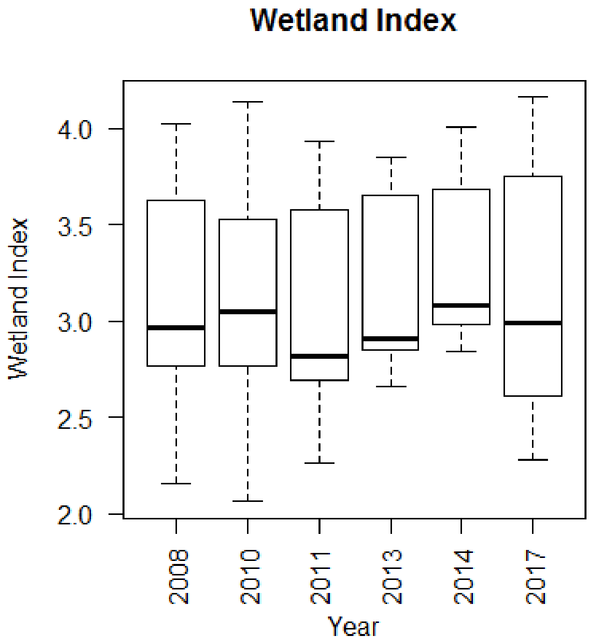


Figure 3-5. Trends in Wetland Index (WI) values for sampling years (from 2008-2017) for transects read among all monitoring years (T1-8), where transects were used as the sampling unit.

Repeated-measures analysis of variance (RM ANOVA) tests, performed to detect change over time in WI show that there were significant differences between sampling years (p=0.064, DF=5) and between transects (p < .001, DF=7 at the alpha level of 0.1). Pairwise post-hoc testing indicated that several pairs of sampling years had WI values that significantly differed from one another (Table 3-2).

Percent Native Cover

Among monitoring years, the mean percent native cover was 62.48%, based on using transect as the sampling unit, where values ranged from a low of 56.38% in 2017 to a high of 68.75% in 2011 (Figure 3-6, Table 3-1). In 2017, the percent native cover was 56.38%, based on using transect as the sampling unit, and 58.96% when using point as the sampling unit (thinned to 4 m apart). Both values indicate a majority of native vegetation (Table 3-1). For these analyses, we assigned a status of native to all vegetative Carex and Juncus species (sedges and rushes), because there are no non-native sedge and rush species known to exist in Yosemite.

Percent native vegetation was highest in 2010, 2011, and 2013. Conversely, percent native vegetation was lowest in 2008, 2014, and 2017. Years with the highest percent native vegetation (2010, 2011, and 2013) did not necessarily correspond with water year for the sampling period. The same was the case for years with lowest percent native vegetation.

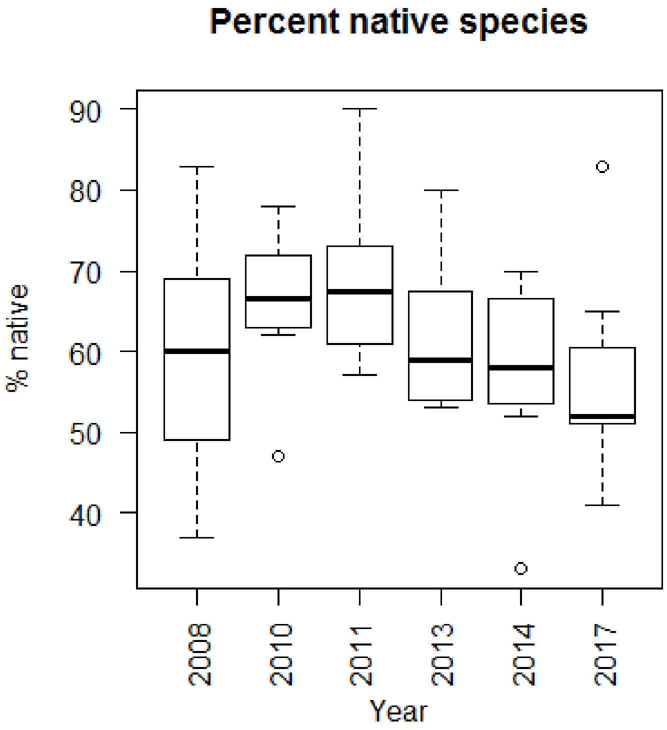


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Figure 3-6. Trends in percent native vegetation cover for sampling years (from 2008-2017) for transects read among all monitoring years (T1-8), where transects were used as the sampling unit.

Repeated-measures analysis of variance (RM ANOVA) tests, performed to detect change over time in native vegetation cover, show that there were significant differences between sampling years (*p*=0.06, DF=5) and between transects (*p*=0.001, DF=7) at the alpha level of 0.1. Pairwise post-hoc testing indicated that several pairs of sampling years had values that significantly differed (Table 3-2).

Table 3-1. Wetland Index (WI) and percent native vegetation cover values for sampling years (from 2008-2017), for transects that were read among all monitoring years (T1-8), in comparison with 2017 values, where point intercept is the sampling unit. Average April 1st percent snow water equivalent (SWE) percentage for the Central Sierra (CDEC 2017) is provided for comparison with vegetation metrics of interest.

Sampling Year	Sampling Unit	Wetland Index (WI)	Native Veg Cover (%)	Central Sierra, April 1st, Percent of Avg. SWE	Peak Spring Run-off Dam Release (cfs)	Tuolumne Watershed Percent of Avg. SWE (April 1st)
2008	Transect	3.11	59.50	87	6800	112
2010	Transect	3.11	66.00	92	7300	101
2011	Transect	3.05	68.75	162	6230	163
2013	Transect	3.17	61.75	53	1780	61
2014	Transect	3.29	57.38	40	1450	36
2017	Transect	3.14	56.38	163	6210	186
2017	Point	3.12	58.96			
MEAN of transects:		3.11	62.48	100	4962	110

Table 3-2. Results of repeated-measures analysis of variance (RM ANOVA) tests for wetland Index (WI) and percent native vegetation values for sampling years (from 2008-2017), for transects that were read among all monitoring years (T1-8). Table conveys P-values, where values of 0.10 or less are considered significant (shown in bold font).

Sampling Year	Wetland Index (WI)					Native Veg Cover (%)				
	2008	*2010*	*2011*	*2013*	*2014*	*2008*	*2010*	*2011*	*2013*	*2014*
2010	0.99					0.09				
2011	**0.10**	0.37				**0.05**	0.51			
2013	0.51	0.60	0.05			0.58	0.15	0.11		
2014	**0.07**	**0.10**	**0.01**	**0.00**		0.65	**0.01**	**0.04**	0.35	
2017	0.72	0.71	0.23	0.81	0.17	0.66	0.13	**0.03**	0.22	0.89

Wetland Delineation

In 2017, we assessed all delineated wetlands within Poopenaut Valley for vegetation and hydrology indicators. We also developed detailed methods to re-delineate wetland polygons upon discovery that the 2012 methods were difficult to replicate objectively. These methods are documented in Appendix C. We then assessed all delineated wetlands within Poopenaut Valley for vegetation and hydrology indicators.

We found that some wetland boundaries substantially contracted, others expanded, and yet others shifted position (Figure 3-7). Specifically, Wetlands 10, 7, 3, 12, 13 contracted, whereas Wetlands 11, 6, 8 and 9, 1c, 1, 14, and 4 expanded. The perimeter of Wetland 5 remained the same but a high mound dominated by upland vegetation was excised. Wetlands 1a, 1b, 1d, 2, 16 and 15 remained the same. Caution must be exercised when interpreting these changes, as some of them are due to areas apparently omitted in previous mapping efforts. We re-mapped observed changes greater than 5m and uploaded these spatial features to our project geodatabase in ArcGIS. We did not re-map any observed changes of less than 5m due to inaccuracies of the GPS units. All USACE wetland determination data forms were scanned and uploaded to our server. Detailed descriptions of the wetlands and changes observed are provided in Appendix D.

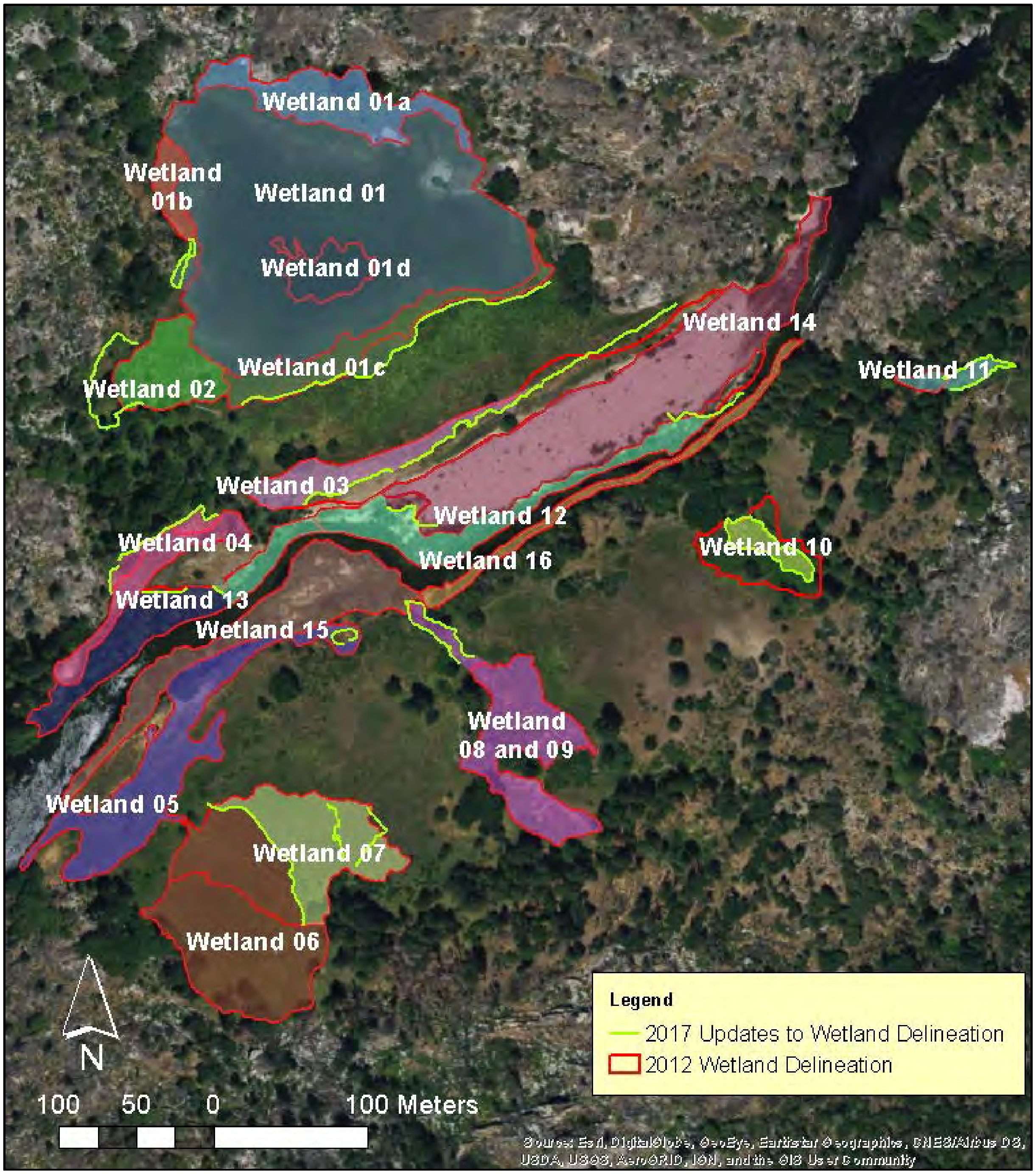


Figure 3-7. Map depicting wetland re-delineation conducted in 2017, where colors indicate the various wetlands map (*n*=16). Red lines indicate 2012 delineated wetland boundaries from 2012, and green lines indicate updates to delineated wetland boundaries in 2017.

3.5 Discussion

Wetland Index (WI)

Among monitoring years, we found that the mean WI value was 3.11, which indicates a prevalence of wetland and meadow vegetation in Poopenaut Valley (see Table 3-1). In 2017, we found that the mean value based on using both transect and point as the sampling unit was similar to, but slightly higher than, the mean WI value among monitoring years. This indicates a possible trend in which wetland vegetation is becoming slightly less prevalent in Poopenaut Valley. Verifying this trend will require further analysis in future years.

Repeated-measures analysis of ANOVA tests showed significant differences between sampling years and transects, where pairwise post-hoc testing showed that several pairs of sampling years had significantly different WI values. For example, the years that most significantly differed from one another were two of the lowest water years: 2013 and 2014 ($p < 0.00$). These two monitoring years were part of a four-year drought that lasted from 2012 to 2015. The driest WI value in the dataset (3.29) in 2014 corresponded with the lowest water year for the sampling period. The 2014 value significantly differed from the 2013 value (3.17), although both values represent an absence of predominantly wetland vegetation, in that they are both ≥ 3. In addition, the WI values for 2013 and 2014 represent the highest WI among monitoring years (lowest prevalence of wetland vegetation). Conversely, the second most significant difference in WI was between the monitoring years 2011 and 2014; where 2011 represents a high water year (163% of average SWE in the Tuolumne River watershed) with the lowest WI value (3.05) or highest prevalence of wetland vegetation, and 2014 represents a drought year with the lowest SWE among monitoring years (36% of average SWE) and highest WI (3.29).

When further comparing WI values with climatic data on SWE for the 1 April date in both the Tuolumne River watershed and Central Sierra, we found that WI values consistently appeared to correspond with SWE. For example, all years with greater SWE had lower WI, and vice versa. The highest WI value (meaning “driest”, 3.29 in 2014) corresponded with the lowest water year for the sampling period, which had 36 % of average 1 April snow water equivalent (SWE) in the Tuolumne River watershed, and 40 % of average SWE in the Central Sierra. The lowest WI value (meaning “wettest”, 3.04 in 2011) corresponded with the second highest water year for the sampling period, which had 163 % of average April 1st snow water equivalent (SWE) in the Tuolumne River watershed, and 162 % of average SWE in the Central Sierra. Similarly, during 2017 sampling, we observed an abundance of Kentucky blue grass (*Poa pratensis*), whose WIC is FAC (WI=3), as opposed to mullein (*Verbascum thapsus*) in earlier drought years, whose WIC is FACU (WI=~3.5). This may be due to the unusually wet winter that occurred in 2017, where SWE was almost double the average value on 1 April for the Tuolumne River watershed. Thus, we see an indication that wetland vegetation may take advantage of wet conditions to expand.

When comparing WI values with O'Shaughnessy Dam spring water release values (in cfs), it appears that higher WI values also corresponded with lower water releases, but lower WI values did not necessarily correspond with higher water releases (Table 3-1). For example, water releases were highest in 2008, 2010, 2011, and 2017 (ranging from 6,210 to 7,300), but WI values were similar (ranging from 3.11 to 3.12), with the exception of 2011 (3.05). Conversely, water releases were lowest in 2013 and 2014 (1,780 and 1,450, respectively), where WI values were also highest in those years (3.17 and 3.29, respectively).

Percent Native Cover

Among monitoring years, we found that the mean percent native cover was 62.48 %, which indicates a dominance of native vegetation in Poopenaut Valley. In 2017, we found that the mean value based on using both transect and point as the sampling unit was comparable by 2 percentage points (56.38 % and 58.96% respectively). This may indicate a slight trend toward non-native vegetation, but percent native vegetation has fluctuated among monitoring years in in Poopenaut Valley. During field data collection in 2017, we observed that native cover was particularly low due to an abundance of Kentucky blue grass (*Poa pratensis*). If we treated this species as naturalized, the percent cover of native vegetation may be higher among monitoring years.

Repeated-measures analysis of variance ANOVA tests showed significant differences between sampling years and between transects, where pairwise post-hoc testing indicated that several pairs of sampling years had significantly different percentages of native vegetation. For example, the years that most significantly differed from one another ($p < 0.01$) were 2010 and 2014. Percent native vegetation in these two years (66 % versus 57.38 respectively) represent the highest and lowest percent native cover values recorded among monitoring years analyzed. These two monitoring years also represent a high water year (2010, 101% of average SWE in the Tuolumne River watershed) versus a drought year (36 % of average SWE). Conversely, the second most significant difference in percent native vegetation was between the monitoring years 2011 and 2017, where both years represent high water years (163 % and 186 % of average SWE in the Tuolumne River watershed, respectively). However, percent native vegetation cover values differed widely, where the 2011 percentage (68.75 %) was the highest value among monitoring years, and the percentage in 2017 (58.96 %) was the lowest among monitoring years. These results suggest that other factors, such as water year and drought, affect the percentage of native plant cover among monitoring years.

In summary, when comparing percent native vegetation with climatic data on snow water equivalent (SWE) for the 1 April date in both the Tuolumne River watershed and Central Sierra, we found that percent native vegetation did not necessarily correspond with water year for the sampling period. One hypothesis could be that there is a time lag in response of native vegetation to SWE, which appears to correspond with our dataset over the monitoring years.

When comparing percent native vegetation with O'Shaughnessy Dam spring water release values (in cfs), it also appeared that percent native vegetation did not necessarily correspond with water releases. For example, water releases were highest in 2008, 2010, 2011, and 2017 (ranging from 6,210 to 7,300), but percent native vegetation was widely divergent (ranging from 58.96 to 68.75 %). Similarly, during years when water releases were lowest in 2013 and 2014 (1,780 and 1,450 respectively), percent native vegetation was also widely divergent (61.75 % and 57.38 % respectively).

Wetland Delineation

Our 2017 wetland re-delineation effort in Poopenaut Valley showed that while some wetland boundaries contracted, expanded, or shifted, most boundaries remained the same (Figure 3-6). Several of the wetland expansions we documented were due to omission in previous delineations; we felt that wetland polygons should be extended due to the presence of contiguous hydrophytic vegetation and hydrologic conditions. The most notable reduction was in Wetland 10, which was marginal upon its delineation in 2007 and appears to have dried somewhat since that time, as it no longer supports hydrophytic vegetation in much of the original polygon. A tributary stream runs through this wetland, which supports wetland vegetation and hydrology, but with increasing distance from the stream conditions are drier and the area no longer qualifies as wetland.

In 2017, we also successfully produced a detailed re-delineation protocol (Appendix C) to ensure that future observers are able to replicate our methods and able to document change over time. For a more detailed summary of wetland changes in 2017, and a description of all wetland mapped, see Appendix D.

3.6 Conclusion

Poopenaut Valley vegetation communities appear to be displaying some response to changes in water releases from O'Shaughnessy Dam during years with low water releases, but not high water releases. Wetland vegetation prevalence, as shown by the wetland index (WI) metric appears correlated with changes in snow water equivalent (SWE) on the 1 April date among monitoring years. Percent native vegetation does not appear to correspond with changes in water releases or SWE, but appears to be fluctuating and potentially slightly declining over time. Management implications of this year's monitoring effort suggest that low water releases are unfavorable for wetland vegetation communities in Poopenaut Valley. However, ecological responses detected during monitoring years could be due to other factors, such as a 4-year drought in 2012-2015, the Rim Fire in 2013, and an unusually high water year in 2017.

In 2018, our draft monitoring strategy calls for limited field data collection (repeat photo points of the study area), and a more thorough analysis of our vegetation monitoring results to-date. We have identified several next steps for further refining monitoring and data analysis efforts. Continued improvement in our vegetation monitoring and analysis efforts will allow us to: 1) better detect change in the ecological condition of vegetation communities in Poopenaut

Valley, and 2) provide information that water managers can use to manage environmental water releases in ways that will more closely replicate natural physical processes and benefit dependent ecosystems in Poopenaut Valley. Next steps for future refinements of data analysis could include stratification of individual wetlands by elevation. Comparison of individual wetlands WI and % native cover by elevation over time may allow us to test whether lower elevation wetlands are inundated/saturated more frequently than higher elevation wetlands, and whether wetlands stratified by elevation show a different response than all wetlands together.

Chapter 4. 2017 Bird Studies in Poopenaut Valley

4.1 Introduction

This chapter addresses the composition of the breeding bird community in Poopenaut Valley. The sensitivity of bird populations to changes in the ecosystem makes them an important indicator of overall habitat quality (Marzluff and Sallabanks, 1998). Long-term monitoring of birds, particularly during the breeding season, can be used to assess habitat health (Ralph et al., 1993). Bird population dynamics have been used as scientifically viable surrogates for evaluation of ecosystem condition because (1) birds are conspicuous, easily observable, and monitoring and analysis are cost effective; (2) as secondary consumers (i.e. insectivores), birds are sensitive indicators of environmental change; and (3) knowledge of the natural history of many bird species has a rich basis in literature. In human-altered riparian areas, bird monitoring can be a valuable tool for assessing changes in habitat quality incurred from restoration efforts, river diversion and channelization projects, water impoundment, and flooding events.

One of the main objectives of studying birds in Poopenaut Valley is to gain a better understanding of how altered hydrology below O'Shaughnessy Dam affects breeding birds. We began investigations in 2007 by completing a California Wildlife Habitat Relationships model that predicts occurrence of vertebrate species (amphibians, reptiles, birds, and mammals) between O'Shaughnessy Dam and the park boundary and in Poopenaut Valley (National Park Service, 2009). Also in 2007, we began ground-truthing the model by conducting area search surveys with the goal of characterizing the breeding bird community in Poopenaut Valley (National Park Service, 2009, 2010, 2012a, 2012b, 2014, 2015, 2016).

Since 2007, we have continued to augment our survey methods in order to delve deeper into the breeding ecology of the bird community in Poopenaut Valley. Besides area searches we perform point count surveys, spot map surveys, nest monitoring, and color band birds. The information gathered through these survey techniques further inform recommendations on timing water releases from O'Shaughnessy Dam in order to benefit breeding birds.

We have focused our studies on four species that commonly breed in Poopenaut Valley which were identified as Riparian Focal Species by The Riparian Bird Conservation Plan (RHJV, 2004): Warbling Vireo (*Vireo gilvus*), Yellow Warbler (*Setophaga petechia*), Song Sparrow (*Melospiza melodia*), and Black-headed Grosbeak (*Pheucticus melanocephalus*). We also considered Western Wood-Pewee (*Contopus sordidulus*), which commonly breeds in the riparian habitat in Poopenaut Valley (Table 4-1). These species play a central role in our goal to relate seasonal population trends of breeding birds in Poopenaut Valley to water availability. Additionally, Yellow Warblers are listed as a California Species of Special Concern; and Song Sparrows typically nest in the lowest vegetation strata, so their nests may be more vulnerable to flooding.

Drawing on eleven years of data from bird surveys in Poopenaut Valley, we have the 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 on a longer time scale. We hope to identify which characteristics of the Tuolumne River flood regime are most important to bird abundance and diversity downstream of Hetch Hetchy Reservoir. Additionally, we are able to compare data from identical surveys in similar habitat between 2011 and 2017 in Yosemite Valley (along the unregulated Merced River) to our Poopenaut Valley data. The comparison of point count surveys in Poopenaut Valley versus Yosemite Valley allows us to use the unregulated Merced River as a reference site to inform better what trends in bird communities might be attributed to regulated hydrology rather than other environmental factors.

In addition to the ongoing influence of river regulation, two additional disturbances, fire and drought, 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. Precipitation levels well below average occurred in consecutive years between 2012 and 2015, which resulted in drought conditions. Both of these disturbances 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.

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

4.2.1 Field Methods

Area Search Surveys

In 2017, we completed the eleventh year of standardized area search surveys (2007–2017) and the tenth year of standardized point count surveys (2008–2017) in Poopenaut Valley with the goal of estimating bird species abundance, community composition, and habitat use in wet meadow and montane riparian habitats. We conducted area searches and point counts between 15 May and 30 June between dawn and 10 a.m. Surveys were ideally conducted three separate times each season, with visits occurring at least ten days apart. In 2017, area search surveys took place on 18 May, 1 June, and 29 June. Typically, 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). However, high water resulting from historic snowfall over the 2016-2017 winter precluded access to the study area north of the Tuolumne River in 2017.

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 (i.e., territorial displays, courtship, copulation, nest building, food or fecal sac carries, and the presence of dependent young). The sampling sequence was rotated each visit to avoid bias due to temporal changes in bird activity. We did not conduct area searches during adverse weather, such as high winds or rain, when probability of detection and bird activity would be reduced.

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

Point Count Surveys

In Poopenaut Valley, we conducted point count surveys at two established points situated on opposite sides of the Tuolumne River (Figure 4-1). 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). We selected these points so that point count surveys would sample a similar area as the area searches; and provide complementary data that could be compared more directly with point count survey data from points with similar habitat characteristics surveyed within Yosemite Valley between 2012 and 2017 (Figure 4-2). This allows us to use the Merced River in Yosemite Valley as a reference site to understand better what trends in bird communities might be attributed to regulated hydrology rather than other environmental factors. Similar to area searches, we visit point count locations in Poopenaut Valley and Yosemite Valley three times each season, although high flows did not allow for surveys to be completed at the northern Poopenaut Valley point during the 2017 season.

In Poopenaut Valley, we used standardized variable circular plot (VCP) point count protocols established by Ralph et al. (1993). At each visit to a survey point in Poopenaut Valley, we counted birds for five minutes. For each observed bird, we recorded the method of detection, the distance to where the bird was first detected, and any indications of breeding status. Surveys took place between 15 May and 30 June, and were conducted at least 10 days apart. 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 collected data following the point count protocol used to conduct park-wide bird surveys as part of the Sierra Nevada Network (SIEN) bird-monitoring program (Siegel et al., 2010). This protocol is designed to be analytically compatible with the VCP and other point count protocols. SIEN point counts lasted seven minutes, split into three separate intervals (one three-minute interval followed by two two-minute intervals). For consistency, we only considered detections from the first 5 minutes of the Yosemite Valley counts.

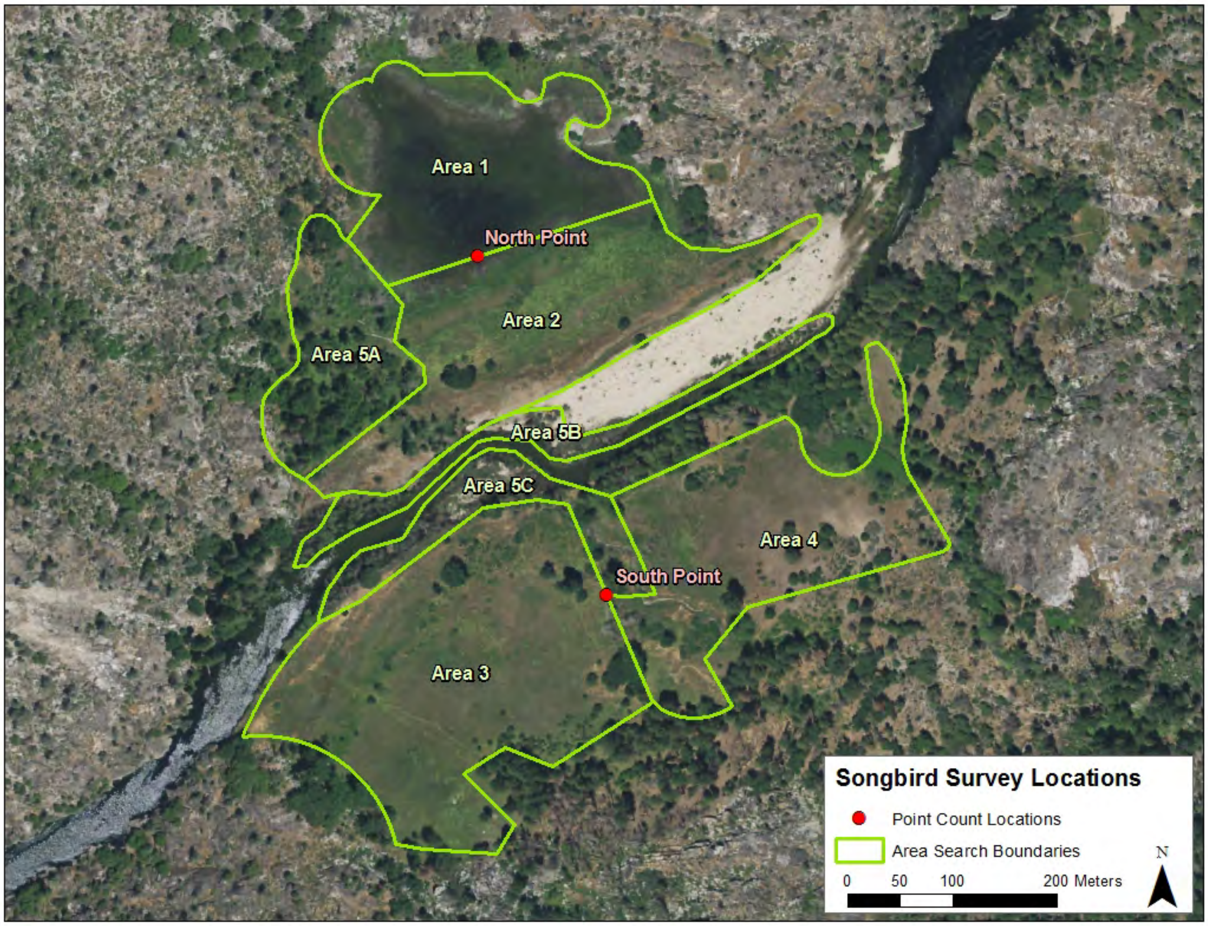


Figure 4-1. Area search and point count locations in Poopenaut Valley.

Figure 4-2. Point count locations in Yosemite Valley that serve as a control for Poopenaut Valley.

Spot Mapping

In 2010, we began spot map surveys of the riparian focal species utilizing the previously established avian search areas in Poopenaut Valley (Figure 4-1) to infer general location and number of bird territories. In 2013, we started color-banding birds to more accurately delineate territories. We adapted spot mapping methods from the standardized spot mapping protocol described by Bibby et al. (1992) and Ralph et al. (1993). We conducted spot mapping surveys between dawn and 10 am while birds were most active. The observer walked an area slowly, taking 40 to 90 minutes to completely survey a plot, 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, noted if males were singing, recorded any and all territorial behavior including chasing or counter-singing, mapped flights with arrows to indicate flight distance and direction, and recorded the presence of dependent young. Occasionally, we supplemented these formal surveys with observations collected incidentally while performing targeted nest searches or other fieldwork on plots, however, we did not enter observations from supplemental surveys into our GIS database and did not include them in analyses since the methods and effort deviated from the spot map protocol. We referenced this supplemental data if there was ambiguity over the location of the boundary of a territory. At the end of the field season, we compiled our spot mapping data on our five focal species and entered it into an ArcGIS geodatabase. We used our digitized location and territorial behavior data to determine the number of territories, and their approximate locations.

In previous years, we used kernel density estimation as a “visual guide” to draw minimum convex polygons and determine the size and location of breeding territories of our riparian focal species. Kernel density analysis assumes random selection of observations in space to determine territory location, and by proxy, habitat use. Our observations are temporally auto-correlated because we follow individual birds during spot mapping sessions, if only for a short time, to collect behavioral data. A stratified-random sample of 30-50 locations during the activity period of interest best balances bias and variance in the locations, resulting in better estimates of territory size (Seaman et al 1999). We are only able to collect six to eight independent locations on each individual each breeding season, and we collect habitat use data between sunrise and 10 am. Because of these methodological constraints, results from previous years should not be used for fine scale habitat use or territory size analyses, though this is commonly the goal of kernel density analyses. Despite these limitations, some avian surveyors in previous years found that kernel density rasters had value as “visual guides” to infer the number of territories, and therefore breeding density. In 2017 we returned to spot mapping guidelines outlined in Ralph et al. (1993), adapted for our study. We drew territories based solely on spot mapping data, and did not use kernel density rasters or minimum convex polygons.

Breeding Birds

We used behavioral information collected from surveys in Poopenaut Valley, as well as incidental observations, to produce a list of confirmed, probable, and possible breeding bird species for each area modified from Breeding Bird Survey criteria (Sauer et al., 2005). ‘Possible breeders’ are birds that are seen or heard at the site during the breeding season. ‘Probable breeders’ are indicated by one or more of the following: more than one singing male in the study area; a male singing during three visits within a month during the breeding season; a pair (male and female) observed together; territorial behavior; courtship behavior; copulation; or visiting a probable nest site during the breeding season. A ‘confirmed breeder’ is indicated by one or more of the following: breeding condition at banding, carrying nesting material, building a nest, downy or recently fledged young present, adult carrying food for young or a fecal sac from the nest a nest with the adults incubating, or a nest with eggs or young.

Target Netting

Beginning in 2012, we 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. Netting efforts were focused on four of the five target species (Black-headed Grosbeak, Song Sparrow, Warbling Vireo, and Yellow Warbler), and data were collected from any birds captured incidentally. During the 2016 and 2017 seasons, we increased capture efforts and sampled blood, feathers, and feces for a trophic dynamics study (see Chapter 5).

We typically initiated netting efforts at dawn and continued for up to six hours after sunrise while birds were 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. We played vocalizations of the target species on portable speakers placed below the net to 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. We obtained all recordings from www.xeno-canto.org. 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. We collected the following data from all birds captured:

- capture code (newly banded, recaptured, band changed, unbanded)
- band number
- species
- age and how aged
- sex (if possible) and how sexed (if applicable)
- extent of skull pneumaticization
- breeding condition of adults (i.e., extent of cloacal protuberance or brood patch)
- extent of juvenal plumage in young birds
- extent of body and flight-feather molt
- extent of primary-feather wear
- presence of molt limits and plumage characteristics
- wing chord
- fat class and body mass
- date and time of capture
- station and net site where captured
- What tissue samples were collected, if any
- any pertinent notes

We collected all banding data under Permit Number 22423, administered by The Institute for Bird Populations. In accordance with the permitting requirements, Institute for Bird Populations will send all electronically entered and proofed banding data to the USGS Bird Banding Laboratory at the Patuxent Wildlife Research Center, thereby contributing to a national long-term monitoring effort of birds.

Nest Search Surveys

Since 2010, we have conducted nest search surveys simultaneously with spot map surveys, and used a standardized nest searching protocol (Martin & Geupel, 1993) as a general guide. We also performed targeted nest searching sessions outside of spot mapping sessions in the afternoon and early evening. Birds exhibiting probable or confirmed breeding activity such as foraging in pairs, carrying nesting material, or carrying food were followed as closely as possible in order to find their nests. For each nest, we recorded the nest location using a Global Positioning System unit and recorded information about the status and location of the nest onto a nest card. During every subsequent site visit, we checked nests and recorded the observed nesting activity onto the nest card. At the end of the season, we transferred information from nest cards into a nest record database and coded the fate of each nest.

Tissue Sampling

To complement our long-term breeding bird study, we continued a study component examining the food web architecture leading to songbirds, which began in the spring of 2016. We captured birds in Poopenaut Valley on 19 May, and 2 June 2017. We also captured birds in Yosemite Valley on 12 June at a site containing similar habitat as Poopenaut Valley, located north of the Merced River (south of Northside Drive), east of Housekeeping Camp. During each mist-netting effort, we deployed at least three nets and used playbacks to attract target birds. For each captured bird, we recorded species, applied a uniquely numbered band, recorded physical attributes (see “Target Netting” above), and collected blood (50 uL) and feather samples. We collected feces opportunistically from the capture bag after removing the bird. We sampled blood according to protocols described in Owen (2011). We drew blood from the brachial vein located on the ventral side humeral-radial-ulnar joint. We punctured the vein using a 26 ga beveled syringe needle and collected the blood 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).

We stored blood samples in 70% ethanol solution, feathers in envelopes, and feces in microcentrifuge tubes with silica beads as a desiccant. Although we focused on trapping and sampling 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 we captured an individual of one of the focal species more than once, we would take tissue samples each time if captures were more than 10 days apart.

Sample processing and stable-isotope analysis – We freeze-dried blood and feather samples from birds in the laboratory. We then packed a small amount of each composite sample into tin capsules. See Chapter 5 for methods describing the processing of algae and detritus. Also, see Chapter 5 for methods describing stable-isotope analysis and continuous flow isotope-ratio mass spectrometry (EA-IRMS).

4.2.2 Analytic 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. We chose these metrics as they are commonly used to describe varying aspects of avian community composition in the literature. We define relative abundance as the average number of individuals observed over all surveys in a year at a survey location. We define species richness as the average number of species observed over all surveys in a year at a survey location.

When investigating annual trends relating to river regulation, we opted to only consider search areas and point count locations that were consistently accessible each year during all water conditions: Search Areas 3 and 4 and the southern point count location.

In addition to assessing hydrologic variables, we also assessed whether relative abundance, abundance of riparian species, and species richness changed after the Rim Fire in Poopenaut Valley and Yosemite Valley using two-sided t-tests. For this analysis, we used data from both the Poopenaut north and south point count locations (Figure 4-1).

Food web component

We used the two-source food-web model from Post (2002) to estimate bird trophic position; $TP = \lambda + \{ \delta c – [\delta b1 * \alpha + \delta b2 * (1-\alpha)]\}/ \Delta n$ where λ is the trophic position of the basal food sources (i.e., 1 for primary producers); δc is the δ15N signature of the consumer; $\delta b1$ and $\delta b2$ are the signatures of the two basal food sources; α is the proportion of N from basal food source 1; and Δn is the enrichment in δ15N per trophic level (i.e., 3.4‰; Post, 2002). We used a two-end member Bayesian isotopic mixing model to determine the proportion of N derived from basal source 1 (i.e., α) with the R software package SIAR (Stable Isotope Analysis in R; Parnell and Jackson 2013). SIAR is equipped to handle variability in sources, consumers, and trophic fractionation factors (Parnell et al., 2010).

Epilithic algae and detritus were the basal food source end members. To estimate the contribution from each food source to the consumer (i.e. bird), we used δ13C and δ15N data.

We estimated trophic fractionation factors for birds using the per trophic step fractionation in Post (2002) (i.e., 3.4‰ ± 0.98‰ for δ15N and 0.39‰ ± 1.3‰ for δ13C) multiplied by the estimated number of trophic transfers between the consumer and basal resources (estimated a priori as the difference between the consumer δ15N and mean basal resource δ15N divided by 3.4‰), which is consistent with other aquatic food-web investigations (e.g., McHugh et al. 2010, Sullivan et al. 2015). However, it is important to note that some recent studies have either questioned the use of a single, fixed enrichment factor (Caut et al. 2009, Hussey et al. 2014) or suggested that 3.4‰ overestimates the per trophic level 15N enrichment for certain consumers (Vanderklift and Ponsard 2003).

We used t-tests to test for differences in reliance on aquatic-terrestrial nutritional subsidies and trophic position of birds sampled in Yosemite Valley and Poopenaut study locations. In addition, we used linear regression to assess correlations between paired blood and feather samples collected from birds and to examine the relationship between trophic position and reliance on an aquatic-energetic pathway.

4.3 Results

During the 2017 season, we observed 58 bird species in Poopenaut Valley. We directly confirmed 15 breeding species, 17 probable breeding species, 20 possible breeding species, and 5 unlikely breeding species. A cumulative record of breeding birds covering 2007 through 2017 is presented in Table 4-2.

Table 4-2. List of 119 bird species detected in Poopenaut Valley in Yosemite National Park, April-July, 2001-2017 by the following methods: area search (AS), point count (PC), spot map (SM), nest search (NS), mist netting (MN), incidental observations (I), or not recorded (NR). Breeding status for each species is reported as unlikely, possible, probable, and confirmed (see National Park Service, 2007). 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. Species detected in 2017 are in bold.

Common Name	Scientific Name	Unlikely	Possible	Probable	Confirmed	Survey Type
	Accipiter sp.	X				I
Acorn Woodpecker	*Melanerpes formicivorus*				T, ON, CF	SM, AS, PC
American Coot	*Fulica americana*				F	NR
American Crow	*Corvus brachyrhynchos*	X				SM
American Dipper	*Cinclus mexicanus*				CF, F	SM, I
American Kestrel	*Falco sparverius*	X				NR
American Robin	*Turdus migratorius*				S, T, CN, CF, ON, BC, F	SM, AS, PC, MN
Anna's Hummingbird	*Calypte anna*				T, CN	SM, AS, PC
Ash-throated Flycatcher	*Myiarchus cinerascens*		X			SM, AS
Bald Eagle	*Haliaeetus leucocephalus*	X				SM
Band-tailed Pigeon	*Patagioenas fasciata*		X			SM, AS
Belted Kingfisher	*Megaceryle alcyon*				CN, CF	SM, AS, FC
Bewick's Wren	*Thryomanes bewickii*			S		SM, AS
Black Phoebe	*Sayornis nigricans*				ON, CF, F	SM, AS, PC
Black-headed Grosbeak	*Pheucticus melanocephalus*				S, T, P, CF, CN, F, ON, BC	SM, AS, PC, MN
Black-throated Gray Warbler	*Setophaga nigrescens*			S, T, P		SM, AS
Blue-gray Gnatcatcher	*Polioptila caerulea*				ON	SM, AS
Brewer's Blackbird	*Euphagus cyanocephalus*				S, CN, CF, F	NR
Brown Creeper	*Certhia americana*				S, ON, CF	SM, AS, PC

Common Name	Scientific Name	Unlikely	Possible	Probable	Confirmed	Survey Type
Brown-headed Cowbird	*Molothrus ater*				F	SM, AS, PC
Bufflehead	*Bucephala albeola*	X				SM
Bullock's Oriole	*Icterus bullockii*				CN, CF F, ON	SM, AS, PC
Bushtit	*Psaltriparus minimus*				S, ON	SM, AS
California Scrub-Jay	*Aphelocoma californica*				T, P, FC, F	SM, AS, PC
California Towhee	*Melozone crissalis*			S, P		SM, AS
Calliope Hummingbird	*Selasphorus calliope*			T, P		AS
Canada Goose	*Branta canadensis*			S, P		SM
Canyon Wren	*Catherpes mexicanus*				S, T, P, F, CN	SM, AS, PC
Cassin's Finch	*Haemorhous cassinii*	X				SM
Cassin's Vireo	*Vireo cassinii*				S, T, P, ON, BC, CF, F	SM, AS, PC
Cedar Waxwing	*Bombycilla cedrorum*	X				AS
Chipping Sparrow	*Spizella passerina*				S, T, P, CN	SM, AS, PC
Cliff Swallow	*Petrochelidon pyrrhonota*	X				SM, I
Common Merganser	*Mergus merganser*				F	SM, AS, PC
Common Nighthawk	*Chordeiles minor*	X				NR
Common Poorwill	*Phalaenoptilus nuttallii*		S			I
Common Raven	*Corvus corax*				F	NR
Common Yellowthroat	*Geothlypis trichas*	X				SM
Dark-eyed Junco	*Junco hyemalis*			S, P		SM, AS
Downy Woodpecker	*Picoides pubescens*				ON, F	SM, AS
Dusky Flycatcher	*Empidonax oberholseri*			S, P		SM, AS, PC
Eagle sp.		X				I
Eared Grebe	*Podiceps nigricollis*	X				
Eurasian Collared-Dove	*Streptopelia decaocto*	X				I
European Starling	*Sturnus vulgaris*	X				I
Evening Grosbeak	*Coccothraustes vespertinus*	X				AS
Fox Sparrow	*Passerella iliaca*	X				I
Golden Eagle	*Aquila chrysaetos*	X				
Golden-crowned Kinglet	*Regulus satrapa*			S		SM

Common Name	Scientific Name	Unlikely	Possible	Probable	Confirmed	Survey Type
Golden-crowned Sparrow	*Zonotrichia atricapilla*	X				I
Gray Flycatcher	*Empidonax wrightii*	X				SM, AS, PC
Great Egret	*Ardea alba*	X				SM
Great Horned Owl	*Bubo virginianus*	X				I
Green-tailed Towhee	*Pipilo chlorurus*	X				I
Hairy Woodpecker	*Picoides villosus*				CF, D	SM, AS, PC
Hammond's Flycatcher	*Empidonax hammondii*			S		SM
Hermit Warbler	*Setophaga occidentalis*	X				SM
House Wren	*Troglodytes aedon*				S, T, P, ON, BC, CF, F	SM, AS, PC, MN
Hutton's Vireo	*Vireo huttoni*			S		AS
Indigo Bunting	*Passerina cyanea*	X				NS
Lark Sparrow	*Chondestes grammacus*	X				SM
Lawrence’s Goldfinch	*Spinus lawrencei*				P, F, ON	NS, I
Lazuli Bunting	*Passerina amoena*				S, T, P, ON	SM, AS, PC
Lesser Goldfinch	*Spinus psaltria*				S, P, ON	SM, AS, PC
Lincoln's Sparrow	*Melospiza lincolnii*				CN	PC, AS
MacGillivray's Warbler	*Geothlypis tolmiei*			S, P		SM, PC, AS
Mallard	*Anas platyrhynchos*				P, F, ON	SM, AS, PC
Marsh Wren	*Cistothorus palustris*	X				SM
Mountain Chickadee	*Poecile gambeli*			S		SM
Mountain Quail	*Oreortyx pictus*				ON, S	SM, AS, PC, NS, I
Mourning Dove	*Zenaida macroura*				P, ON	SM, AS
Nashville Warbler	*Oreothlypis ruficapilla*				S, T, P, CF, F	SM, AS, PC
Northern Flicker	*Colaptes auratus*				D, CF, ON, F	SM, AS, PC
Northern Pygmy-Owl	*Glaucidium gnoma*				F	NS
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*				CN, ON	SM, AS, PC
Northern Saw-whet Owl	*Aegolius acadicus*		X			I
Nuttall's Woodpecker	*Picoides nuttallii*			D, S		SM, AS
Oak Titmouse	*Baeolophus inornatus*		X			SM, PC
Olive-sided Flycatcher	*Contopus cooperi*	X				I

Common Name	Scientific Name	Unlikely	Possible	Probable	Confirmed	Survey Type
Orange-crowned Warbler	*Oreothlypis celata*			S, F		SM, PC, MN
Osprey	*Pandion haliaetus*		X			SM
Ovenbird	*Seiurus aurocapilla*	X				I
Pacific Wren	*Troglodytes pacificus*		X			I
Pacific-slope Flycatcher	*Empidonax difficilis*			S		SM, AS
Painted Redstart	*Myioborus pictus*	X				I
Pied-billed Grebe	*Podilymbus podiceps*	X				NR
Pileated Woodpecker	*Dryocopus pileatus*			X		I
Pine Siskin	*Spinus pinus*				BC	SM, AS, NR
Purple Finch	*Haemorhous purpureus*				S, P, CN	SM, AS, PC
Red-breasted Nuthatch	*Sitta canadensis*			S		SM, AS, PC
Red-tailed Hawk	*Buteo jamaicensis*	X				I
Red-winged Blackbird	*Agelaius phoeniceus*				S, CN, F	SM, AS, PC
Ruby-crowned Kinglet	*Regulus calendula*	X				SM
Savannah Sparrow	*Passerculus sandwichensis*	X				SM, AS
Song Sparrow	*Melospiza melodia*				S, T, P, C, CN, CF, F, ON, BC	SM, AS, PC, MN
Spotted Owl	*Strix occidentalis*				S, P, F	I
Spotted Sandpiper	*Actitis macularius*			T, P		SM, AS
Spotted Towhee	*Pipilo maculatus*				S, P, CF, F, ON, BC	SM, AS, PC, MN
Steller's Jay	*Cyanocitta stelleri*			T, P, F		SM, AS, PC
Swainson’s Thrush	*Catharus ustulatus*	X				I
Townsend's Warbler	*Setophaga townsendi*	X				SM
Tree Swallow	*Tachycineta bicolor*		X			SM
Vaux’s Swift	*Chaetura vauxi*	X				I
Violet-green Swallow	*Tachycineta thalassina*				F	SM, AS, PC
Virginia Rail	*Rallus limicola*		X			SM
Warbling Vireo	*Vireo gilvus*				S, T, P, CN, CF, F, ON, BC	SM, AS, PC, MN
Western Bluebird	*Sialia mexicana*		X			SM

Common Name	**Scientific Name**	**Unlikely**	**Possible**	**Probable**	**Confirmed**	**Survey Type**
Western Kingbird	*Tyrannus verticalis*	X				SM
Western Meadowlark	*Sturnella neglecta*	X				I
Western Tanager	*Piranga ludoviciana*				CN, S, T, P	SM, AS, PC
Western Wood-Pewee	*Contopus sordidulus*				S, P, CN, ON, BC, F	SM, AS, PC, MN
White-breasted Nuthatch	*Sitta carolinensis*	X				PC
White-crowned Sparrow	*Zonotrichia leucophrys*	X				AS
White-faced Ibis	*Plegadis chihi*	X				NR
White-headed Woodpecker	*Picoides albolarvatus*		D			PC
White-throated Swift	*Aeronautes saxatalis*			S, P, C		SM, AS, PC
Wilson's Warbler	*Cardellina pusilla*		X			SM, AS
Wood Duck	*Aix sponsa*			P		SM
Wrentit	*Chamaea fasciata*			S		SM, AS, PC
Yellow Warbler	*Setophaga petechia*				S, T, P, C, CN, CF, F ON, BC	SM, AS, PC, MN
Yellow-breasted Chat	*Icteria virens*		S			SM, AS, PC
Yellow-rumped Warbler	*Setophaga coronata*			S		SM, AS, PC
Total (including 2 unidentified species) : 119		**41**	**10**	**23**	**45**	

Area Search Results

During the 2017 area search surveys we recorded a cumulative total of 236 individuals of 32 species. During each area search, an average of 26.2 birds belonging to 12.3 species was detected within a search area. Because high flows in the Tuolumne River through the entirety of the breeding season precluded access to the northern survey areas, we sampled Areas 3, 4 and 5C three times, and none of the others in 2017. Across the sampled sites, the five most common birds based on relative abundance were Red-winged Blackbird, Mallard, Black-headed Grosbeak, Western Wood-Pewee, and Song Sparrow (Table 4-3). Focal species abundance averaged across the sampled sites was 8.6 individuals per area, per survey during the 2017 breeding season.

We collated area search results over the history of the project in areas 3 and 4 (the only areas surveyed in all years; Figure 4-1). In 2017, relative abundance was 28.2 individuals on average per survey, relative abundance of riparian focal species was 9 individuals on average per survey, and species richness was 12.7 species on average per survey (Table 4-4).

Table 4-3. Relative abundance of the five most commonly detected species during area search surveys in 2017 in Poopenaut Valley.

Common Name	Scientific Name	Relative Abundance
Red-winged Blackbird	*Agelaius phoeniceus*	3.3
Mallard	*Anas platyrhynchos*	2.8
Black-headed Grosbeak	*Pheucticus melanocephalus*	2.6
Western Wood-Pewee	*Contopus sordidulus*	2.6
Song Sparrow	*Melospiza melodia*	1.8

Table 4-4. Species richness, relative abundance, and riparian focal species relative abundance in search areas 3 and 4 over the history of the study (2007-2017) in Poopenaut Valley.

Year	Species Richness	Relative Abundance	Riparian Relative Abundance
2007	9.7	18.3	4.4
2008	8.7	13.8	3.3
2009	14.0	20.8	5.8
2010	11.4	20.1	7.3
2011	15.2	29.3	10.0
2012	15.5	23.3	5.5
2013	15.2	25.2	6.8
2014	7.8	12.8	4.3
2015	4.7	6.5	3.5
2016	12.3	19.1	6.3
2017	12.7	28.2	9.0
Mean	11.5	19.8	6.0

Point Count Results

During point count surveys conducted in 2017, we recorded a cumulative total of 66 individual birds of 20 different species. During each point count, we detected an average of 22 birds of 11.7 species. Due to high river stage on the Tuolumne River preventing access to the north side of the survey area, we were unable to sample the north point, and sampled the south point three times. The five most common birds based on relative abundance were Red-winged Blackbird, Steller's Jay, Western Wood-Pewee, Song Sparrow, and Black-headed Grosbeak. One of these species, Steller's Jay, is an upland species less prevalent during area searches with clear, loud vocalizations that carry well (Table 4-5).

We collated point count results over the history of the project at the South Point (the only point surveyed in all years; Figure 4-1). In 2017, relative abundance was 22 individuals on average per survey, riparian relative abundance was 8.7 individuals on average per survey, and species richness was 11.7 species on average per survey (Table 4-6).

Table 4-5. Relative abundance of the five most commonly detected species during 2017 point count surveys in Poopenaut Valley.

Common Name	Scientific Name	Relative Abundance
Red-winged Blackbird	*Agelaius phoeniceus*	3.3
Steller's Jay	*Cyanocitta stelleri*	2.3
Western Wood-Pewee	*Contopus sordidulus*	2.3
Song Sparrow	*Melospiza melodia*	2.0
Black-headed Grosbeak	*Pheucticus melanocephalus*	1.7

Table 4-6. Species richness, relative abundance, and riparian focal species relative abundance at the southern point count location over the history of the study (2008-2017) in Poopenaut Valley.

Year	Species Richness	Relative Abundance	Riparian Relative Abundance
2008	12.7	21.3	7.3
2009	15.0	23.7	9.7
2010	12.3	22.0	7.0
2011	15.7	27.0	10.7
2012	12.3	16.0	5.3
2013	15.7	25.0	7.7
2014	12.0	16.0	4.7
2015	12.8	19.3	5.3
2016	13.8	20.0	6.3
2017	11.7	22.0	8.7
Mean	13.4	21.2	7.3

In Yosemite Valley, we detected 3,184 individuals belonging to 76 species while conducting point counts at our ten control points between 2011 and 2017.

We noted a reduction in overall relative abundance and the relative abundance of riparian focal species post-Rim Fire in Poopenaut Valley (25.22±7.42 pre versus 18.21±2.46 post, and 8.03±2.48 pre versus 5.33±1.86 post, respectively), but not in Yosemite Valley. We did not observe a reduction in species richness in either Poopenaut or Yosemite Valley post-Rim Fire (Table 4-7; Figure 4-3).

Table 4-7. Test statistics from two-sided t-tests investigating avian community composition in Poopenaut and Yosemite Valleys pre- and post- Rim Fire. The null hypothesis is that the mean of the metric of interest is the same before and after the Rim Fire.

		$\Delta \bar{x}$	**df**	**t**	***p***
Poopenaut Valley	Species Richness	1.4	15	2.0	0.0595
	Relative Abundance	7.0	12	2.8	0.0172 *
	Riparian Abundance	2.7	15	2.4	0.0277 *
Yosemite Valley	Species Richness	0.16	64	0.4	0.700
	Relative Abundance	1.4	35	1.6	0.130
	Riparian Abundance	0.70	36	1.4	0.167

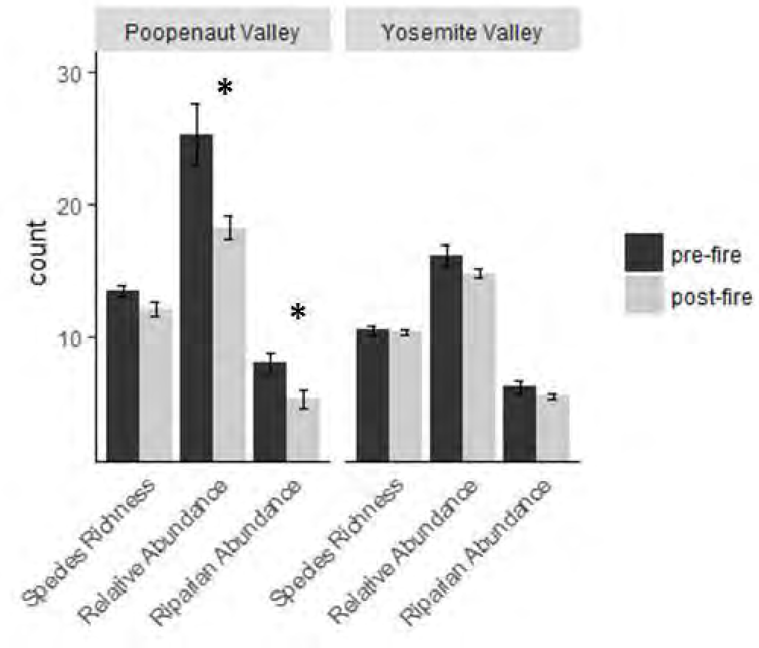


Figure 4-3. Comparison of avian community composition metrics in Poopenaut and Yosemite Valleys, pre and post Rim Fire. We found support for a difference in overall relative abundance and riparian relative abundance in Poopenaut Valley pre and post fire. Error bars are mean ± standard error.

Spot Mapping

During the 2017 season, we completed 15 spot map surveys focused on our five riparian focal species. Because high water prevented us from accessing the search areas north of the river, we focused primarily on Areas 3, 4, and the unflooded portions of Area 5 south of the river. In 2017, we mapped Area 3 six times, Area 4 eight times, and Area 5 one time.

We re-sighted seven color-banded birds during the 2017 season. Five of these were color banded in 2017, and the remaining two were banded in 2016 (Table 4-8).

Table 4-8: Color banded birds re-sighted during the 2017 breeding season in Poopenaut Valley.

Species	Colors	Sex	Year Banded
Black-headed Grosbeak	WK/US	M	2016
Black-headed Grosbeak	OK/SO	F	2017
Black-headed Grosbeak	OO/RS	F	2017
Black-headed Grosbeak	KO/SU	M	2017
Song Sparrow	GR/RS	M	2017
Warbling Vireo	KK/RS	F	2017
Warbling Vireo	OW/KS	M	2016

Black-headed Grosbeak

We delineated four territories and monitored four nests belonging to Black-headed Grosbeaks during the 2017 breeding season in Poopenaut Valley (Figure 4-4). Of our five riparian focal species, we concentrated the most nest searching effort on Black-headed Grosbeaks because finding nests facilitates the unambiguous delineation of territories, and historically Black-headed Grosbeak territories have been difficult to delineate (National Park Service, 2016).

We made our first material carry observation of the 2017 breeding season on 18 May. The female OK/SO made multiple trips with lining material to her nest in the northern portion of her territory (Figure 4-4). This nest was active through June 1 (Figure 4-5). On the date of our next visit to Poopenaut Valley on 20 June 2017, this nest had fallen from the small live oak that was supporting it. The adults, OK/SO and WK/US, were not seen attending fledglings, thus this nest failed. We suspected that the pair re-nested in the northeast portion of their territory. We observed the female infrequently on 28 and 29 June, suggesting she was incubating a new nest. We observed the male actively foraging and repeatedly flying to an area that may have contained the new nest; however, we were unable to locate a nest.

We found our second Black-headed Grosbeak nest on 31 May. An unbanded female and banded male, KO/SU, were actively foraging and feeding at least two well developed nestlings in a nest located about two meters above water level in a willow (Figure 4-4). We suspect that this nest fledged, however, the young likely died after fledging. The pair re-nested just south of the first nest in a black oak (Figures 4-4 & 4-6), and while the female was incubating/brooding the new nest on 20 and 28 June the male was out, actively singing from south of the nest, and was never seen foraging in a way that would suggest he was feeding dependent young. We do not know the fate of this second nest, as it was still active on the date of our last visit to Poopenaut Valley during the breeding season on 29 June. However, we suspect that this nest fledged; when on a visit to the valley on 14 July to maintain bat detectors we heard a young Black-headed Grosbeak begging and observed a male bringing food to the area of the begging. We observed this interaction within the bounds of this pair's territory.

We located another Black-headed Grosbeak nest on 31 May approximately 20 meters up in a black oak leaning into the meadow in the southwest portion of the study area. This nest was attended by an unbanded male, and the banded female, OO/RS (Figure 4-4). This nest fledged at least two young. We observed the male actively foraging and repeatedly feeding dependent young on 20 June. We monitored for, and did not detect double brooding in this pair during 2017.

A fourth Black-headed Grosbeak territory was located across the Tuolumne River, in the northern portion of the study area (Figure 4-4). We were unable to visit the north side of the river in 2017 due to high flows from the O'Shaughnessy Dam, thus we do now know if the pair from this territory was banded. We delineated the territory based on counter-singing and a few sightings of the counter-singing male making forays to the south side of the river, and then back again.

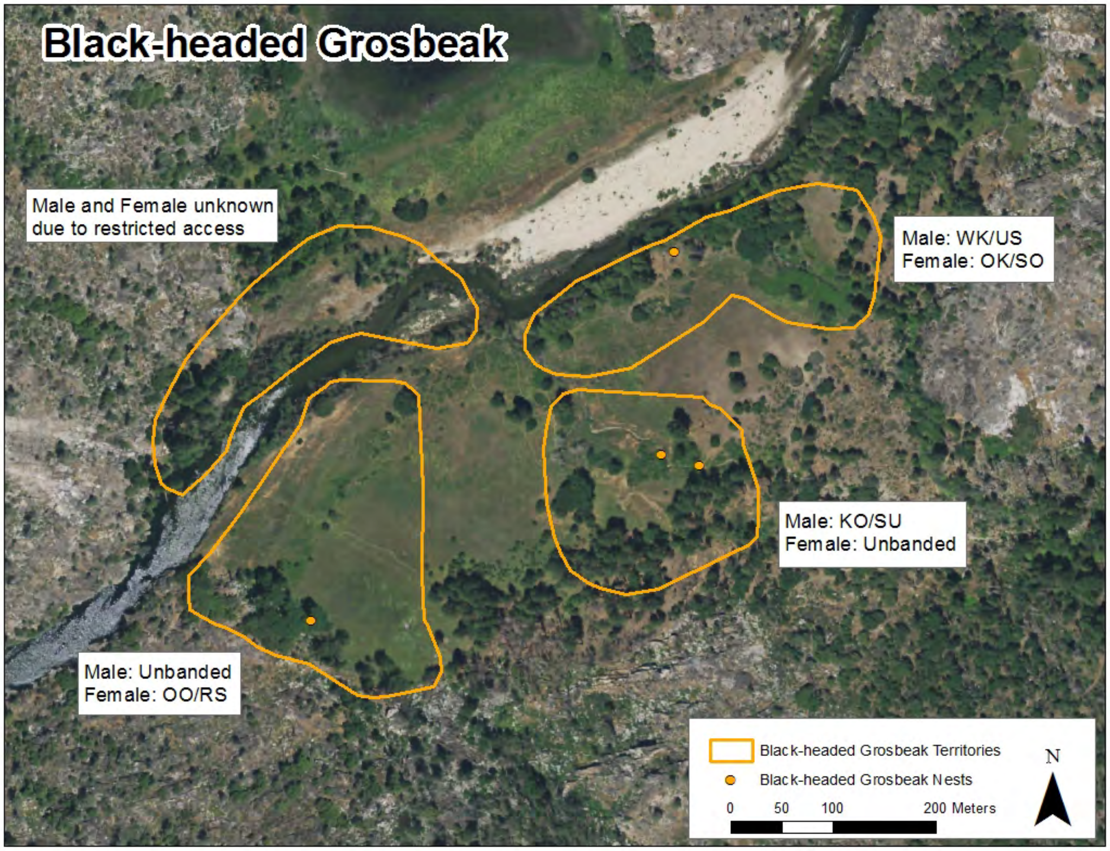


Figure 4-4. Black-headed Grosbeak territories, nests, and color band combinations observed during the 2017 breeding season in Poopenaut Valley.

Figure 4-5. Black-headed Grosbeak female, OK/SO, incubating her first nest of the season on 1 June, 2017.

Figure 4-6. Black-headed Grosbeak nest belonging to an unbanded female and the banded male, KO/SU. This was their second nest of the season. This nest was still active on the last visit of the season to Poopenaut Valley, thus its fate is unknown.

Yellow Warbler

We delineated two Yellow Warbler territories during the 2017 breeding season in Poopenaut Valley (Figure 4-7). We suspect that a third territory may have been located across the river to the north, but we were unable to gather sufficient data on that bird due to the high flows from O'Shaughnessy Dam in 2017.

We did not locate any Yellow Warbler nests during the 2017 breeding season, and in fact, we detected no Yellow Warblers in Poopenaut Valley on our third and fourth visits, June 20-21 and 28-29. This is consistent with Yellow Warbler behavior observed in Poopenaut Valley in 2015, when no individuals were detected after 23 June (National Park Service, 2016).

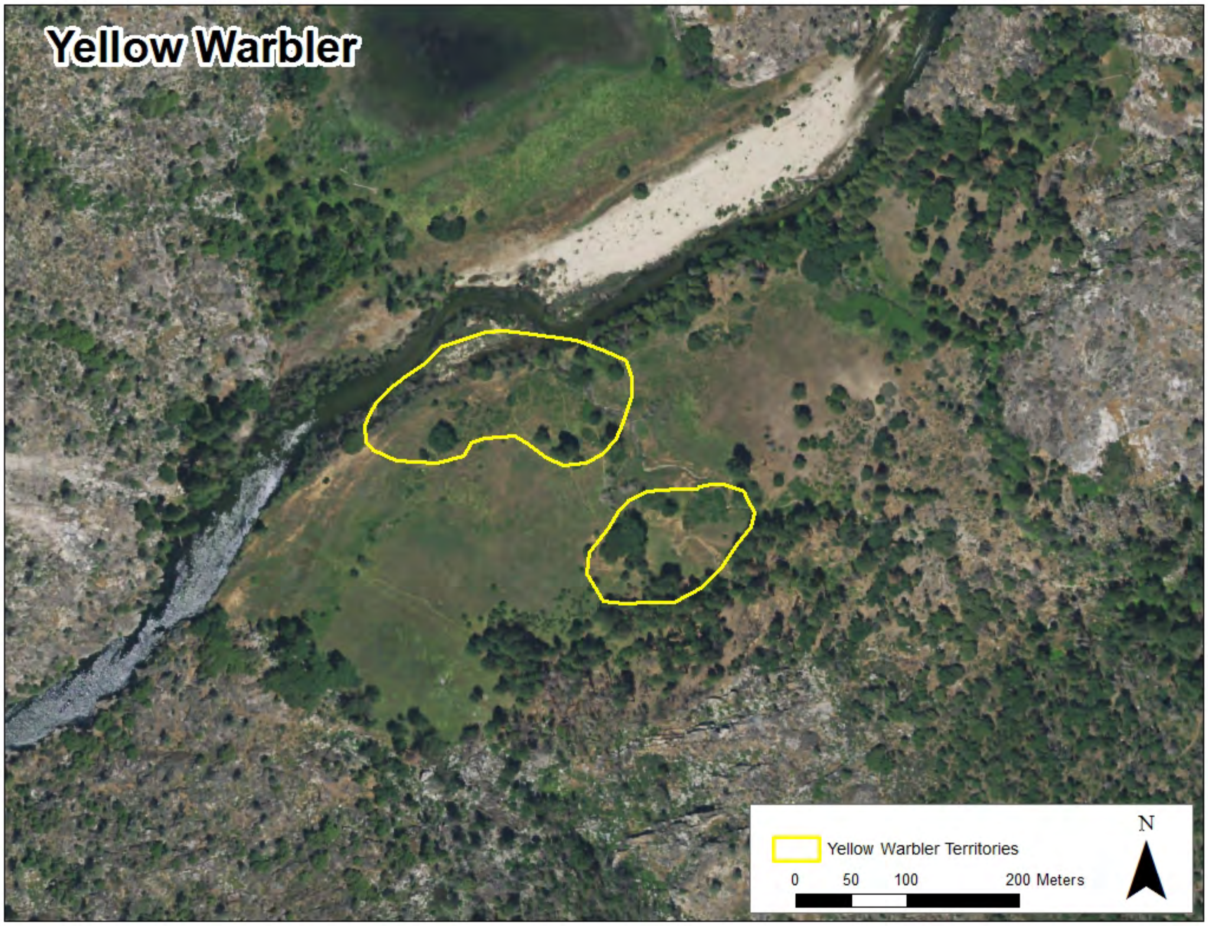


Figure 4-7. Yellow Warbler territories observed during the 2017 breeding season in Poopenaut Valley.

Warbling Vireo

We delineated six territories and monitored one nest belonging to Warbling Vireos during the 2017 breeding season in Poopenaut Valley (Figure 4-8).

We color banded six Warbling Vireos during target netting sessions on 19 May and 2 June. Three of these birds, OS/KR, RY/OS and KR/RS were determined to be breeding territory holders based on the presence of a cloacal protuberance at capture (Appendix E).

The banded female KK/RS was seen gathering material and being followed closely by her unbanded mate on 20 June. We did not locate the nest on that day, as she had just started building and the nest was not visible yet. On the following visit on 27 June the female was incubating a nest approximately 13 meters up in a black oak on the south bank of the Tuolumne River. The fate of this nest is unknown as it was still active when we ended monitoring for the season. Also on 27 June, we observed a banded male, OW/KS, feeding at least two fledglings in the southeast portion of the study area (Figure 4-8). We did not observe a female.

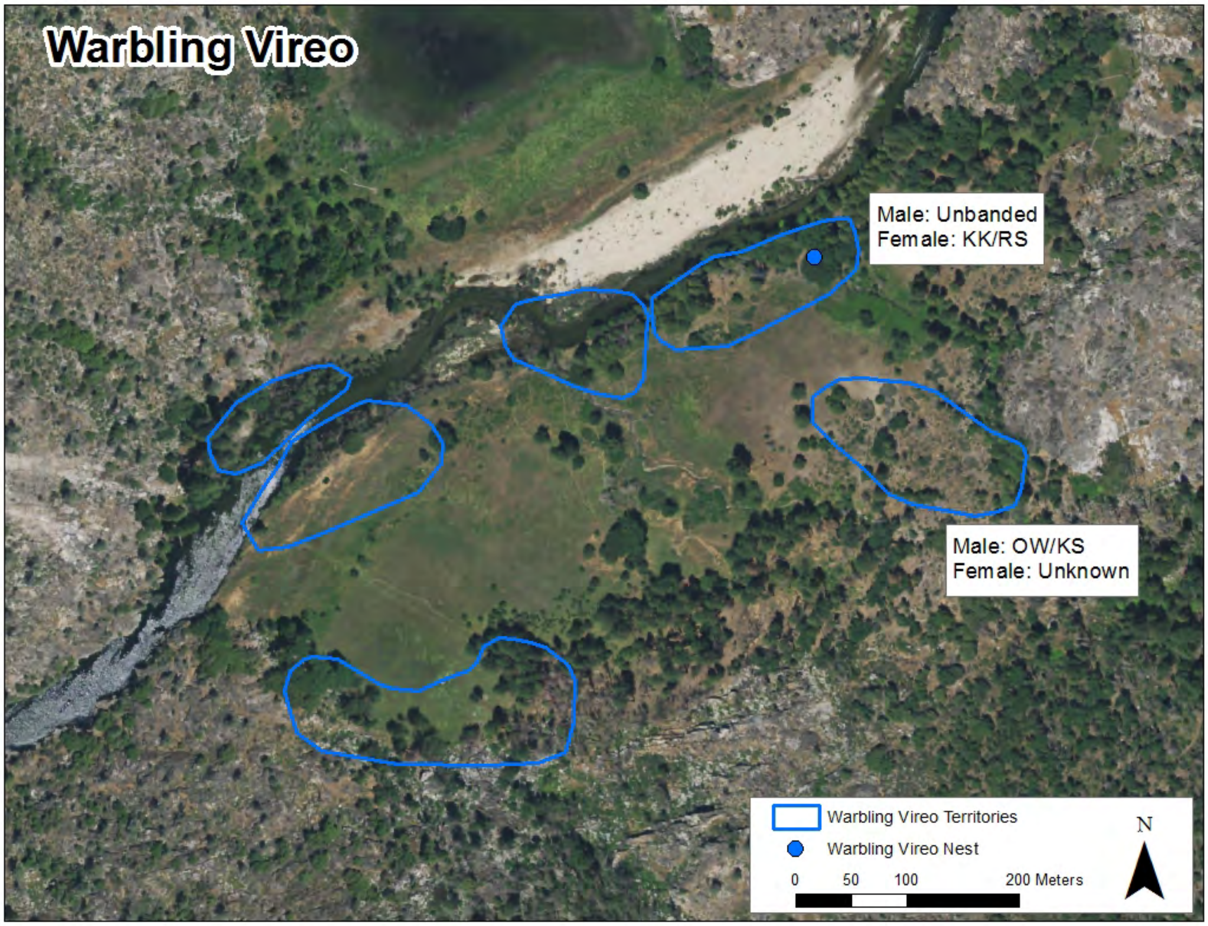


Figure 4-8. Warbling Vireo territories, nests, and color band combinations observed during the 2017 breeding season in Poopenaut Valley.

<u>Song Sparrow</u>

We delineated five territories belonging to Song Sparrows during the 2017 breeding season in Poopenaut Valley (Figure 4-9).

We color banded one adult female and two adult male Song Sparrows in 2017. We determined that these birds were territorial based on the observation of breeding condition (cloacal protuberance or brood patch) at capture (Appendix E). We observed a group of fledglings with an unbanded, singing territorial male on 28 June in the area of GR/RS's territory. It is not uncommon for territory boundaries to break down once nests have fledged and the breeding season is nearly complete, as we noted in this instance.

Figure 4-9. Song Sparrow territories and color band combinations observed during the 2017 breeding season in Poopenaut Valley.

Western Wood-Pewee

We delineated five territories and monitored four nests belonging to Western Wood-Pewees during the 2017 breeding season in Poopenaut Valley (Figure 4-10). Two of these nests failed, one fledged, and the fate of the fourth is unknown as it was still active on the date of our last visit for the season. One of these nests was a re-nest after the first one failed.

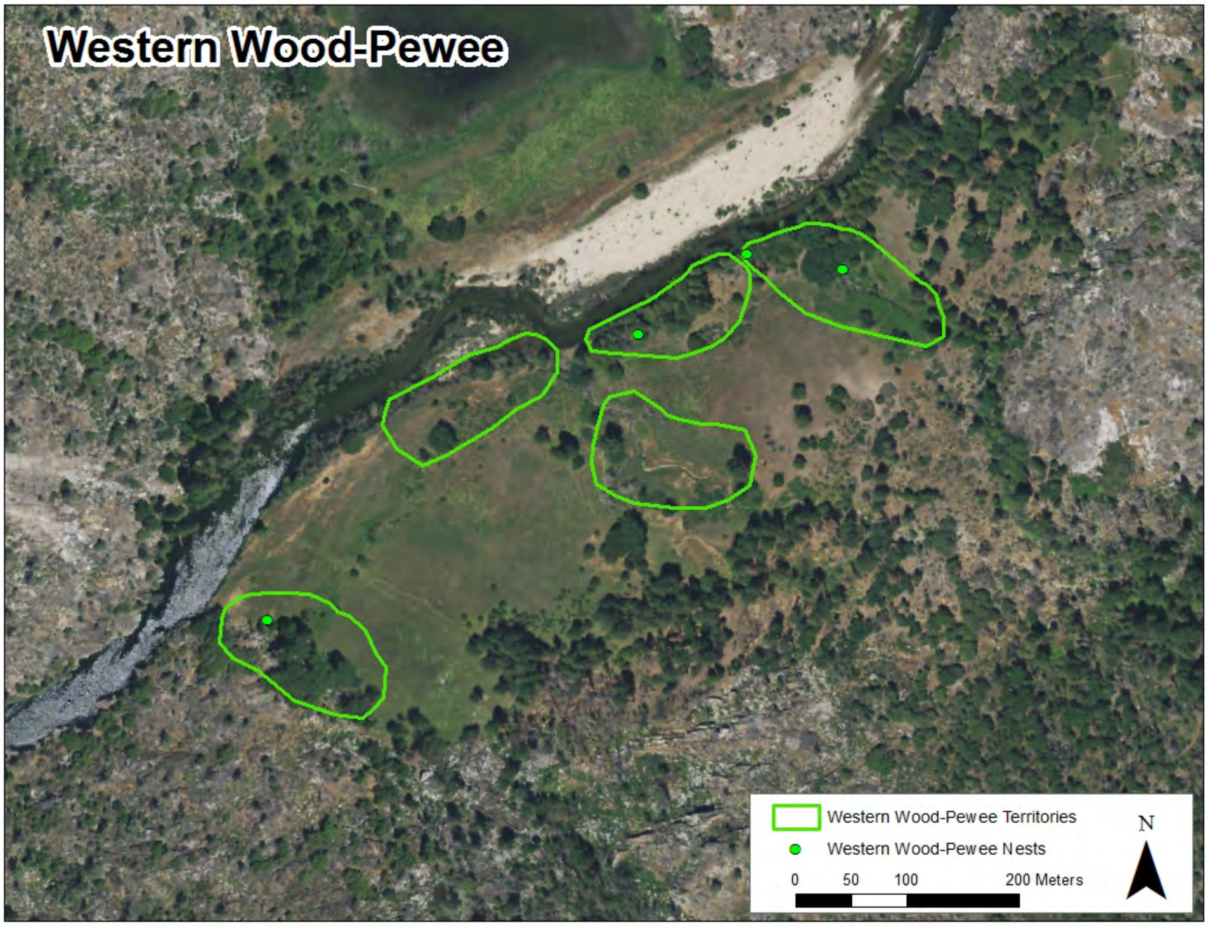


Figure 4-10. Western Wood-Pewee territories and nests observed during the 2017 breeding season in Poopenaut Valley.

Nest Searching Summary

In total, we monitored 14 nests in 2017 (Figure 4-11, Table 4-9). Nine of these were nests made by riparian focal species. Five nests fledged at least one young, five nests failed, and four nests were classified as an unknown fate when we could not determine if a nest had fledged or been depredated, or the nest was still active at the end of our survey period.

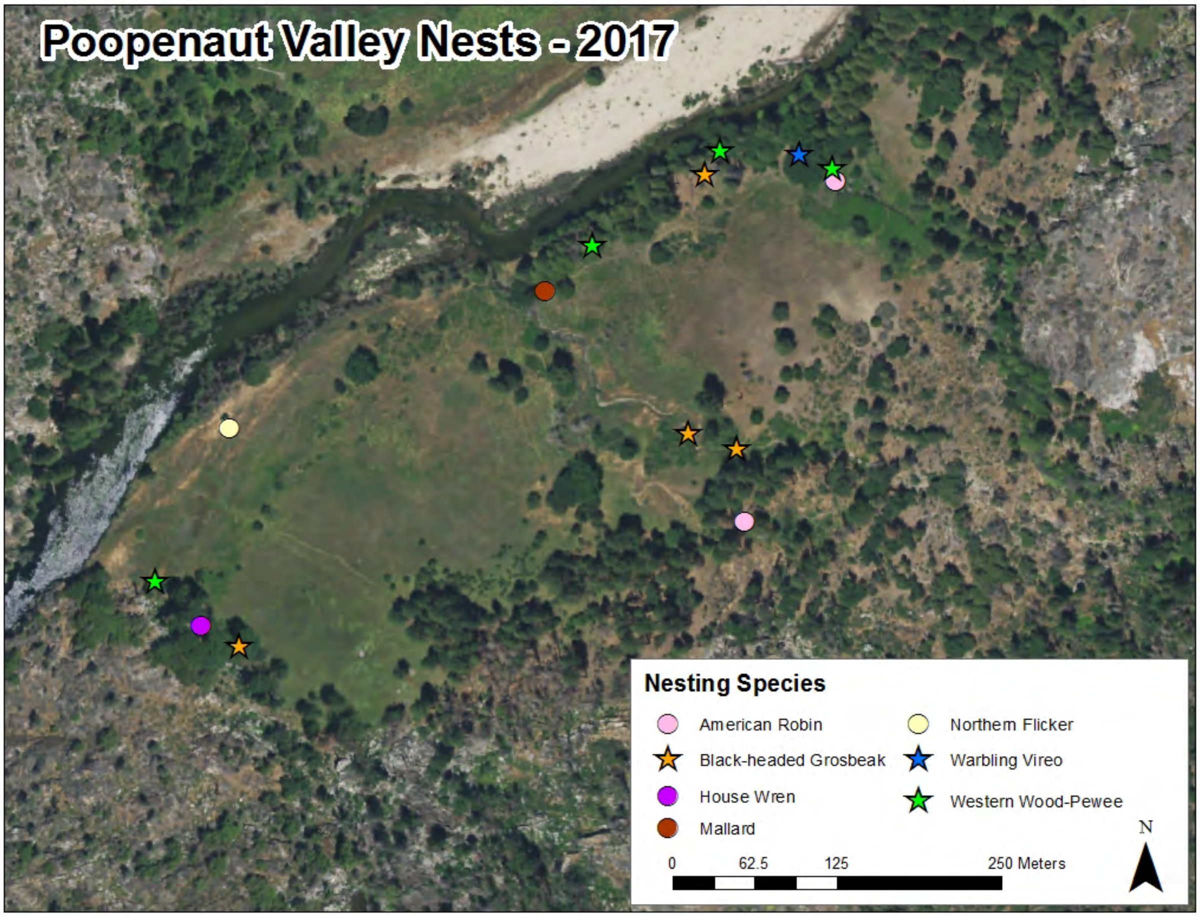


Figure 4-11. Nests found in Poopenaut Valley during the 2017 breeding season. Stars indicate riparian focal species.

Table 4-9. Nests located and monitored during the 2017 breeding season in Poopenaut Valley.

Species	Date Found	Stage	Male Colors	Female Colors	Fate
Black-headed Grosbeak	5/18/2017	Building	WK/US	OK/SO	FAIL
Western Wood-Pewee	5/31/2017	Building	-	-	FAIL
Black-headed Grosbeak	5/31/2017	Nestlings	KO/SU	-	Fledge
Black-headed Grosbeak	5/31/2017	Incubating	-	OO/RS	Fledge
Western Wood-Pewee	6/1/2017	Building	-	-	Fledge
Western Wood-Pewee	6/1/2017	Building	-	-	FAIL
Northern Flicker	4/20/2017	Building	-	-	Fledge
American Robin	6/1/2017	Incubating	-	-	Unknown
Mallard	5/18/2017	Incubating	-	-	FAIL
House Wren	6/20/2017	Nestlings	-	-	Fledge
American Robin	6/20/2017	Incubating	-	-	FAIL
Black-headed Grosbeak	6/20/2017	Incubating	KO/SU	-	Unknown
Western Wood-Pewee	6/20/2017	Building	-	-	Unknown
Warbling Vireo	6/20/2017	Building	-	KK/RS	Unknown

Food web component

We are currently processing and analyzing 2017 samples and expect to have results later this winter. In 2016, we captured 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 E). Of the 61 birds captured in 2016, we recaptured eight 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.

Mean δ13C of bird blood collected from riparian focal species was -24.6‰ ± 0.50‰ (SD) in Poopenaut Valley and -24.6‰ ± 1.11‰ (SD) at the Yosemite sites. Mean δ15N was 4.9‰ ± 0.64‰ and 5.3‰ ± 0.77‰ respectively. Basal sources collected from all sites were not sufficiently distinct for use in our mixing models (Post 2002). Therefore, we used basal sources collected between 2011 and 2014 from tributary and mainstem locations along both the Merced and Tuolumne rivers for our mixing models (n = 77): mean δ13C is -21.37‰ ± 5.42‰ for epilithic algae and -27.35‰ ± 1.15‰ for detritus. Mean δ15N for epilithic algae is -1.69‰ ± 2.28‰ and -2.21‰ ± 1.71‰ for detritus (Jackson and Sullivan, 2017).

Summary statistics for δ13C and δ15N of bird blood collected from non-target species is presented in Appendix F.

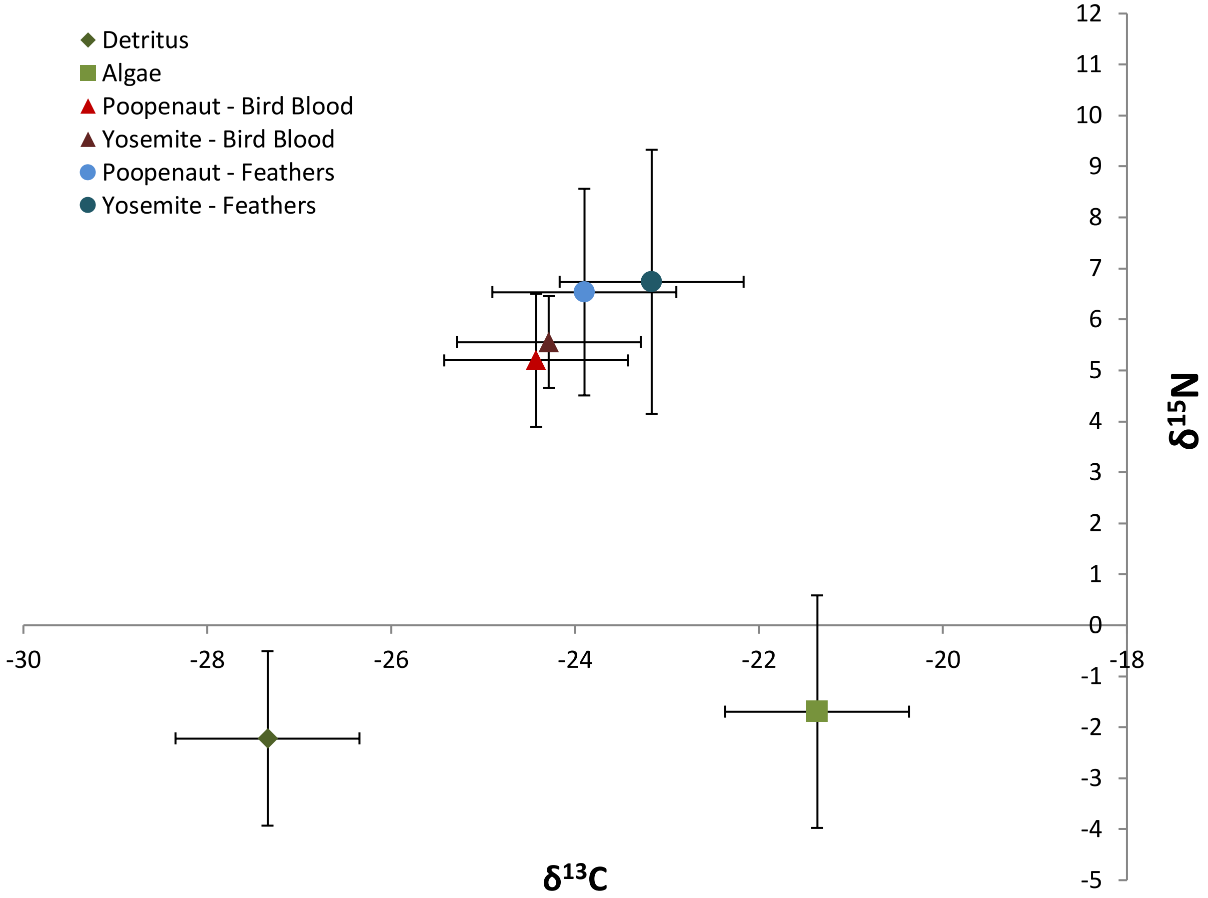


Figure 4-12. Bi-plot of δ13C and δ15N values for detritus, algae, bird blood, and feathers from Yosemite and Poopenaut Valley. Markers indicate mean, bars are one standard deviation from the mean. All sites and dates from 2016 are included. Algae and detritus estimates are those measured by Jackson and Sullivan (2017) from 77 locations along the Merced, Tuolumne, and the South Fork of the Merced Rivers and their tributaries.

Bird reliance on aquatically derived nutritional subsidies, as estimated from blood samples, ranged from 0.40 to 0.84 in both locations ($\bar{x}$ = 0.58 ± 0.03% (SD) and 0.60 ± 0.11 (SD), for Poopenaut and Yosemite respectively; Table 4-12). Song Sparrows sampled in Poopenaut Valley were significantly more reliant on an aquatic-energetic pathway than those sampled in Yosemite Valley (estimates from blood; n = 30, t= 2.16, p = 0.039). Conversely, Black-headed Grosbeaks sampled in Poopenaut Valley were significantly less reliant on an aquatic-energetic pathway than those sampled in Yosemite Valley (n = 12, t = -2.36, p = 0.036). We did not have sufficient sample size to justify comparisons of other riparian focal species. Reliance on aquatically derived nutritional subsidies by all birds estimated from blood was not significantly correlated with estimates from feather samples (R2 = 0.08 for Poopenaut, and R2 = 0.37 for Yosemite; Figure 4-13).

Table 4-10. Summary statistics for estimates of δ15N, δ13C, reliance on aquatically derived energy, and trophic position generated from all blood samples collected from riparian focal species in 2016 from Poopenaut and Yosemite Valley sampling locations. SOSP=Song Sparrow, BHGR=Black-headed Grosbeak, WAVI=Warbling Vireo, YEWA=Yellow Warbler.

	n	$\delta^{15}N$				$\delta^{13}C$				% aquatic				trophic position			
Month/Site/Species		min	$\bar{x}$	SD	max	min	$\bar{x}$	SD	max	min	$\bar{x}$	SD	max	min	$\bar{x}$	SD	max
May																	
Poopenaut																	
SOSP	8	5.7	6.1	0.26	6.4	-26.3	-25.2	0.57	-24.4	0.53	0.56	0.03	0.60	3.25	3.36	0.07	3.45
BHGR	4	4.8	5.5	0.77	6.5	-24.6	-23.9	0.52	-23.4	0.54	0.58	0.07	0.69	2.97	3.17	0.22	3.46
WAVI	10	4.3	5.7	0.74	6.7	-23.9	-23.2	0.45	-22.3	0.54	0.64	0.07	0.75	2.84	3.23	0.21	3.51
YEWA	3	4.7	5.4	0.70	6.1	-24.1	-23.7	0.55	-23.1	0.54	0.59	0.05	0.62	2.94	3.15	0.20	3.33
All	**25**	**4.3**	**5.7**	**0.32**	**6.7**	**-26.3**	**-24.0**	**0.85**	**-22.3**	**0.53**	**0.59**	**0.03**	**0.75**	**2.84**	**3.23**	**0.09**	**3.51**
Yosemite																	
SOSP	1	6.4	6.4	-	6.4	-23.6	-23.6	-	-23.6	0.67	0.67	-	0.67	3.42	3.42	-	3.42
BHGR	4	4.7	5.7	0.77	6.4	-23.7	-23.4	0.27	-23.0	0.54	0.63	0.06	0.68	2.94	3.24	0.22	3.42
WAVI	2	5.0	5.3	0.43	5.6	-23.6	-23.3	0.40	-23.1	0.59	0.60	0.00	0.60	3.02	3.11	0.13	3.19
YEWA	1	7.2	7.2	-	7.2	-23.3	-23.3	-	-23.3	0.76	0.76	-	0.76	3.65	3.65	-	3.65
All	**8**	**4.7**	**6.1**	**0.83**	**7.2**	**-23.7**	**-23.4**	**0.12**	**-23.0**	**0.54**	**0.66**	**0.07**	**0.76**	**2.94**	**3.35**	**0.23**	**3.65**

Table 4-10 Continued.

June																	
Poopenaut																	
SOSP	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BHGR	3	5.3	5.6	0.28	5.9	-26.3	-25.5	1.33	-24.0	0.46	0.51	0.08	0.61	3.15	3.22	0.07	3.29
WAVI	2	4.2	4.7	0.75	5.3	-24.3	-24.1	0.38	-23.8	0.52	0.53	0.02	0.54	2.81	2.96	0.22	3.11
YEWA	1	4.9	4.9	-	4.9	-24.1	-24.1	-	-24.1	0.74	0.74	-	0.74	2.47	2.47	-	2.47
All	**6**	**4.2**	**5.1**	**0.48**	**5.9**	**-26.3**	**-24.6**	**0.83**	**-23.8**	**0.46**	**0.60**	**0.13**	**0.74**	**2.47**	**2.88**	**0.38**	**3.29**
Yosemite																	
SOSP	4	4.8	5.2	0.29	5.6	-26.0	-25.4	0.75	-24.3	0.46	0.49	0.03	0.52	2.99	3.09	0.09	3.20
BHGR	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WAVI	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
YEWA	1	5.0	5.0	-	5.0	-24.7	-24.7	-	-24.7	0.84	0.84	-	0.84	3.06	3.06	-	3.06
All	**5**	**4.8**	**5.1**	**0.11**	**5.6**	**-26.0**	**-25.0**	**0.45**	**-24.3**	**0.46**	**0.67**	**0.25**	**0.84**	**2.99**	**3.08**	**0.02**	**3.20**
July																	
Poopenaut																	
SOSP	5	5.3	5.7	0.30	6.0	-27.2	-26.0	1.26	-24.2	0.48	0.50	0.03	0.55	3.12	3.24	0.09	3.35
BHGR	3	2.5	3.1	0.82	4.1	-24.5	-24.1	0.50	-23.6	0.45	0.47	0.02	0.49	2.30	2.50	0.24	2.76
WAVI	2	4.3	4.6	0.42	4.9	-24.9	-24.9	0.06	-24.8	0.47	0.48	0.01	0.49	2.84	2.92	0.12	3.01
YEWA	1	4.8	4.8	-	4.8	-25.0	-25.0	-	-25.0	0.67	0.67	-	0.67	2.47	2.47	-	2.47
All	**11**	**2.5**	**4.5**	**1.05**	**6.0**	**-27.2**	**-25.0**	**0.78**	**-23.6**	**0.45**	**0.53**	**0.09**	**0.67**	**2.30**	**2.78**	**0.37**	**3.35**

Table 4-10 Continued.

September

Poopenaut																	
SOSP	6	4.5	5.7	1.08	7.6	-27.4	-25.8	1.18	-24.3	0.43	0.53	0.12	0.75	2.92	3.26	0.30	3.76
BHGR	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WAVI	1	3.0	3.0	-	3.0	-23.7	-23.7	-	-23.7	0.73	0.73	-	0.73	1.92	1.92	-	1.92
YEWA	1	3.9	3.9	-	3.9	-25.7	-25.7	-	-25.7	0.56	0.56	-	0.56	2.26	2.26	-	2.26
All	**8**	**3.0**	**4.2**	**1.41**	**7.6**	**-27.4**	**-25.1**	**1.18**	**-23.7**	**0.43**	**0.60**	**0.11**	**0.75**	**1.92**	**2.48**	**0.69**	**3.76**
Yosemite/Sentinel/Cascade																	
SOSP	9	3.8	4.6	0.52	5.4	-27.7	-25.5	1.50	-22.6	0.40	0.47	0.07	0.62	2.70	2.94	0.15	3.15
BHGR	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WAVI	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
YEWA	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
All	**9**	**3.8**	**4.6**	**-**	**5.4**	**-27.7**	**-25.5**	**-**	**-22.6**	**0.40**	**0.47**	**-**	**0.62**	**2.70**	**2.94**	**-**	**3.15**

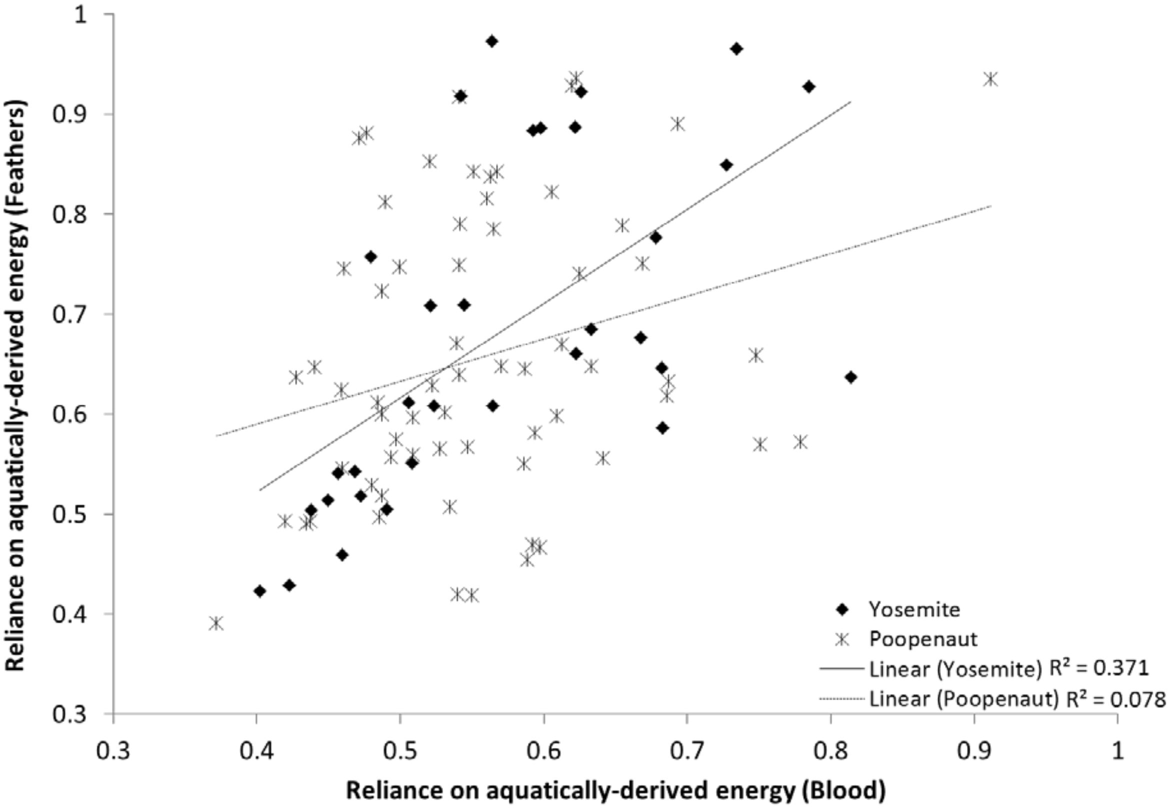


Figure 4-13. Linear relationship between bird reliance on aquatically derived nutritional subsidies estimated from blood and feather samples. Diamonds represent birds sampled in Yosemite Valley (R^2 = 0.37), and asterisks represent birds sampled in Poopenaut Valley (R^2 = 0.08). Estimates from blood give an indication of diet from the last few days, while estimates from feathers indicate diet over months.

Trophic position of riparian focal species estimated from blood samples was between 1.92 to 3.76 for both study sites. The mean was 2.84 ± 0.31 (SD) in Poopenaut Valley and 3.12 ± 0.21 (SD) in Yosemite Valley (Table 4-10) Song Sparrows sampled in Poopenaut Valley fed at a significantly higher trophic position than those sampled in Yosemite Valley ($n = 30$, $t = 4.14$, $p < 0.001$). There was no significant difference in trophic position between sites for Black-headed Grosbeaks, and we did not have sufficient sample size to test for difference among other bird species. Trophic position of all birds estimated from blood samples was positively related to trophic position estimated from feather samples, but the relationship was weak (R^2 = 0.19 for Poopenaut and R^2 = 0.21 for Yosemite; Figure 4-14).

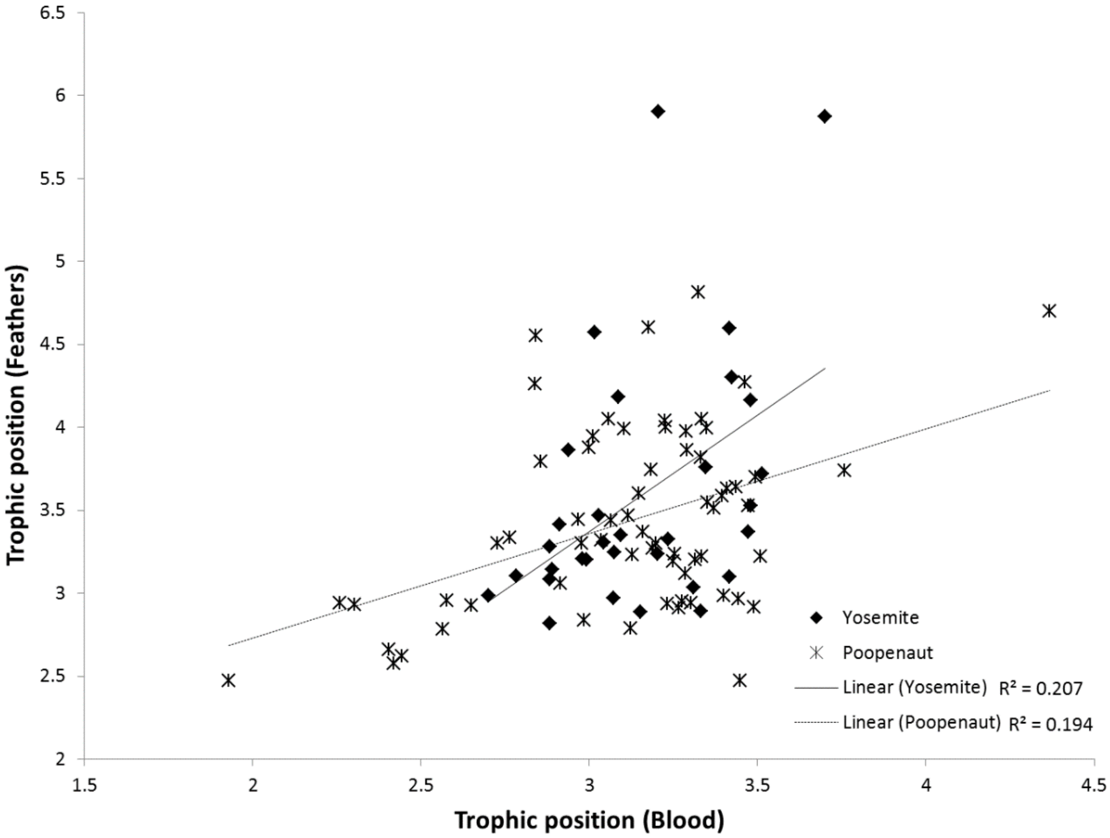


Figure 4-14. Linear relationship between bird trophic positions estimated from blood and feather samples. Diamonds represent birds sampled in Yosemite Valley (R^2 = 0.21), and asterisks represent birds sampled in Poopenaut Valley (R^2 = 0.19). Estimates from blood give an indication of diet from the last few days, while estimates from feathers indicate diet over months.

For all riparian focal species sampled in Poopenaut Valley, trophic position was positively related to reliance on an aquatic energetic pathway (Figure 4-15). This pattern is also evident for Black-headed Grosbeaks sampled in Yosemite Valley, but not Song Sparrows (Figure 4-16). Sample size for all other bird species was insufficient for comparison.

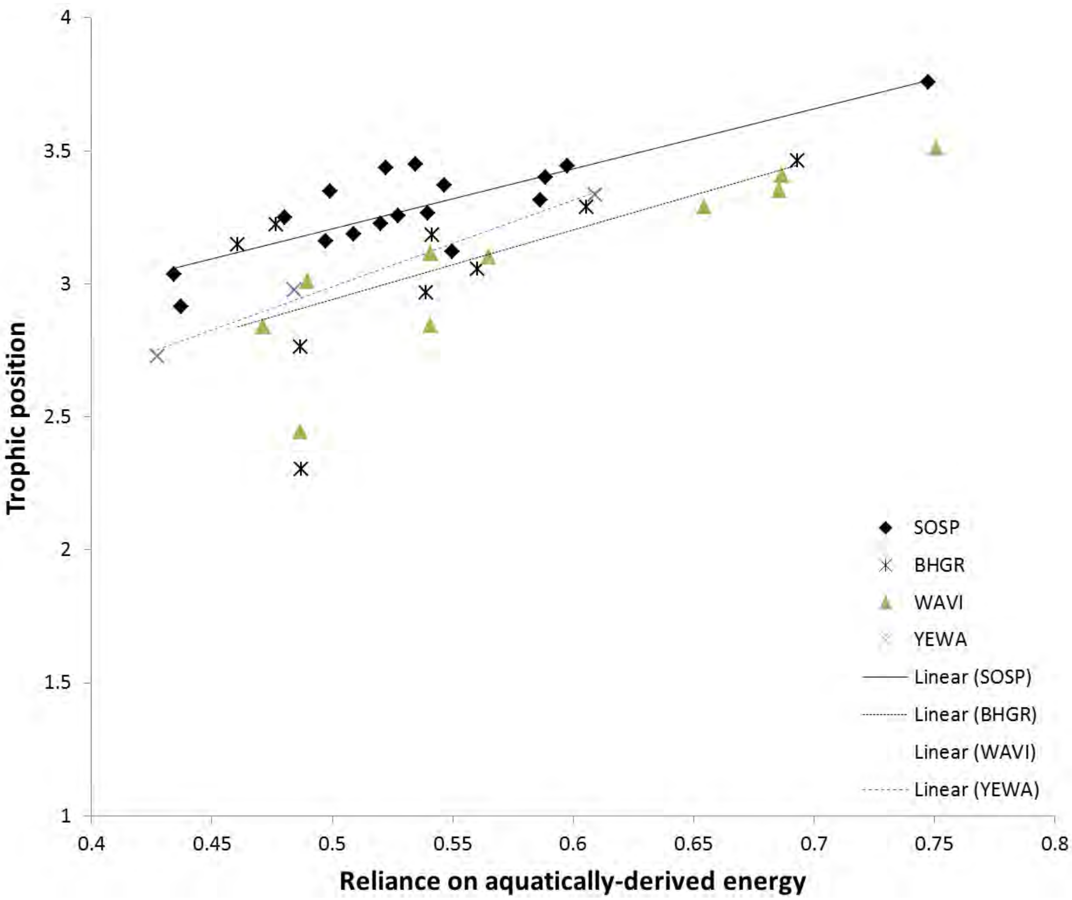


Figure 4-15. Linear relationship between reliance on aquatically derived energy by birds and trophic position estimated from blood samples taken in Poopenaut Valley. Diamonds represent Song Sparrow (R^2 = 0.72), asterisks represent Black-headed Grosbeak (R^2 = 0.32), triangles represent Warbling Vireo (R^2 = 0.76), and "x"s represent Yellow Warbler (R^2 = 0.99).

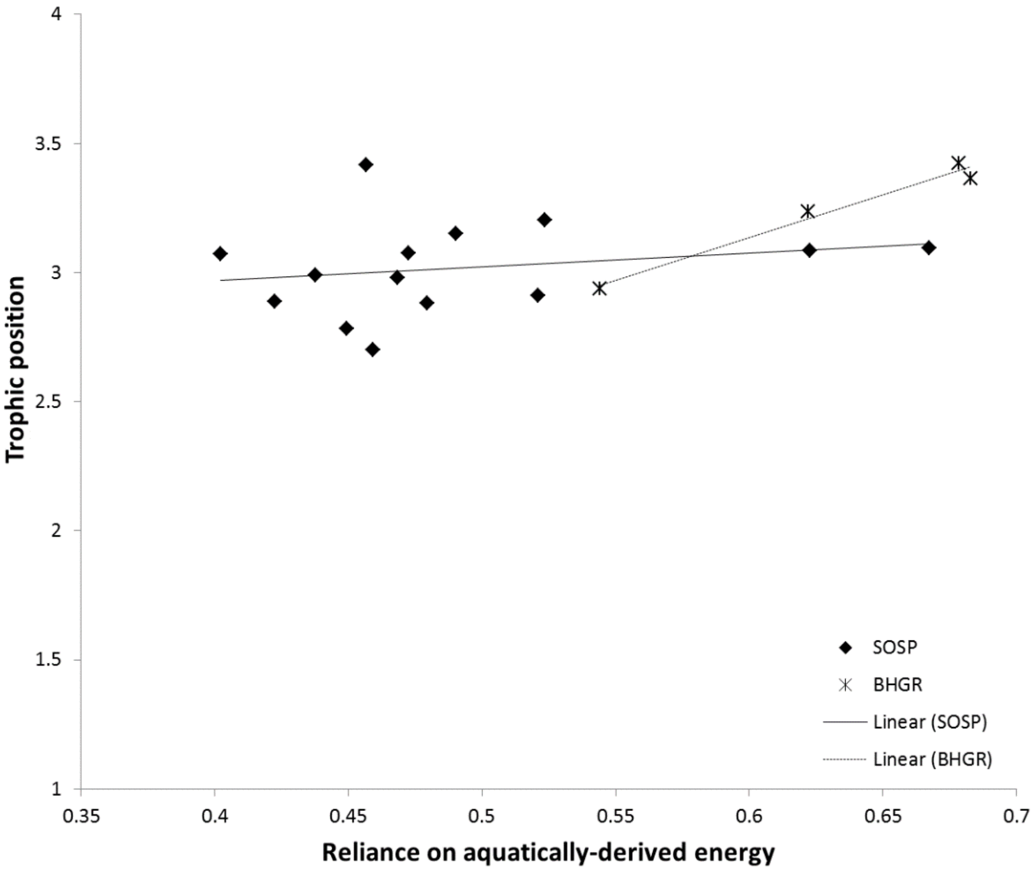


Figure 4-16. Linear relationship between reliance on aquatically derived energy by birds and trophic position estimated from blood samples taken in Yosemite Valley. Diamonds represent Song Sparrow (R^2= 0.05), and asterisks represent Black-headed Grosbeak (R^2 = 0.97).

Although we did not receive the results from 2017 in time to include in this report, we captured 23 individual birds of five different species in Poopenaut Valley, including eight Black-headed Grosbeaks, four Song Sparrows, and six Warbling Vireos (Appendix E). We did not capture any Yellow Warblers in Poopenaut Valley in 2017; they were detected on only the first two of four visits to Poopenaut Valley. In Yosemite Valley, we captured 15 individual birds of five different species including two Warbling Vireos, two Song Sparrows, and eight Black-headed Grosbeaks (Appendix E). We fit 17 birds with color bands in Poopenaut Valley, including seven Black-headed Grosbeaks, four Song Sparrows, and six Warbling Vireos. We plan to share the combined results from 2016 and 2017 this winter.

4.4 Discussion

2017 marks the 11th year of avian surveys during the breeding season in Poopenaut Valley for the Looking Downstream Project. The near record snowpack from the winter of 2016/2017 in the Tuolumne River watershed led to incredibly wet conditions in Poopenaut Valley in the spring. Researcher access was limited to the south side of the river, and on occasion, large portions the southern study area was underwater (Figure 4-17). Willow vegetation located in search area 5 (Figure 4-1), which provided preferential nesting habitat for riparian focal species in drier years (National Park Service, 2016), was nearly completely inundated for the duration of the 2017 breeding season (Figure 4-18). This forced birds up out of the riparian corridor and into nesting substrates that may not be a first choice in drier years (Figure 4-11 and 4-18).

Figure 4-17. View of area 3 from the west, mostly underwater on 20 June 2017.

Figure 4-18. Riparian vegetation in area 5 completely inundated on 21 June 2017 (left), and revealed on 6 September 2017 (right) after flows subsided.

Flooding persisted throughout the breeding season and prohibited access to areas 1, 2, and most of area 5 in 2017. Flooding in search areas 3 and 4 made access to these areas difficult and time consuming. Although we devoted significant time to nest searching, we were unable to follow birds and find nests as effectively as in previous years. Effort expended on nest searching has been variable over the history of the study; therefore, we do not have strong empirical evidence indicating a reduction in suitable nesting habitat, or whether the wet year led to sub-optimal nest placement and greater nest failure than previous years.

Flooding was associated with near-average diversity of bird species breeding in Poopenaut Valley. Species richness as measured by area search surveys was slightly above average in 2017 compared to other years (Table 4-4). However, species richness as measured by point count surveys was below average (Table 4-6). This implies that good habitat for breeding was available for many species, but some species recorded in previous years may not have found suitable breeding habitat in 2017.

In past years, we recorded the greatest number of species in search area 5, which is primarily comprised of riparian willow habitat. This area was inaccessible in 2017, but species using search areas 3, 4, and 5 can be detected using point count surveys at the south point (Figure 4-1). In 2017 search area 5 was completely inundated throughout the breeding season, which may explain lower-than-average species richness observed by point count surveys. Some, but not all avian species were apparently able to find suitable nesting habitat up out of the stream corridor, contributing to the apparent rise in species richness in search areas 3 and 4, but species richness decreased overall in the three search areas as measured by point counts.

Both relatively wet and dry hydrologic conditions are likely important for maintenance of riparian vegetation structure and community composition that provides nesting and foraging habitat for breeding bird communities. Relatively low flow years allow access to dense willow habitat that have historically supported the greatest avian species richness and relative abundance (National Park Service, 2016), while relatively high flow years recharge wetlands that would otherwise transition to upland, and prevent the encroachment of invasive species as well as native conifers (National Park Service, 2014c).

Songbirds that use riparian habitat are adapted to natural variation in flood magnitude, timing, duration, and frequency. Significant departure from the natural range of variation in disturbance regimes can have deleterious effects on breeding birds. For example, later peak flows, which are common in regulated systems, flood nest locations in both relatively dry and wet years (National Park Service, 2016 & 2017). Although riparian birds are resilient to occasional flooding of nest location, and may re-nest if time allows, river regulation may create an incorrect cue leading birds to choose nesting sites that will soon be flooded.

At the time of this report we are designing analyses to assess which hydrologic variables best predict overall avian abundance, the abundance of riparian focal species, and overall species richness in Poopenaut Valley and Yosemite Valley. The Yosemite Valley point counts will serve as a control for the Poopenaut Valley points. This comparative analysis will allow us to evaluate which changes in our avian community metrics in Poopenaut Valley can be correlated with the hydrology downstream of the dam and not widespread changes in riparian habitat found across the park.

We observed a reduction in the overall abundance and abundance of our riparian focal species after the Rim Fire in Poopenaut Valley, but did not measure a reduction in bird abundance over the same time in Yosemite Valley. We did not observe a reduction in species richness in either Poopenaut or Yosemite Valley after the Rim Fire (Table 4-7; Figure 4-3). Fires reduce vegetation structure important for nest building. Additionally, the greater the historic median interval between fires in a system, the longer the abundance of invertebrate prey that evolved in that system may be reduced post-fire (New, 2014). Both of these factors have the potential to reduce bird abundance for years after a fire, but possibly not reduce species richness. However, we know from preliminary analyses in 2016 that bird abundance in Poopenaut Valley is negatively associated with years since average (or greater) discharge (National Park Service, 2017). The Rim Fire occurred after the breeding season in 2013, concomitant with below average discharge from 2012 through 2015. Separating the influence of the Rim Fire from persistent low-flows is 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.

The addition of the food web component of our study allowed us to measure bird dependence on aquatic productivity directly. We found that the birds we sampled relied heavily on aquatic primary production deriving 40% to 84% of their energetic demand from an aquatic-energetic pathway (Table 4-10). This was consistent across avian species. To our knowledge, this is the only study to measure the magnitude of an aquatic-terrestrial energetic pathway in these species of birds. However, other studies have estimated the aquatic contribution to other riparian insectivores including riparian swallows (23% - 54%, Kautza and Sullivan 2016), Tetragnathid spiders (40% to 90%; Jackson and Sullivan, 2015, 2017), and riparian rove beetles

(14% to 46%, Kautza and Sullivan, 2016). It is remarkable that birds in this study rely much more heavily on an aquatic energetic pathway than perhaps any other organism studied (although see Chapter 5). This suggests that breeding birds in this study selectively prey on emergent aquatic insects and that those insects primarily feed on benthic algae. Given that reliance on an aquatic-energetic pathway by emergent aquatic insects can range from 10% to 97% (Jonsson and Stenroth, 2016, Kautza and Sullivan, 2016, Jackson and Sullivan, 2015), it is not impossible that these estimates are correct. However, if the basal resources we are using in our models (i.e., algae and stream-conditioned leaf litter) are not representative of the most important primary producers in this system, our estimates could be incorrect.

Trophic position of birds in this study ranged from 1.92 to 3.76 with a mean near 3.0 (Table 4-10). If birds occupy a trophic position of three, this suggests a food chain consisting of a primary producer, a secondary consumer, and the bird itself. Therefore, the food chain leading to birds in this study can include one predatory invertebrate, and that omnivory is common. Bird reliance on an aquatic-energetic pathway was positively correlated with trophic position across study sites (Figures 4-15 and 4-16). Birds that relied more heavily on an aquatic energetic pathway generally fed at a higher trophic position, suggesting that aquatic-to-terrestrial food webs leading to birds are more complex than terrestrial food webs, include more predators or omnivores, and are perhaps more resistant or resilient to disturbance (Downing and Leibold 2010).

Estimates of bird reliance on an aquatic-energetic pathway and trophic position derived from blood samples were positively correlated with estimates derived from feather samples, albeit not very strongly (Figures 4-13 and 4-14). Many birds consume more insect prey during the breeding season, and some of the birds sampled in this study are migratory. Therefore, we expect that many of the birds in this study consume much different food items at different times of the year leading to a weak relationship between the isotopic composition of blood and feather samples.

Together these results indicate that the birds captured in these riparian systems rely disproportionately on food webs supported by photosynthesis occurring within rivers and streams, therefore emphasizing the importance of intact aquatic ecosystem processes to these communities. This year, we continued the food web component of our study with additional sampling of birds in the spring. In addition, we collected additional basal resources (i.e., algae, stream-conditioned leaf litter, and riparian plant materials) during the summer in order to check that the primary producers we are using in our models are those of actual importance in the ecosystem.

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. Further, concomitant changes in climate and regional bird habitat destruction will likely interact with river regulation to drive changes in bird populations and diversity. Therefore, the more that dam operators are able to emulate historic disturbance regimes, the more likely it is that the Tuolumne River downstream of Hetch Hetchy Reservoir will remain suitable habitat for birds.

Chapter 5. 2017 Bat Studies in Poopenaut Valley

5.1 Introduction

Bats utilize riverine habitat for multiple purposes, are highly mobile, and are sensitive to disturbance. Bats use rivers and riparian habitat for roosting, foraging, and migrating. Some species such as *Yuma myotis* forage directly over the water, feeding almost exclusively on emergent aquatic insects like mayflies and caddisflies. Others, such as Mexican free-tailed bats may primarily forage and roost in upland areas, but are known to forage frequently over rivers when emergent aquatic prey availability is high. In addition, almost all species of bats rely on rivers or other water bodies to drink, making these areas bat hotspots on the landscape. Given that most bats are highly mobile and migratory, they are likely sensitive to shifts in river conditions across space and time. Therefore, shifts in bat activity, community composition, and habitat use may be indicative of changes in ecosystem function and resistance and resilience of stream-riparian ecosystems to disturbance (including river regulation).

The riparian zone of Poopenaut Valley may be an important landscape feature to bats. 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, a seasonal pond, a spring, deciduous riparian forest composed of willow and cottonwood along the river itself, 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 of these are special status species that have experienced statewide 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 determinant 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 may derive a high proportion of their energetic demand from aquatic prey subsidies. In addition, bats may 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 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.

We added a fifth study objective 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.

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

Acoustic surveys

From April 2011 to August 2017, 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). From May 2016 to August 2017 we operated 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 habitats. In addition, we added a detector in Yosemite Valley to serve as a reference. We deployed this detector near the southeast corner of the Camp 6 pond on the north side of the Merced River and monitored it from May to October 2016.

At the two meadow sites in Poopenaut Valley, we secured one detector and external battery in a locked metal box near the base of a 20-foot tall metal pole (Figure 5-2). At the top of the metal pole, we mounted an external microphone beneath a weatherproof 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. We attached the microphone for the river detector to a branch positioned approximately 15 meters above the water surface, and attached the microphone for the Yosemite Valley detector 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 we secured in a locked metal box. Each detector recorded sound in the high frequency range continuously at two different time periods: (1) 1900 - 2300 and (2) 0300 - 0800. We scheduled detector checks on a monthly basis; however due to high-volume of bat passes at the Yosemite Valley study location, we checked this detector fortnightly.

We used Pettersson D500x ultrasound recording units coupled with SonoBat™ 4.1 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), we did not achieve continuous monitoring. Total seasonal monitoring effort for each site is shown in Table 5-2.

The Rim Fire burned the north side of Poopenaut Valley August 23-24, 2013 and the south side September 10-11, 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 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.

In 2017, the Sierra experienced a record water year resulting in several peak flow events downstream of Hetch-Hetchy Reservoir with discharge nearing 10,000 cfs. Six peak flows (and even more minor peaks) occurred in January, February, March, April, and July (Figure 5-5).

Food web component

To complement our long-term acoustic monitoring dataset, we piloted a new study component to examine food web architecture leading to bats beginning in the spring of 2016. We mist-netted bats in Poopenaut Valley and in three reaches of the Merced River: two in Yosemite Valley (Camp 6 pond and Swinging Bridge), and one downstream of Yosemite Valley at Cascade Falls. We conducted surveys over three separate sampling efforts in May, June, and September 2016. We captured bats in Poopenaut Valley on the nights of May 1-2, June 13-14, and September 16. In Yosemite Valley, we captured bats at the Camp 6 pond location on May 3 and June 15, at Swinging Bridge on June 16 and September 17, and at the Cascade reach on September 18. We deployed multiple nets during each sampling effort (5-6 3 m high nets) in addition to a single 10 m high net. We classified all captured bats to species, recorded physical attributes, and collected blood (50 uL) and hair samples. We opportunistically collected guano from the capture bags after removing the bat. We stored blood samples in 70% ethanol solution, and stored hair and guano in microcentrifuge tubes with silica beads as a desiccant. We collected skin biopsy samples from the tails of bats during the first round of sampling in May; however, the sample was insufficient for stable isotope analysis, so we discontinued collection after the first round.

We collected algae and stream conditioned leaf litter (i.e., detritus) from upstream, mid-reach, and down-stream locations along each study reach to use as basal resources (~ 10 samples per study reach). All algae and detritus samples were stored in 70% ethanol for transportation and storage.

Sample processing - We freeze-dried blood and hair samples from bats in the laboratory. We then packed a small amount of each composite sample into tin capsules. We sorted epilithic algae and detritus from other materials and rinsed the samples with distilled water. After oven-drying at 60ºC for 24 hours, epilithic algae and detritus were homogenized into a fine powder using a Pica Blender Mill (Cianflone Scientific Instruments Corporation, Pittsburgh, Pennsylvania) or mortar and pestle before packing samples into tin capsules for analysis.

Stable-isotope analysis – Naturally abundant stable-isotope analysis is a valuable tool for describing food webs because it addresses trophic position and diet (Collier et al. 2002, Hicks et al. 2005). The ratio of ^{13}C to ^{12}C ($\delta^{13}C$) can vary between terrestrial and aquatic primary producers. For example, stream algae can exhibit a distinct $\delta^{13}C$ signature from riparian deciduous shrubs (Finlay 2001). This distinction is retained in consumer organisms so that the source of a consumer's energy requirements (or diet) can be determined from the isotopic signature. In addition, the trophic position of a consumer organism can be determined from its nitrogen isotope signature as there is in general a 3-4‰ enrichment of $\delta^{15}N$ (the ratio of ^{15}N to ^{14}N) with each trophic step (Post 2002).

Continuous flow isotope-ratio mass spectrometry (EA-IRMS) was used to determine $\delta^{13}C$ and $\delta^{15}N$ for all samples at Washington State University's Stable Isotope Core (Pullman, Washington). The results are reported in δ (‰) notation defined as: $\delta^{13}C$ or $\delta^{15}N$ = [(Rsample/Rstandard)-1] * 100 where R is $^{13}C/^{12}C$ or $^{15}N/^{14}N$ for the sample or standard, with Vienna Pee Dee Belemite as the standard for C and atmospheric N^2 as the standard for N. Typical analytical precision was 0.08‰ for $\delta^{15}N$ and 0.19‰ for $\delta^{13}C$ determination.

Estimating trophic position and aquatically-derived nutritional subsidies - After processing, we used the two-source food-web model from Post (2002) to estimate bat trophic position; $TP = \lambda + \{ \delta_c – [\delta_{b1} * \alpha + \delta_{b2} * (1-\alpha)]\}/ \Delta_n$ where λ is the trophic position of the basal food sources (i.e., 1 for primary producers); δ_c is the $\delta^{15}N$ signature of the consumer; δ_{b1} and δ_{b2} are the signatures of the two basal food sources; α is the proportion of N from basal food source 1; and Δ_n is the enrichment in $\delta^{15}N$ per trophic level (i.e., 3.4‰; Post 2002). A two-end member Bayesian isotopic mixing model was used to determine the proportion of N derived from basal source 1 (i.e., α) with the R software package SIAR (Stable Isotope Analysis in R; Parnell and Jackson 2013). SIAR is equipped to handle variability in sources, consumers, and trophic fractionation factors (Parnell et al. 2010).

Epilithic algae and detritus were the basal food source end members. To estimate the contribution from each food source to the consumer, $\delta^{13}C$ and $\delta^{15}N$ data were used. Trophic fractionation factors for bats were estimated using the per trophic step fractionation in Post (2002) (i.e., 3.4‰ ± 0.98‰ for $\delta^{15}N$ and 0.39‰ ± 1.3‰ for $\delta^{13}C$) multiplied by the estimated number of trophic transfers between the consumer and basal resources (estimated a priori as the difference between the consumer $\delta^{15}N$ and mean basal resource $\delta^{15}N$ divided by 3.4‰), which is consistent with other aquatic food-web investigations (e.g., McHugh et al. 2010, Sullivan et al. 2015). However, it is important to note that some recent studies have either questioned the use of a single, fixed enrichment factor (Caut et al. 2009, Hussey et al. 2014) or suggested that 3.4‰ overestimates the per trophic level ^{15}N enrichment for certain consumers (Vanderklift and Ponsard 2003).

Numerical analysis and statistics

We used summary statistics and graphic displays to assess differences in bat activity, reliance on aquatically derived energy, and trophic position 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, year, and site. We used t-tests to test for differences in reliance on aquatic-terrestrial nutritional subsidies and trophic position of bats sampled in Yosemite Valley and Poopenaut study locations. In addition, we used linear regression to assess correlations between paired blood and hair samples collected from bats. PC-ORD software was used for ordination. All other analysis was performed in R.

Figure 5- 1. Acoustic monitoring sites targeting bat species in Poopenaut Valley, Yosemite National Park. Monitoring occurred between April 2011 and August 2017 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 August 2017.

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.

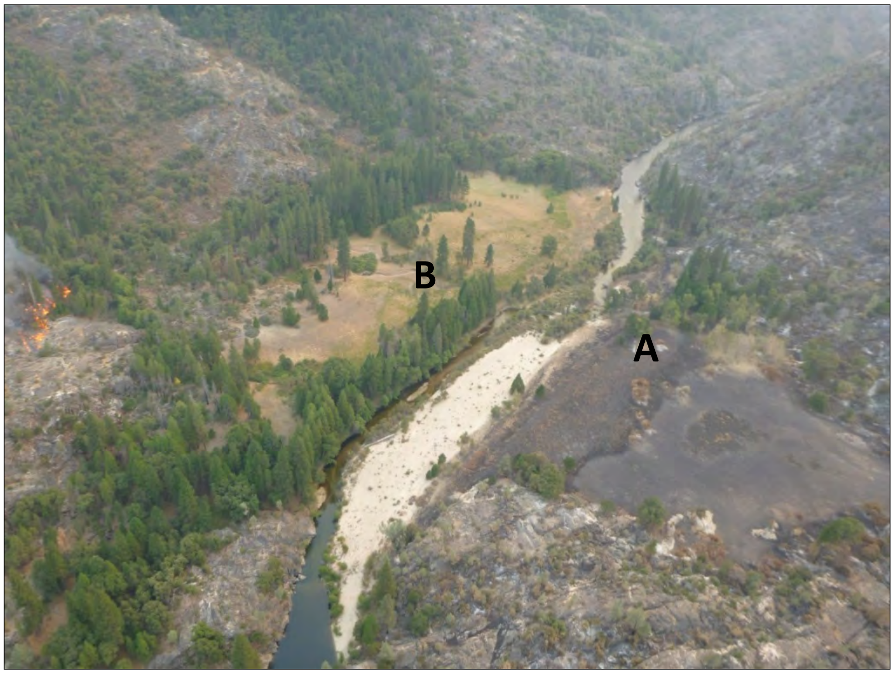


Figure 5-3. Aerial image of Poopenaut Valley taken 10 September 2013 showing active burn front of the Rim Fire on the south side of the valley, and the area on the north side of the valley that burned on 23-24 August 2013. The northern area includes the seasonal pond and site of the north bat detector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

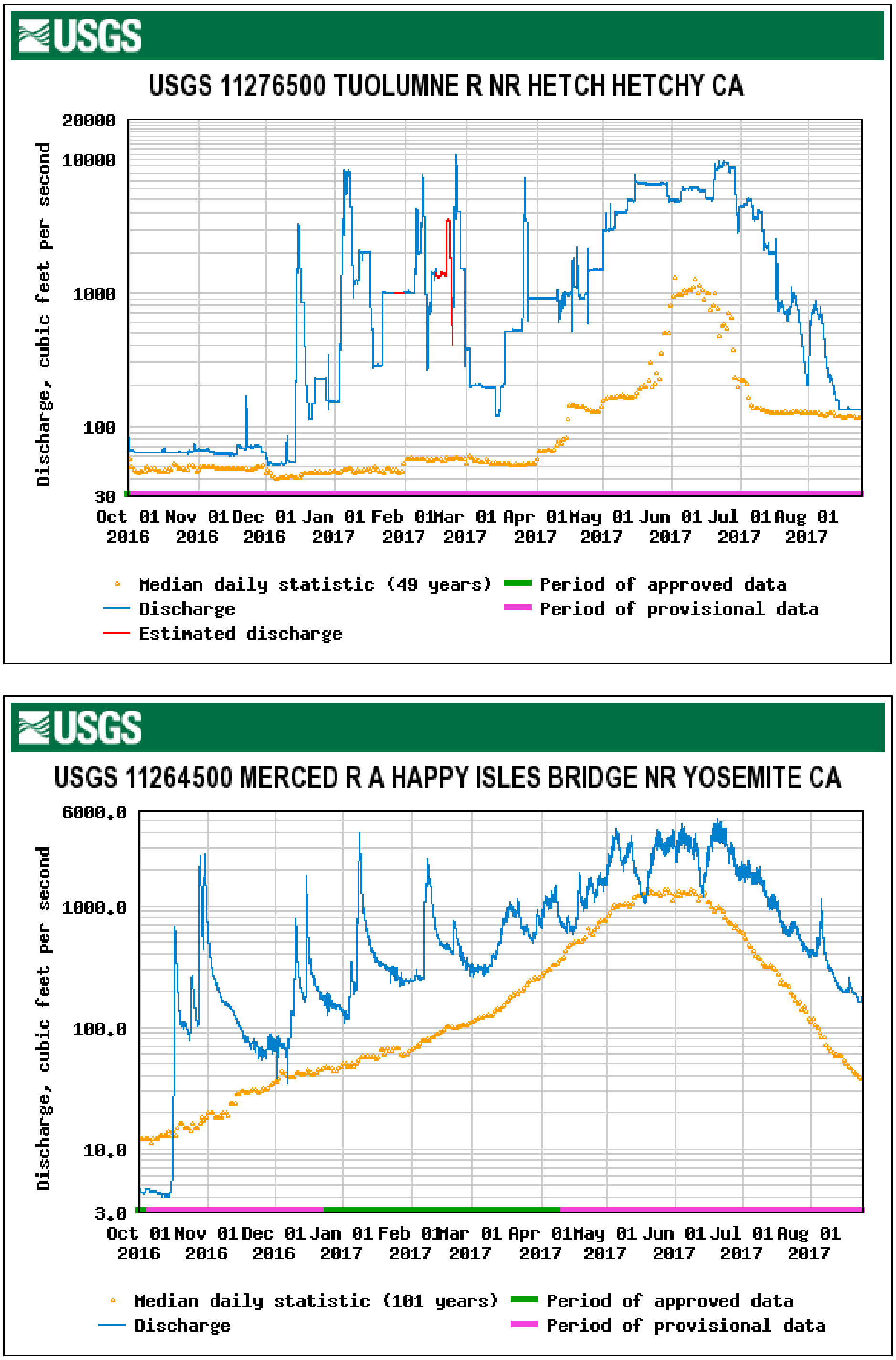


Figure 5-5. USGS hydrographs for the Hetch-Hetchy reach of the Tuolumne River and the Happy Isles reach of the Merced River from 1 October 2016 to 24 August 2017.

5.3 Results

We documented a high diversity of bat species in Poopenaut Valley from spring 2011 through summer 2017. Over this six-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. Over the entire study the majority of detections of bats echolocating at a high frequency are from California myotis (48%) followed by canyon bat (30%), Yuma myotis (20%), and western long-eared myotis (0.6%) (Figure 5-6).The vast majority of detections of low-frequency echolocations are from spotted bats (40%) followed by western mastiff bat (39%), Mexican free-tailed bat (15%), hoary bat (2%), and silver-haired bat (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 a small proportion of the total number of detections only represents some of these species, all five have been detected at least once each year since the beginning of the study period with the exception of Townsend's big-eared bat. This species has only made an appearance on a handful of occasions: once in 2011 (May 9 at 11:08 pm); three times is 2014 (January 27 at 6:09pm, September 12 at 7:54 pm, and September 29 at 10:49 pm); and twice in 2016 (July 13 at 10:46 pm and July 26 at 9:22 pm). The two detections in 2016 were both recorded by the detector placed alongside the river. It is possible that Townsend's big-eared bats passed through Poopenaut Valley in other years, but were not recorded because they were solely using the river corridor.

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. Mexican free-tailed bats are the only species that have been detected every winter during the study period. Habitat requirements and annual activity levels of the eight most frequently detected bat species in Poopenaut Valley are described in Table 5-3.

Species richness as recorded by the north and south acoustic recorders was generally highest in August, September, and July each year (14 ± 1.8 (SD), 13 ± 1.9, and 13 ± 1.8 species respectively). Species richness in March varied most from year to year (6 ± 4.5 (SD). Throughout the study period, January was the least species rich month (3 ± 2.1) (Figure 5-10).

Preliminary results show that community composition of bat activity in Poopenaut Valley varies by season (Figure 5-11), site (Figures 5-12 and 5-13), and year (Figure 5-14). Using NMS ordination, we described seasonal bat community composition with a two-axis solution representing 68.6% 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).

We observed significant differences among all detector locations including the newly added Poopenaut river and Yosemite Valley sites (Figure 5-13). We described summer bat community composition with a three-axis NMS solution representing 85.8% 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 23 through September 10, 2013. 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 5-15).

The effect of river regulation on bat activity has been difficult to discern because environmental conditions have not remained constant. Over the duration of this study (2011-2017), five consecutive years were drier than usual, which resulted in drought conditions (Figure 5-16) with actual summer discharge in the Tuolumne River far below the estimated unregulated discharge. 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 subsided (Figure 5-17). Then in July, the pattern 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 5-17). 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 5-17). Bat activity levels in Poopenaut were at the highest for each of the three recorders in September 2016, meanwhile in Yosemite Valley bat activity levels continued to decline.

We recorded all 17 species of bats known to utilize Poopenaut Valley over the last year (August 2016 to August 2017). Richness was highest at the river and south sites (16 species each). Only 14 species were detected on the north side, but a few months of recording were lost due to river flows being too high to cross. From May to October 2016 we observed 16 species in Yosemite Valley (Figure 5-18). The rarest species from the last year included Townsend’s big-eared bat, Pallid bat, and little brown bat.

Food web component

In Poopenaut Valley we collected blood and hair samples from 33 bats representing five species (Yuma Myotis, California Myotis, fringed Myotis, Western long-eared Myotis, and silver-haired bat) over all sampling periods. In Yosemite Valley and Cascade, we collected blood and hair samples from 39 bats representing six species (Yuma Myotis, California Myotis, fringed Myotis, Mexican free-tailed bat, big brown bat, and little brown bat). All data are summarized in Table 5-6 and Figure 5-19. Sample sizes were small in May and June. Therefore, we only considered samples collected from Yuma Myotis in September from Poopenaut Valley and Cascade (n = 23 and 27 respectively).

Mean $\delta^{13}C$ of bat blood was -22.7‰ ± 1.83‰ (SD) in Poopenaut Valley and -22.9‰ ± 2.28‰ (SD) at the Cascade site. Mean δ15N was 7.8‰ ± 2.68‰ and 8.3‰ ± 2.69‰ respectively. Basal sources collected from all sites were not sufficiently distinct for use in our mixing models (Post 2002). Therefore, we used basal sources collected between 2011 and 2014 from tributary and mainstem locations along both the Merced and Tuolumne rivers for our mixing models (n = 77): mean $\delta^{13}C$ was -21.37‰ ± 5.42‰ for epilithic algae and -27.35‰ ± 1.15‰ for detritus. Mean $\delta^{15}N$ for epilithic algae was -1.69‰ ± 2.28‰ and -2.21‰ ± 1.71‰ for detritus (Jackson and Sullivan 2017).

We found no significant differences between sites for either reliance on aquatically derived energy or trophic position of bats. Bat reliance on aquatically derived nutritional subsidies, as estimated from blood samples, ranged from 0.53 to 0.98 in both locations ($\bar{x}$ = 0.76 ± 0.11% (SD) and 0.77 ± 0.14 (SD), for Poopenaut and Cascade respectively; Table 5-6). Reliance on aquatically derived nutritional subsidies by bats estimated from blood was positively correlated with estimates from hair samples ($R^2 = 0.52$ for Poopenaut and $R^{2=}$ 0.77 for Cascade; Figure 5-20).

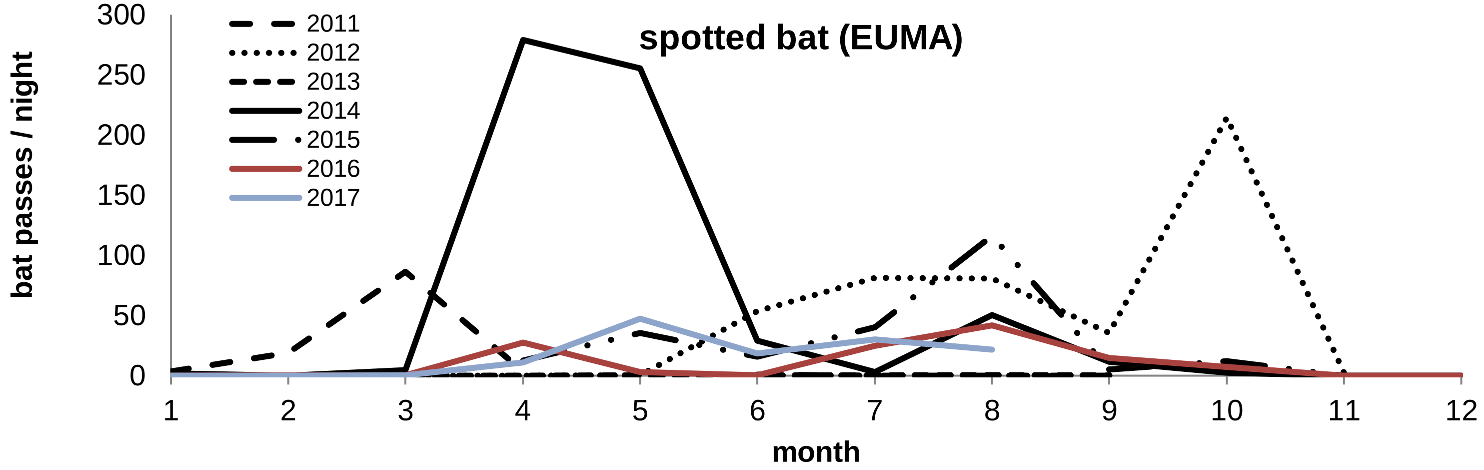
Trophic position of bats estimated from blood samples was between 3.16 to 6.70 for both study sites. The mean was 3.84 ± 0.77 (SD) in Poopenaut Valley and 3.98 ± 0.78 (SD) at Cascade (Table 5-6) Again, trophic position estimated from blood samples was positively correlated with trophic position estimates from hair ($R^2 = 0.79$ for Poopenaut and $R^2 = 0.80$ for Cascade; Figure 5-21).

Table 5-2. Percentage of operational days for each acoustic bat detector out of all days elapsed within a season. Spring is March-May, Summer is June-August, Fall is September-November, and Winter is December-February. The seasonal monitoring effort for Poopenaut North, Poopenaut South, Poopenaut River, Yosemite Valley are presented.

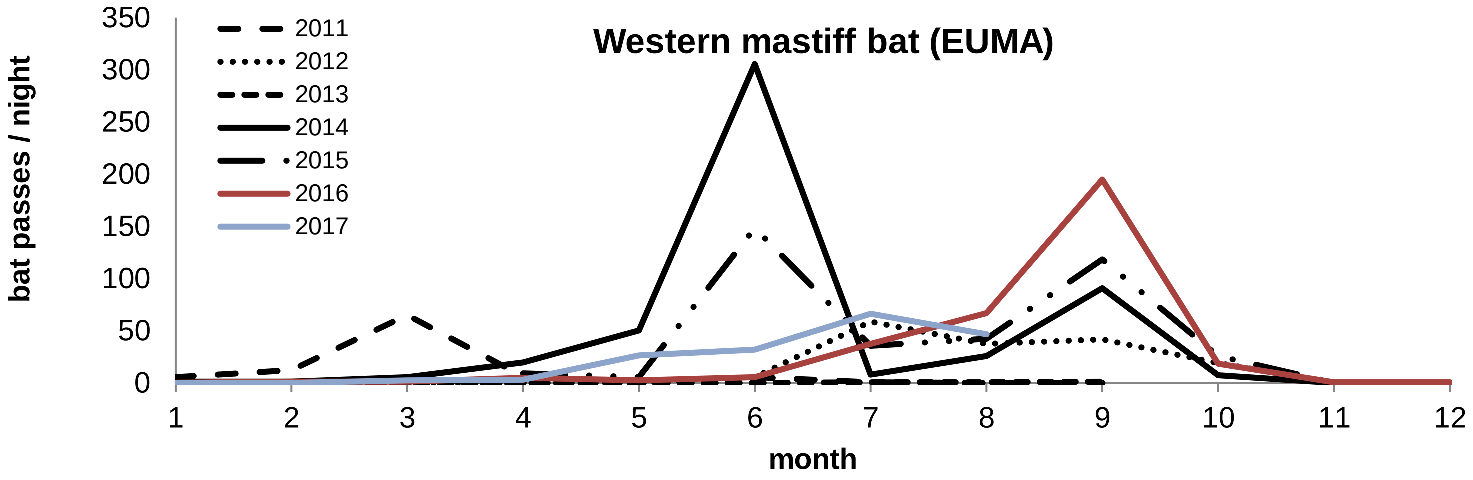
Year	Season	North	South	River	Yosemite
2011	**Spring**	63%	67%	-	-
	Summer	5%	14%	-	-
	Fall	52%	92%	-	-
2012	**Winter**	84%	87%	-	-
	Spring	100%	93%	-	-
	Summer	96%	100%	-	-
	Fall	81%	100%	-	-
2013	**Winter**	93%	100%	-	-
	Spring	100%	100%	-	-
	Summer	100%	99%	-	-
	Fall	22%	20%	-	-
2014	**Winter**	19%	34%	-	-
	Spring	71%	67%	-	-
	Summer	51%	58%	-	-
	Fall	100%	86%	-	-
2015	**Winter**	99%	91%	-	-
	Spring	99%	41%	-	-
	Summer	83%	59%	-	-
	Fall	100%	68%	-	-
2016	**Winter**	100%	82%	-	-
	Spring	100%	100%	1%	4%
	Summer	95%	95%	45%	34%
	Fall	100%	91%	10%	68%
2017	**Winter**	32%	78%	11%	-
	Spring	42%	65%	10%	-
	Summer	5%	72%	22%	-

Table 5-3. Occurrence, habitat requirements, and bat detections by season of the eight most frequently detected bat species in Poopenaut Valley from 14 April 2011 to 8 August 2017. The vertical axis on graphs represents the number of bat detections normalized by the number of recording nights per month. The maximum number of recordings between the North and South detector are presented for each month. Broken lines indicate a gap in monitoring.

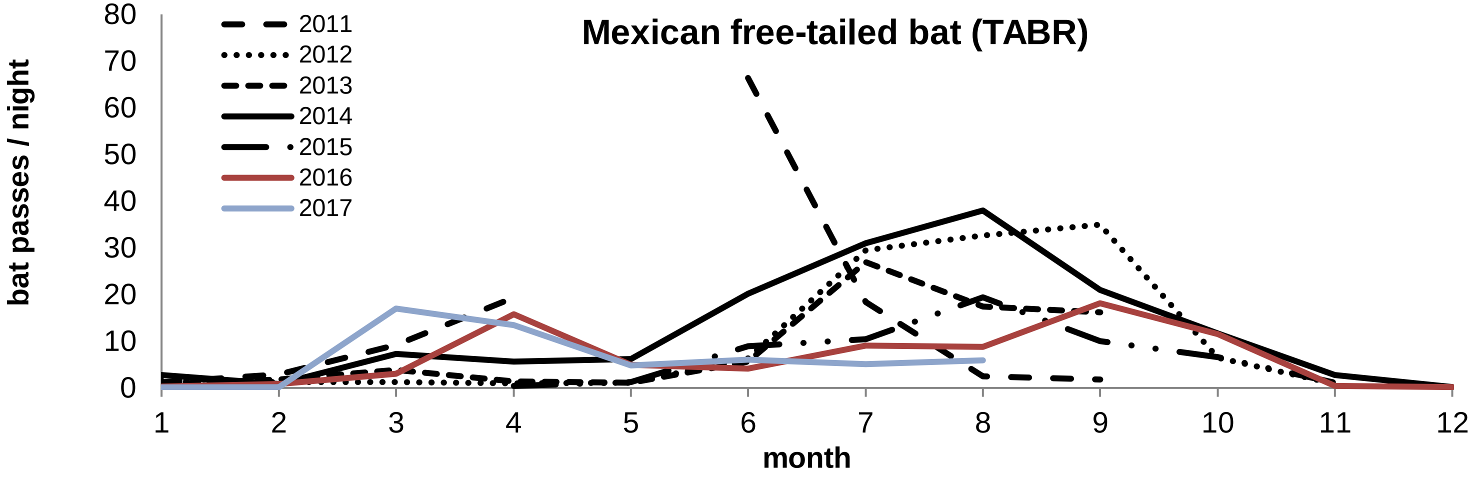
SPOTTED BAT	
Occurrence/habitat	Widely distributed throughout Sierra Nevada, with records > 3000 m. Occurs in habitats ranging from desert scrub to montane coniferous forests.
Feeding type/food source	Forages in a wide variety of habitats,5-15 m off the ground, primarily for moths.
Roosting structure	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.



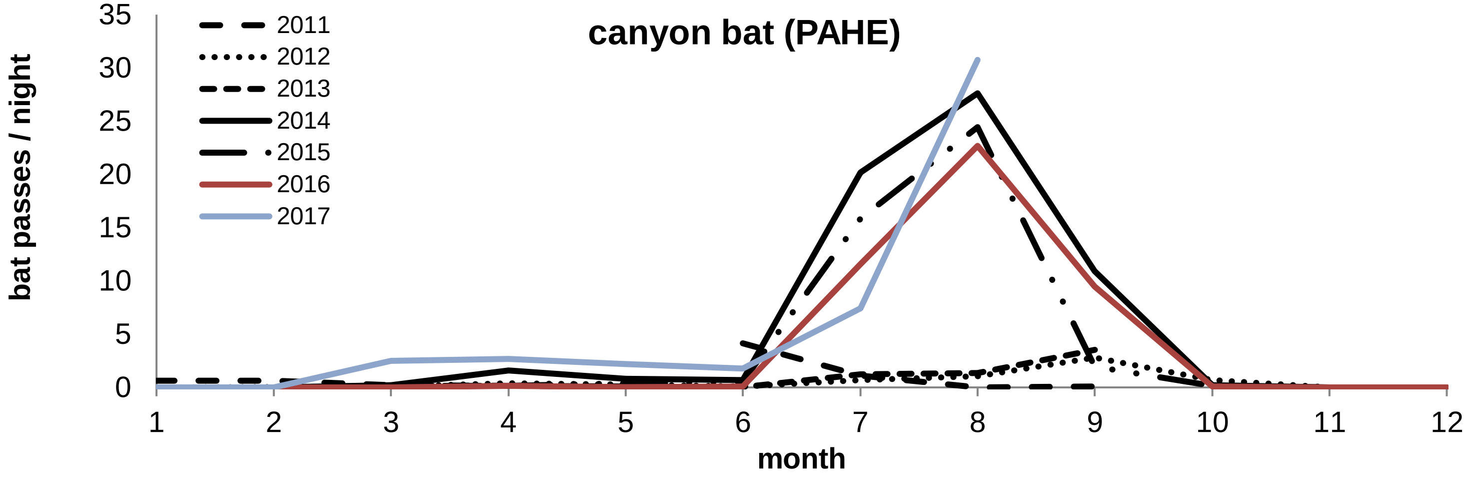
WESTERN MASTIFF BAT	
Occurrence/habitat	Found in a variety of habitats to > 3000 m in elevation. From desert scrub to chaparral to oak woodland and into the ponderosa pine belt.
Feeding type/food source	Detected most often over meadows and other open areas, but will also feed above forest canopy; sometimes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



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.

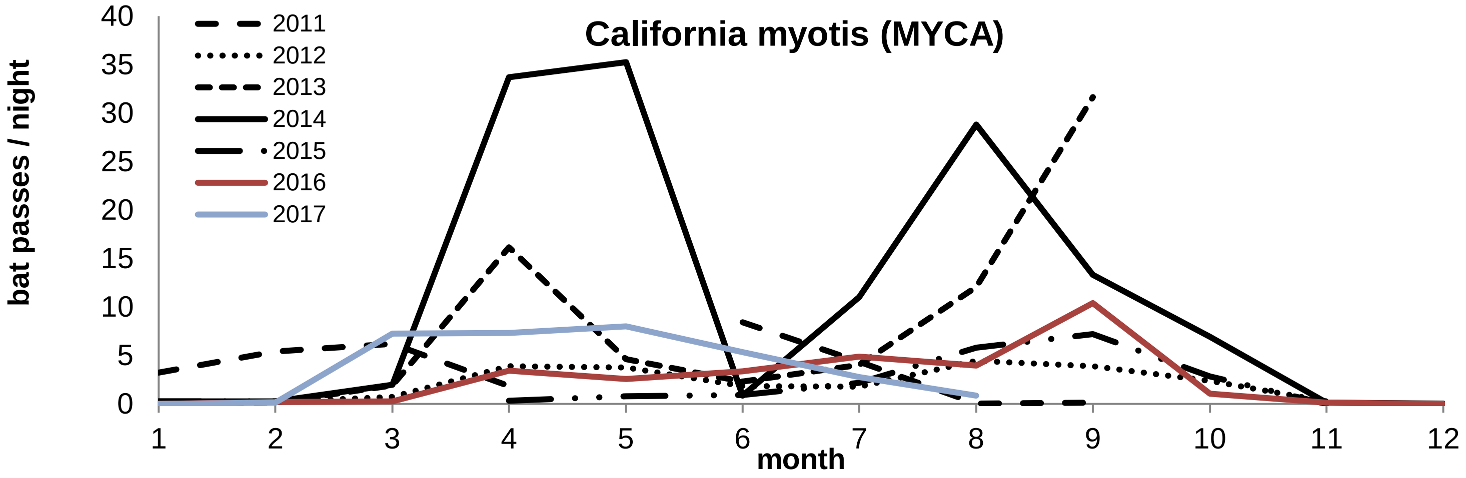


CANYON BAT	
Occurrence/habitat	Wide range including desert, grassland, woodland, and mixed conifer forests. Yearlong resident in California.
Feeding type/food source	Feeds at low to moderate heights over water, rocky canyons, and along cliff faces.
Roosting structure	Roosts in rock crevices, mines, caves, and buildings.
Seasonal movements	Yearlong resident in California. May make local movements.

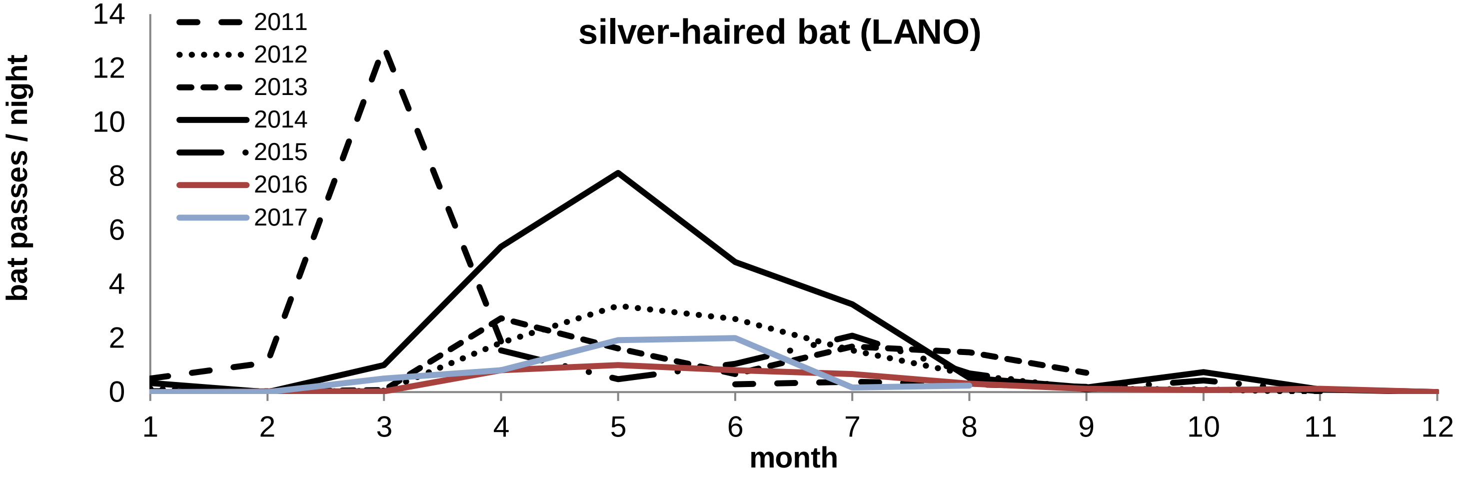


CALIFORNIA MYOTIS

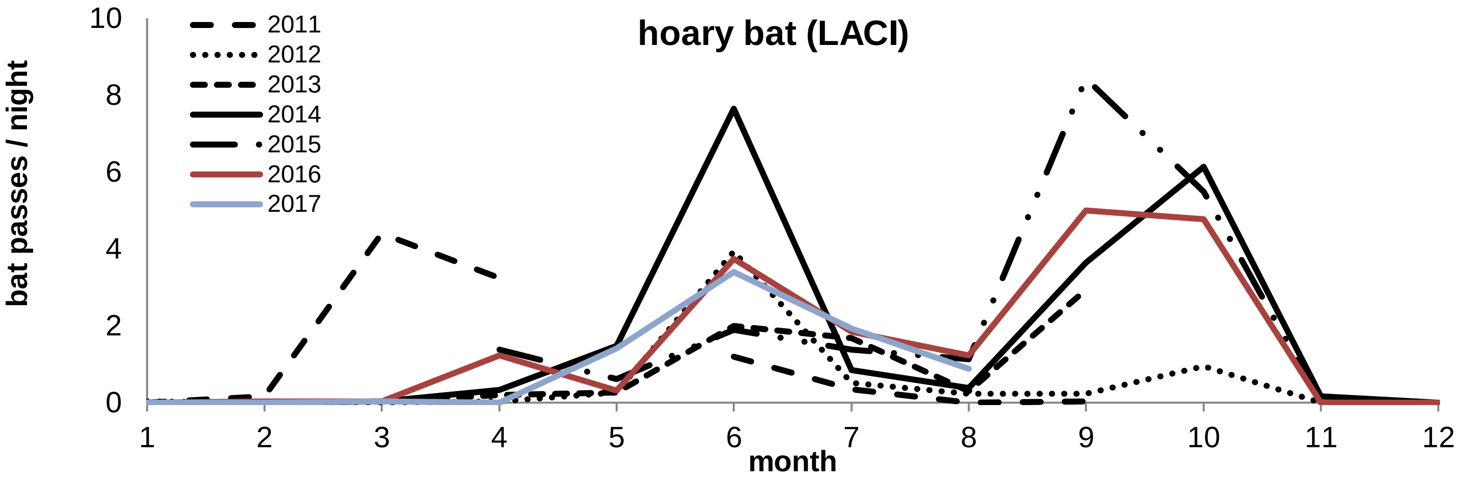
Occurrence/habitat	Broad distribution over western North America, most abundant at mid-elevations. Found in almost every habitat.
Feeding type/food source	Forages in canopy and along riparian corridors on insects and moths.
Roosting structure	Uses crevices in wide variety of natural and anthropogenic structures.
Seasonal movements	Individuals can be active in winter, even in below freezing temperatures.



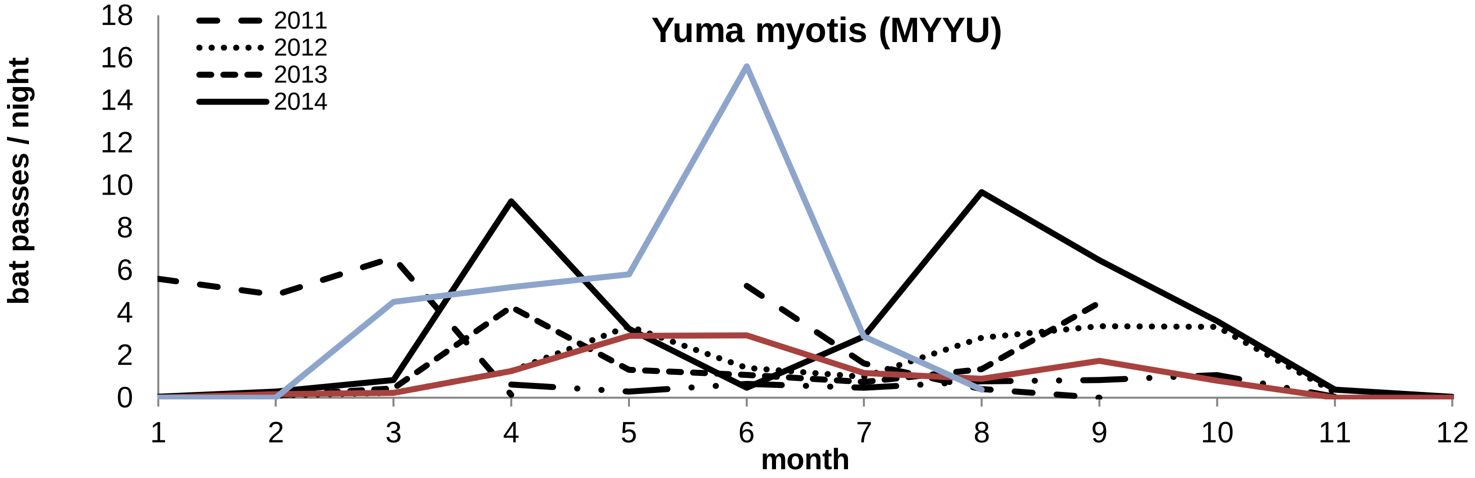
SILVER-HAIRED BAT	
Occurrence/habitat	Broad distribution concentrated in northern part of CA.
Feeding type/food source	Forages above canopy, in forest clearings, and in riparian zone along water courses for wide variety of insects and moths.
Roosting structure	Roosts in trees.
Seasonal movements	Migratory



HOARY BAT	
Occurrence/habitat	The hoary bat is the most widespread North American bat. Habitats include cottonwood riparian habitat, forested areas, and woodlands.
Feeding type/food source	Feeds primarily on moths.
Roosting structure	Roosts in dense foliage of medium to large-size trees.
Seasonal movements	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.



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.



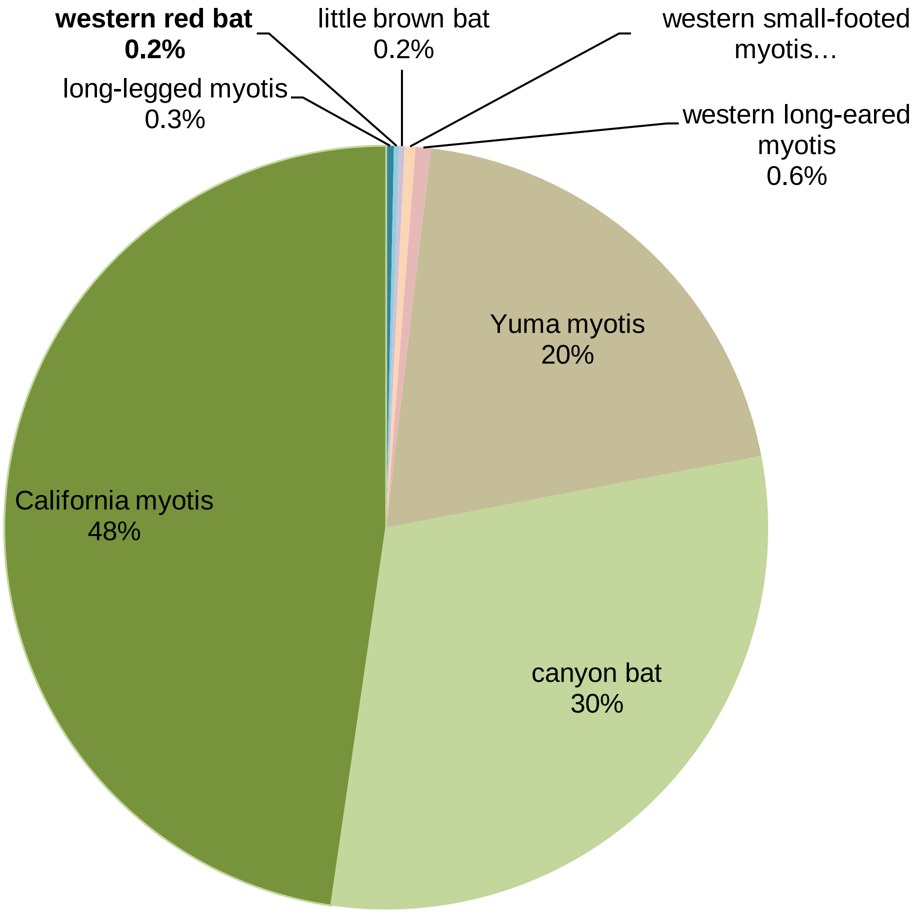


Figure 5-6. Percentage of all detections between April 2011 and August 2017 belonging to each species (high-frequency calls).

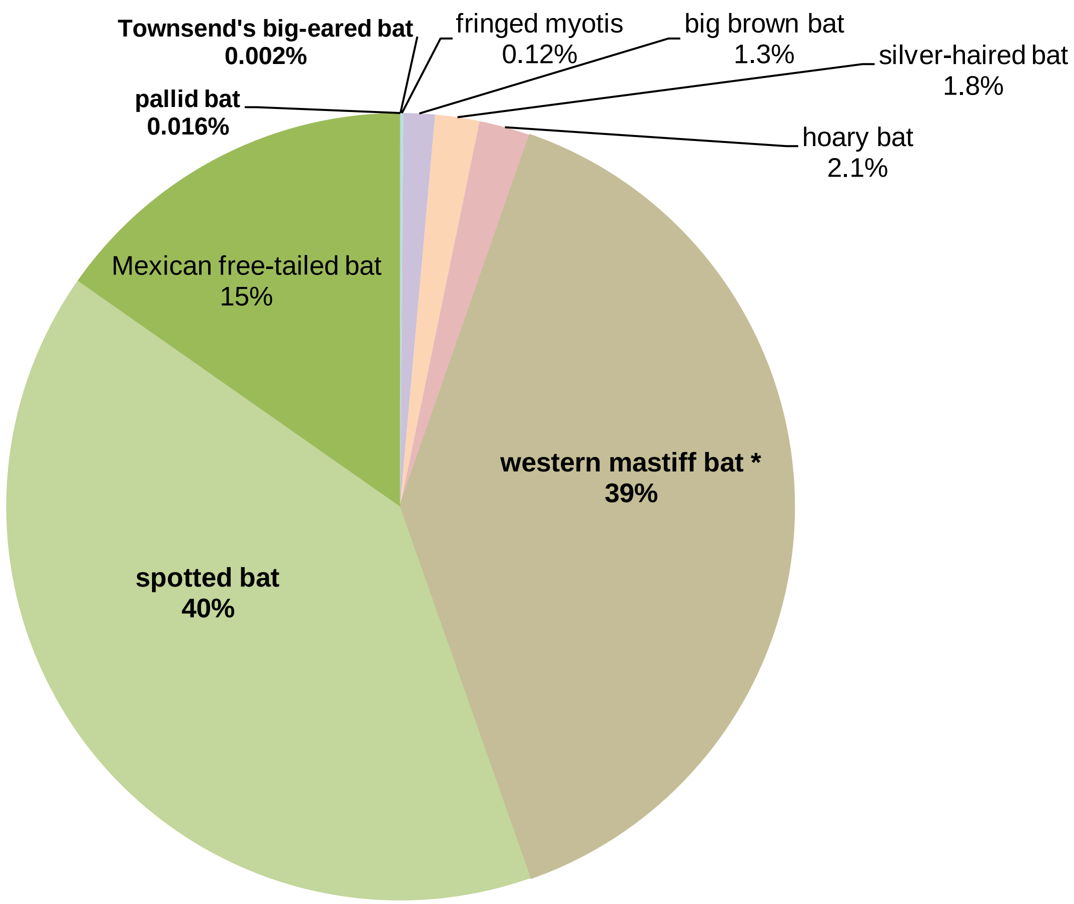


Figure 5-7. Percentage of all detections between April 2011 and August 2017 belonging to each species (low-frequency calls). *Spotted bat and western mastiff bat emit calls that are at very low frequency and are audible to the human ear. These two species are the easiest to detect with an acoustic sensor.

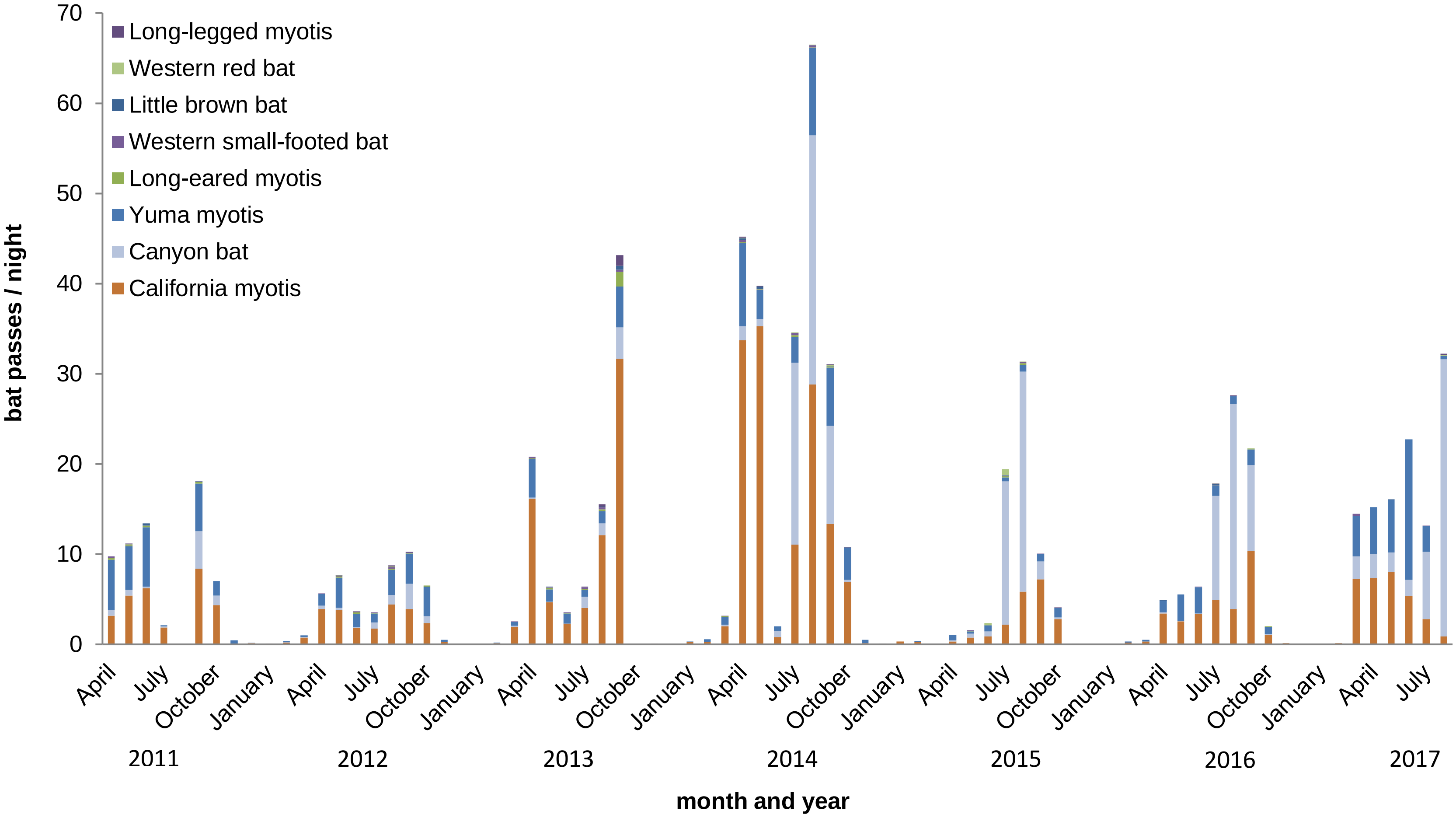


Figure 5-8. Bat detections by month of 8 species that echolocate at a high frequency. Passes per night are calculated as the max between the north and south detectors from 14 April 2011 to 8 August 2017. The vertical axis is number of bat passes normalized by the number of recording nights that month.

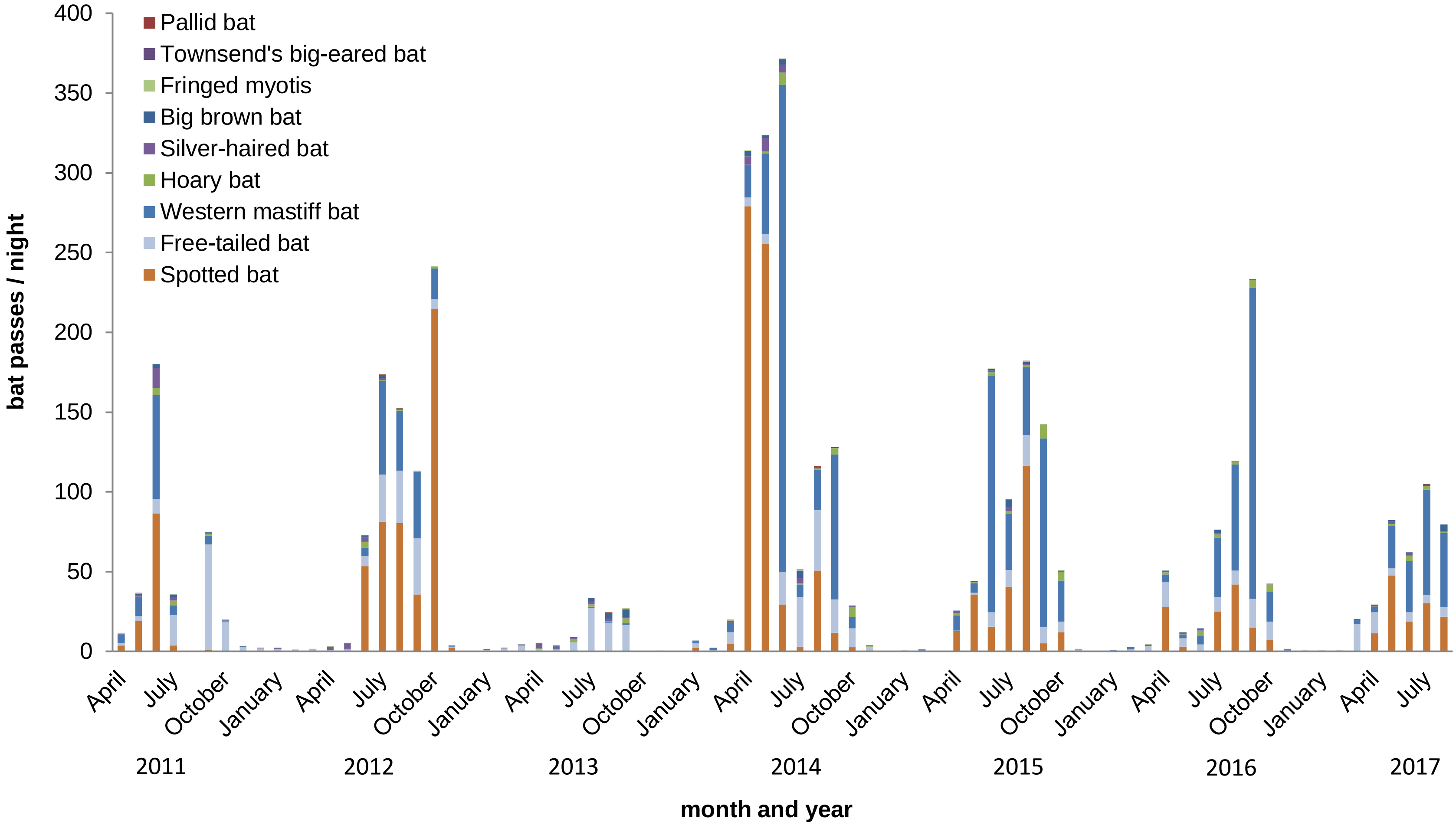


Figure 5-9. Bat detections by month of 9 species that echolocate at a low frequency. Passes per night are calculated as the maximum between the north and south detectors from 14 April 2011 to 8 August 2017. The vertical axis is number of bat passes normalized by the number of recording nights that month.

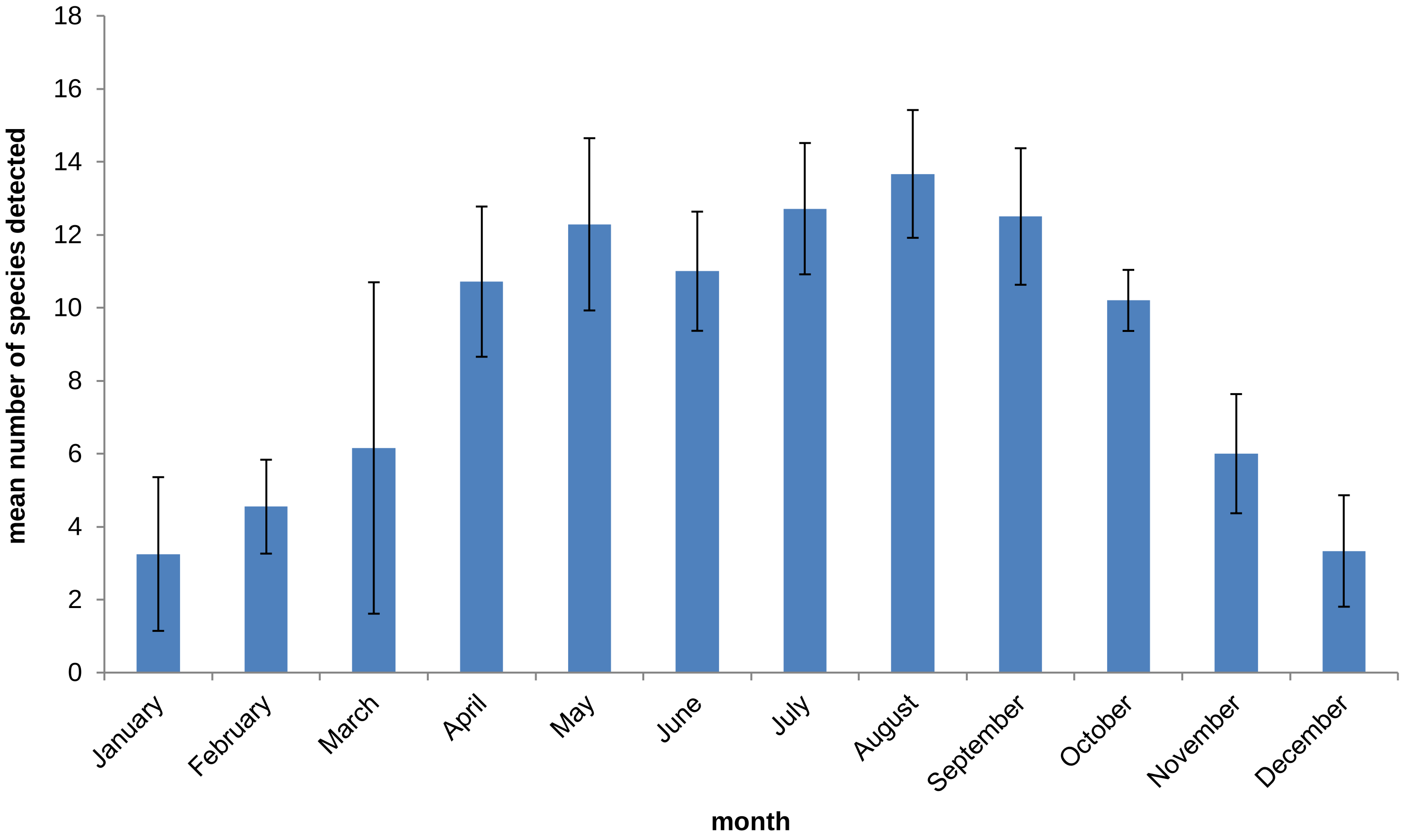


Figure 5-10. Bat species richness detected in Poopenaut Valley at both detector sites. Mean is presented per month from 2011-2017. Error bars represent one standard deviation.

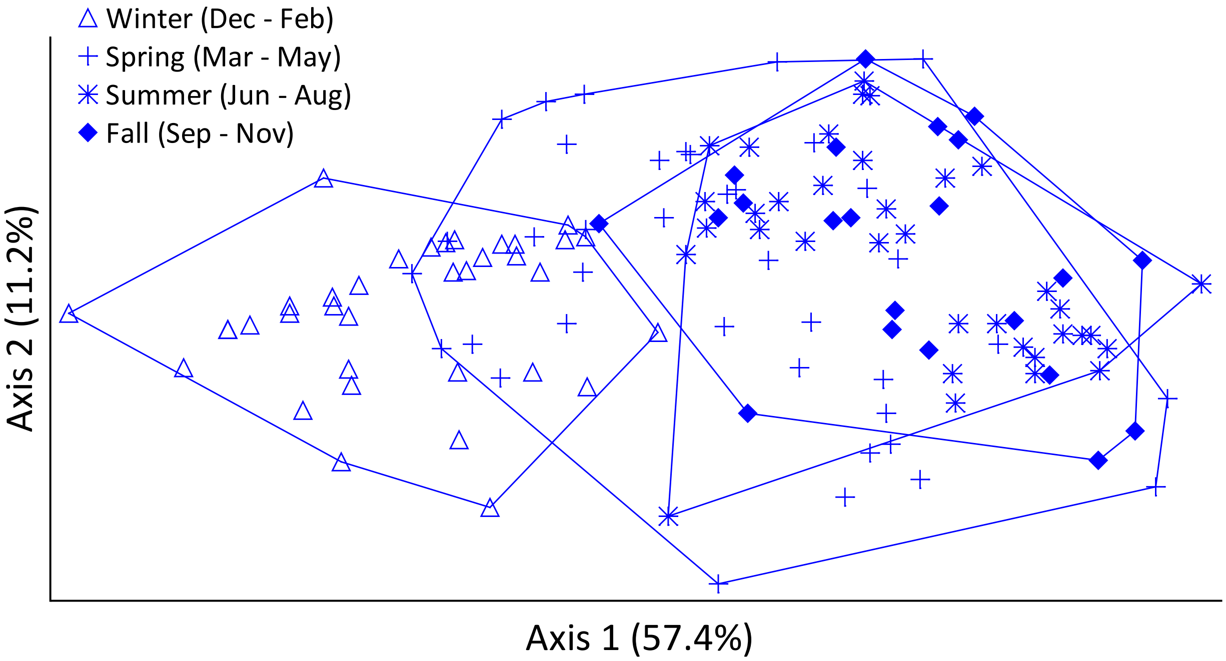


Figure 5-11. Non-parametric multidimensional scaling (NMS) representation of bat activity community composition in Poopenaut Valley from 2011 to 2017. Distances are Sorenson (Bray-Curtis). A two-dimensional solution was recommended (stress = 9.7). Symbols represent community composition for each month. Hulls represent seasons. Community composition of bat activity is significantly different between seasons with winter being the most distinct. However, summer community composition was not distinct from community composition in the fall (see Table 5-4).

Table 5-4. Differences in bat activity community composition from April 2011 to August 2017 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>Season</u>	0.14	0.000*
Winter vs. Spring	0.09	0.000**
Winter vs. Summer	0.19	0.000**
Winter vs. Fall	0.17	0.000**
Spring vs. Summer	0.05	0.000**
Spring vs. Fall	0.04	0.000**
Summer vs. Fall	0.00	0.293

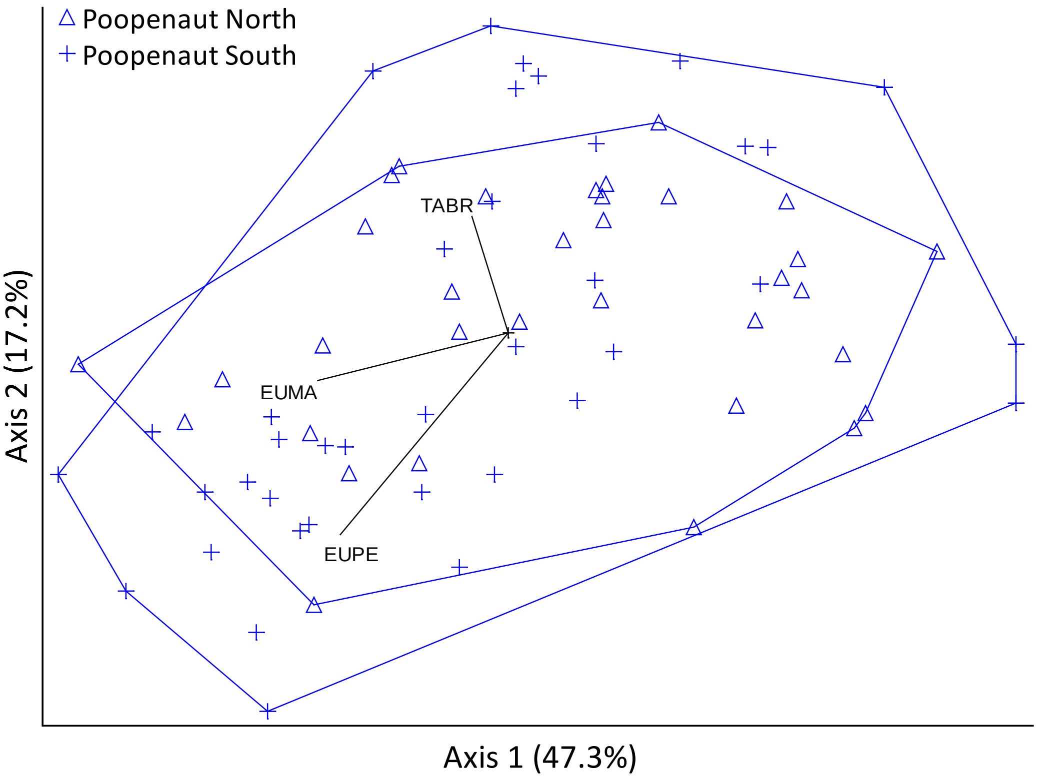
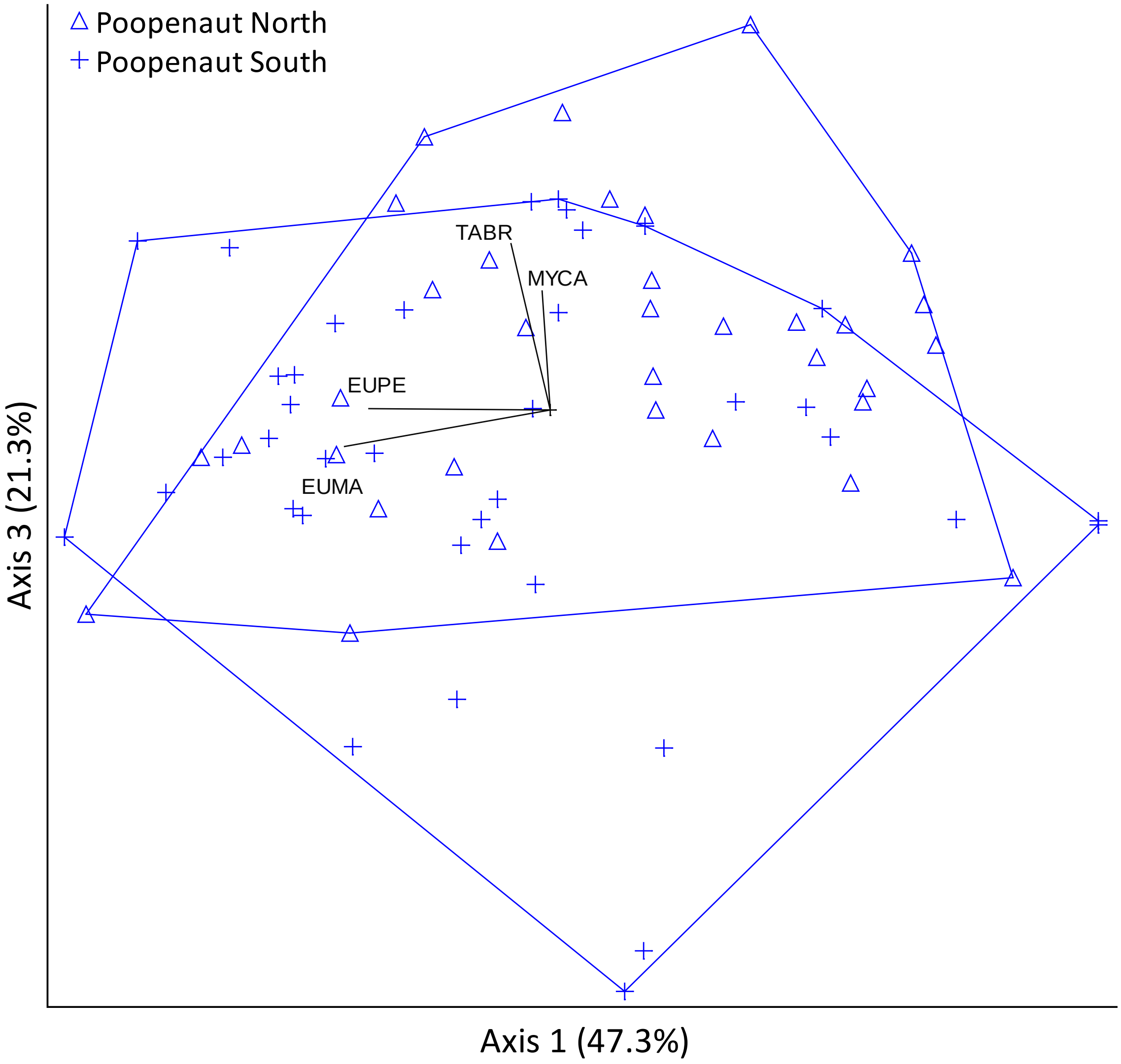


Figure 5-12. Non-parametric multidimensional scaling (NMS) representation of bat activity community composition in Poopenaut Valley from 2011 to 2017. Only non-winter months are represented (May – October). Distances are Sorenson (Bray-Curtis). A three-dimensional solution was recommended (stress = 9.9). Symbols represent community composition for each month. Hulls represent study locations. Vectors represent the correlation of species to each axis where the length of the vector is proportional to the degree of correlation. Kendall R^2 > 0.20 are shown. Community composition of bat activity was significantly different between sites (Table 5-5).

Figure 5-12 Continued.



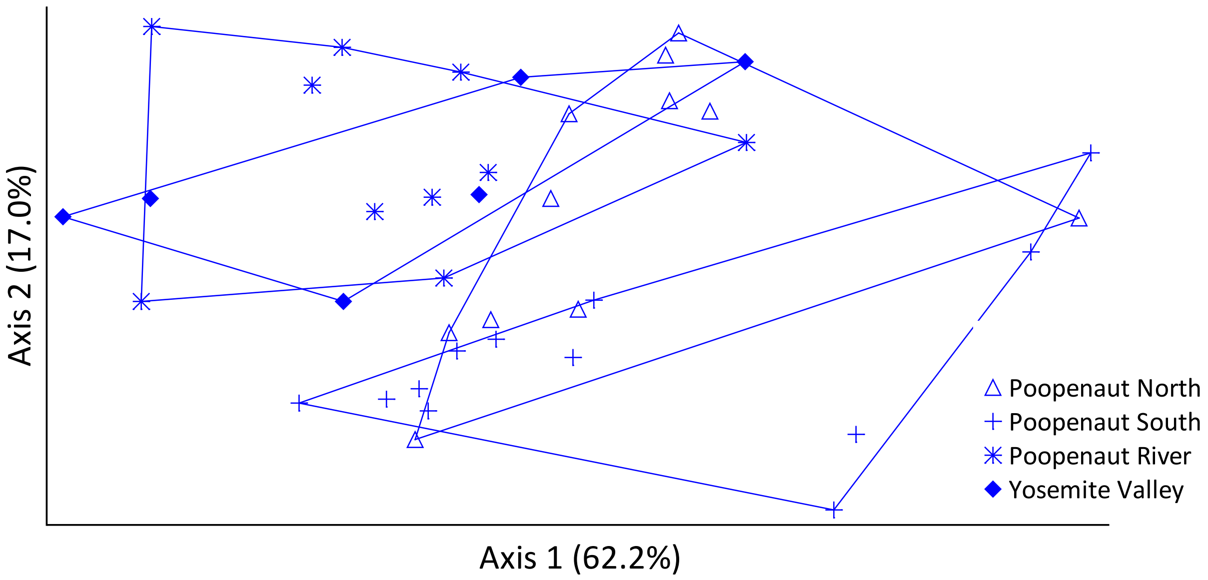


Figure 5-13. Non-parametric multidimensional scaling (NMS) representation of bat activity community composition in Poopenaut Valley and Yosemite Valley from May 2016 to August 2017. Only non-winter months are represented (May – October). Distances are Sorenson (Bray-Curtis). A two-dimensional solution was recommended (stress = 9.3). Symbols represent community composition for each month. Hulls represent study locations. Community composition of bat activity is significantly different between Poopenaut River and both the Poopenaut North and South sites (see Table 5-5).

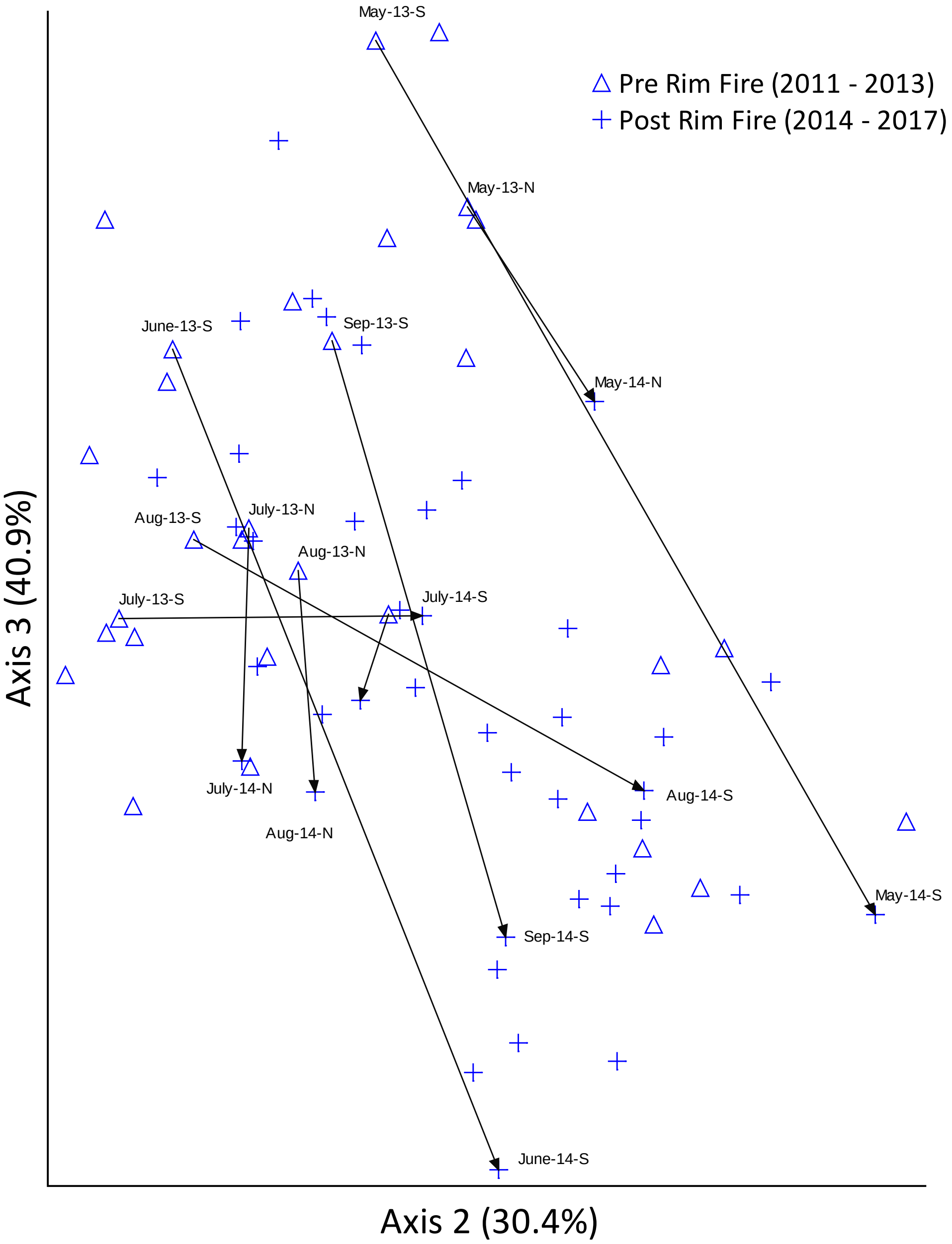


Figure 5-14. Non-parametric multidimensional scaling (NMS) representation of bat activity community composition in Poopenaut Valley from 2011 to 2017. Only non-winter months are represented (May – October). Distances are Sorenson (Bray-Curtis). A three-dimensional solution was recommended (stress = 9.6) Symbols represent community composition for each month. Hulls represent years before and after the Rim Fire. Vectors represent the distance in community space between bat community composition in a given month in 2013 versus 2014. Community composition of bat activity was significantly different between before and after the Rim Fire (Table 5-5).

Figure 5-14 Continued. Hulls represent pre and post fire community composition. Vectors represent the correlation of species to each axis where the length of the vector is proportional to the degree of correlation. Kendall R^2 > 0.20 are shown.

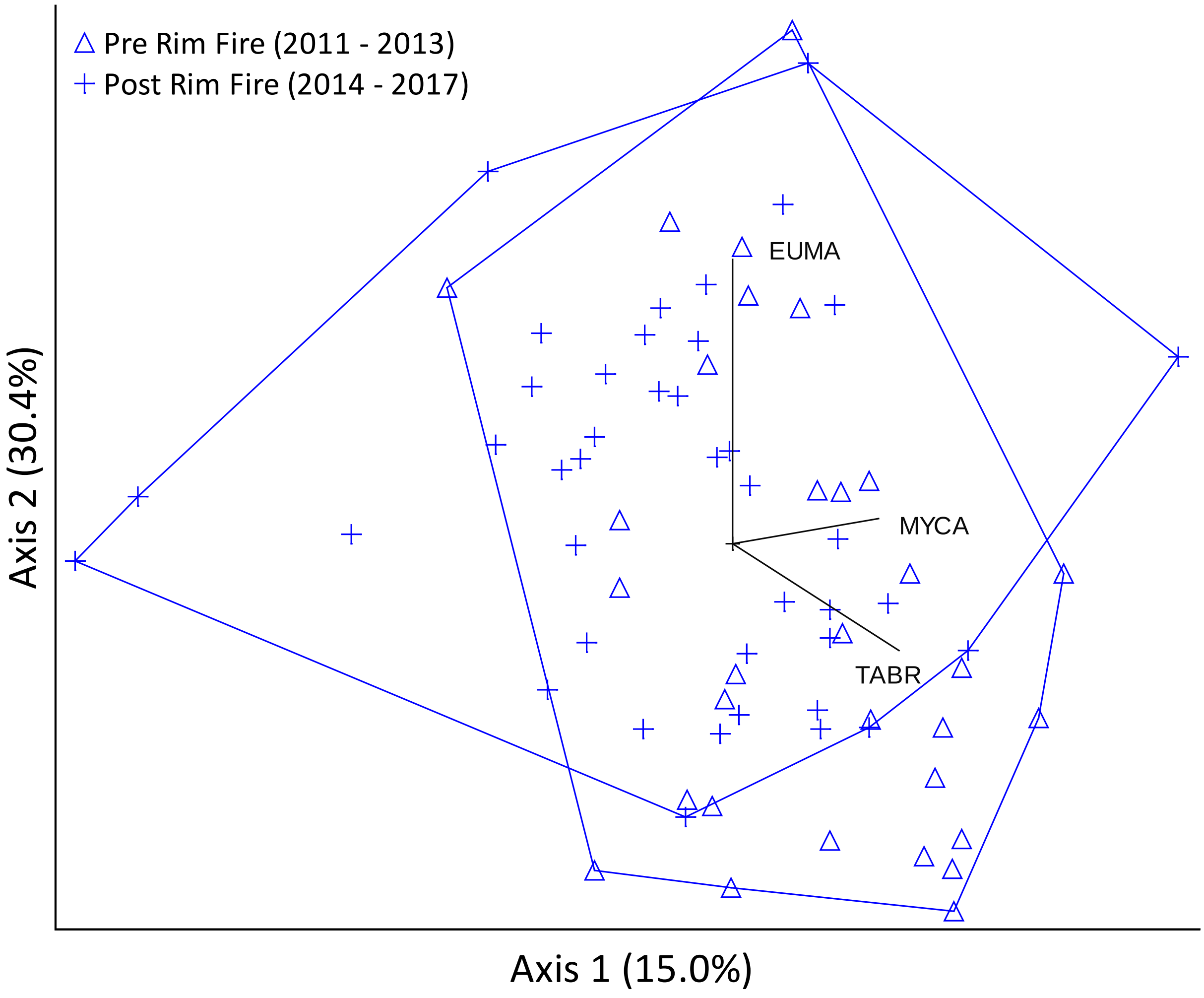


Figure 5-14 Continued. Hulls represent pre and post fire community composition. Vectors represent the correlation of species to each axis where the length of the vector is proportional to the degree of correlation. Kendall R^2 > 0.20 are shown.

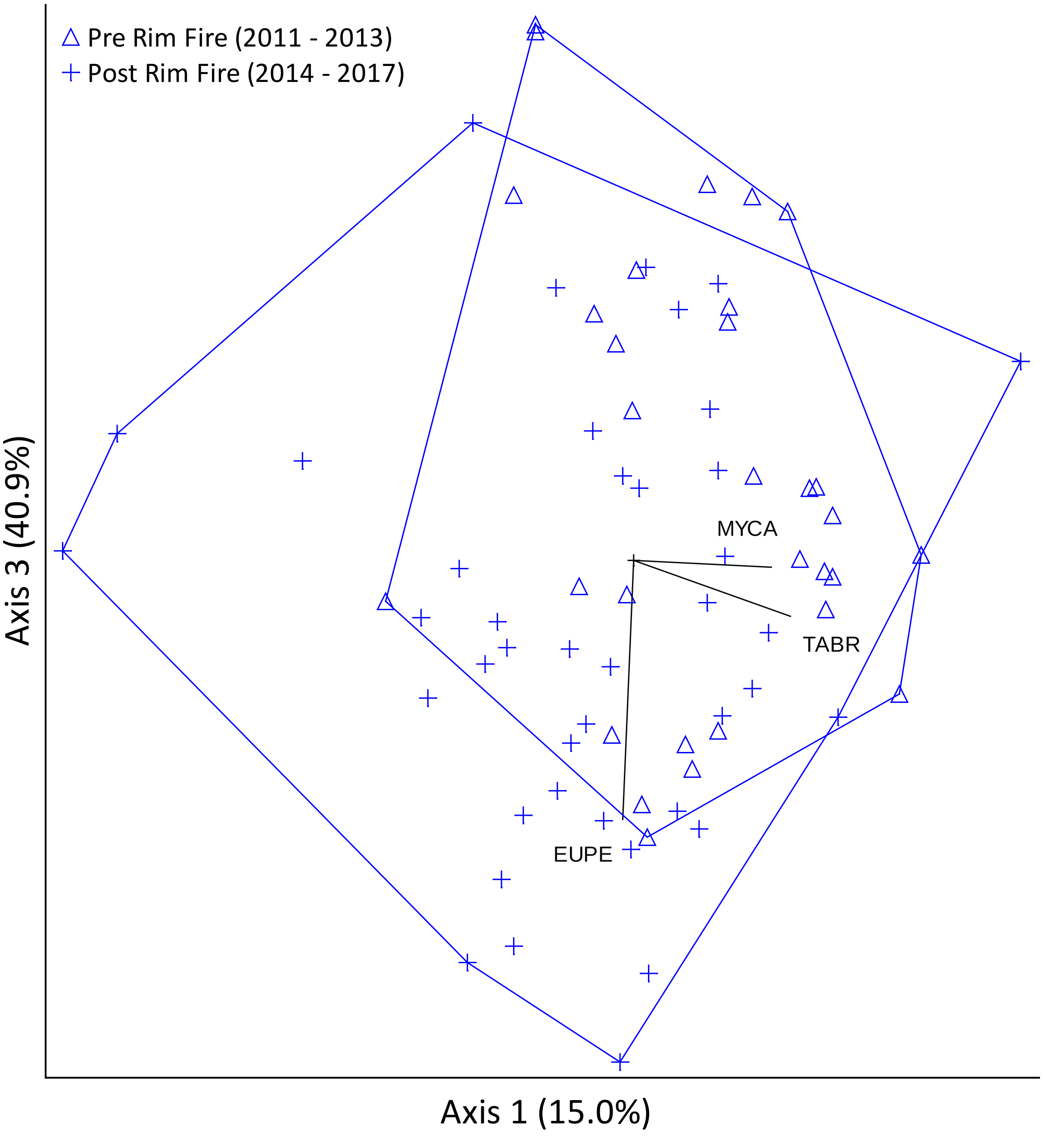


Table 5-5. Differences in non-winter (May – October) bat activity community composition from April 2011 to July 2017 between study sites and years determined by multi-response permutation procedure (MRPP). Significance at the α < 0.05 level is represented by *. A Bonferoni correction was applied to pairwise comparisons (α = 0.05 / 6 or 21 = 0.008 or 0.0024). Significance at the α < 0.008 / 0.0024 level is represented by **.

Source	Bat Community Composition	
	A	*p*
Rim Fire (before & after)	0.03	0.000*
Acoustic survey location (north vs. south – 2011 to 2017)	0.02	0.002*
Acoustic survey location (all sites – 2016 to 2017)	0.07	0.000*
South vs. North	0.03	0.044
South vs. River	0.09	0.000**
North vs. River	0.07	0.002**
South vs. Yosemite	0.05	0.025
North vs. Yosemite	0.02	0.147
River vs. Yosemite	-0.00	0.460

Table 5-5 Continued.

Source	Bat Community Composition	
	A	*p*
Year	0.05	0.004*
2011 vs. 2012	0.00	0.576
2011 vs. 2013	0.02	0.153
2011 vs. 2014	0.01	0.212
2011 vs. 2015	0.01	0.278
2011 vs. 2016	0.01	0.300
2011 vs. 2017	0.12	0.003
2012 vs. 2013	0.04	0.036
2012 vs. 2014	0.03	0.066
2012 vs. 2015	0.00	0.371
2012 vs. 2016	0.02	0.103
2012 vs. 2017	0.10	0.006
2013 vs. 2014	0.09	0.000**
2013 vs. 2015	0.06	0.008
2013 vs. 2016	0.07	0.003
2013 vs. 2017	0.25	0.000**
2014 vs. 2015	0.02	0.126
2014 vs. 2016	0.02	0.140
2014 vs. 2017	0.09	0.002**
2015 vs. 2016	-0.02	1.000
2015 vs. 2017	0.06	0.029
2016 vs. 2017	0.06	0.027

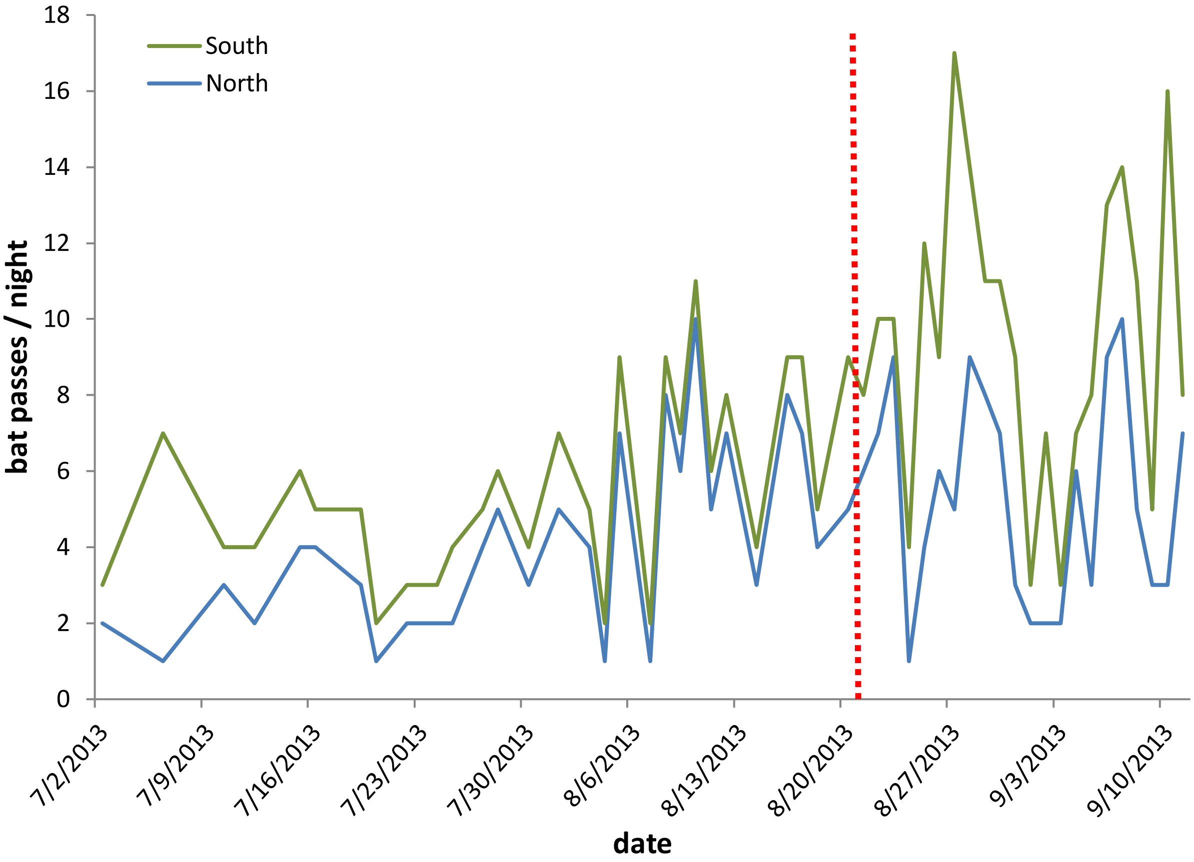


Figure 5-15. Bat detections by night of California myotis from July 1 to September 10, 2013. The vertical red line represents the arrival of the Rim Fire, which burned on the north side of the river from August 23 to August 24 and on the south side from September 9 to September 10, 2013.

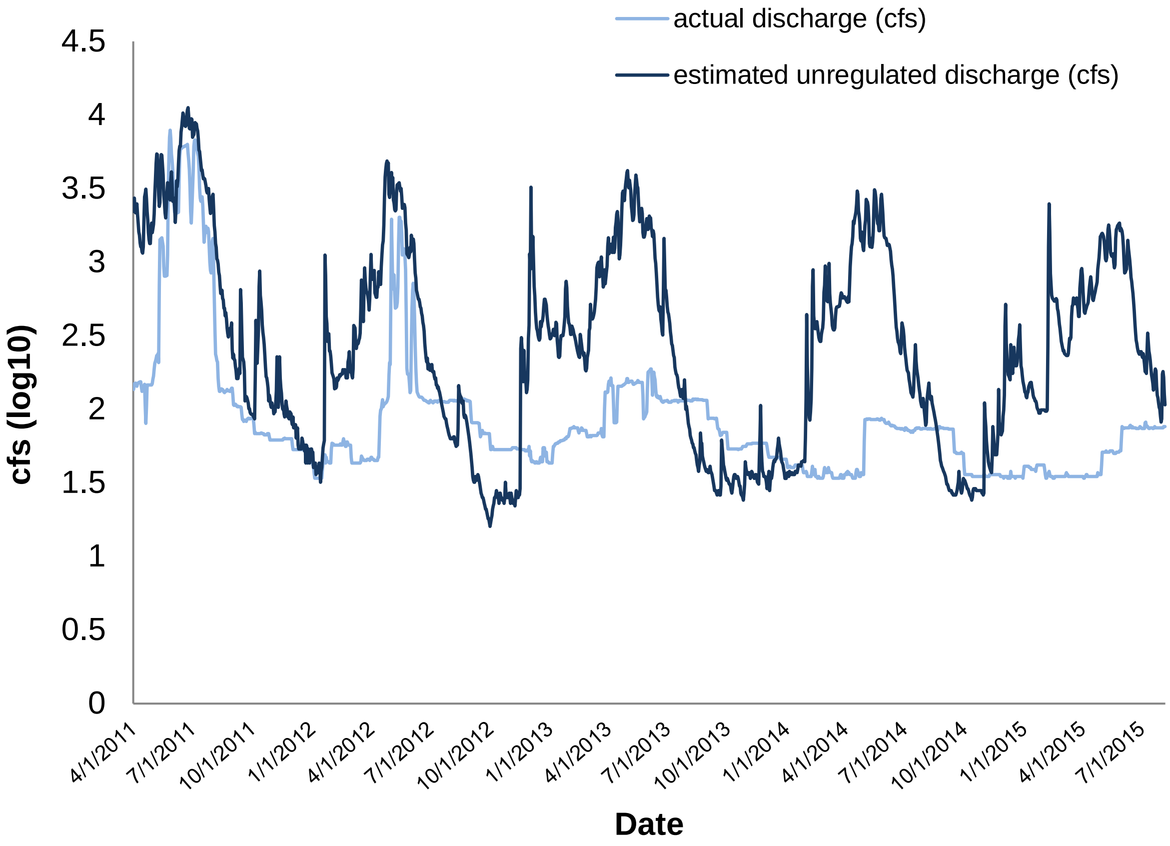


Figure 5-16. Discharge in cfs from April 2011 to April 2015 for the Hetch-Hetchy reach of the Tuolumne River. Data from the USGS.

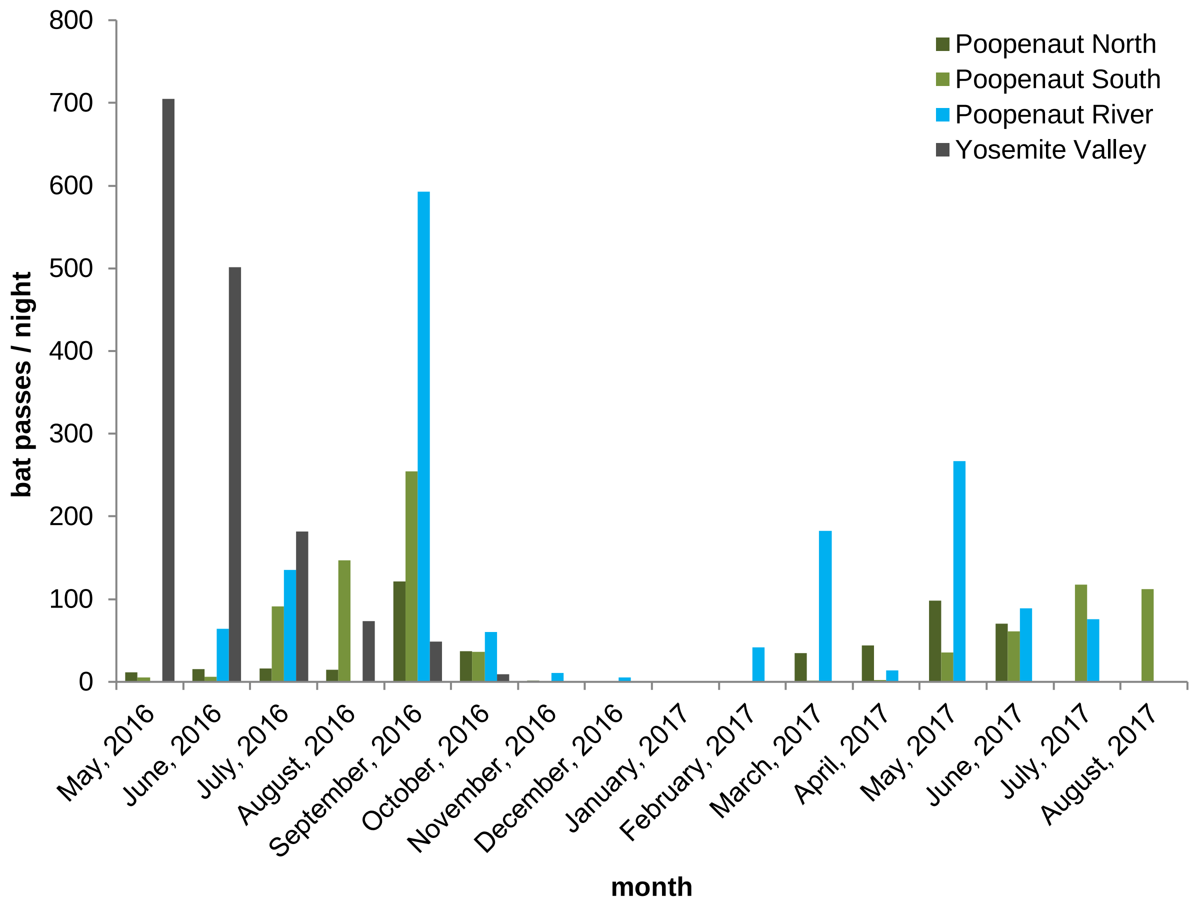


Figure 5-17. Number of bat passes per night for each study location from May 2016 to August 2017. The Yosemite Valley detector was removed after October, 2016. In addition, no data was collected from the following: Poopenaut North from December 2016 to February 2017 and July 2017; Poopenaut South in November 2016; and Poopenaut River in May 2016 and August 2017.

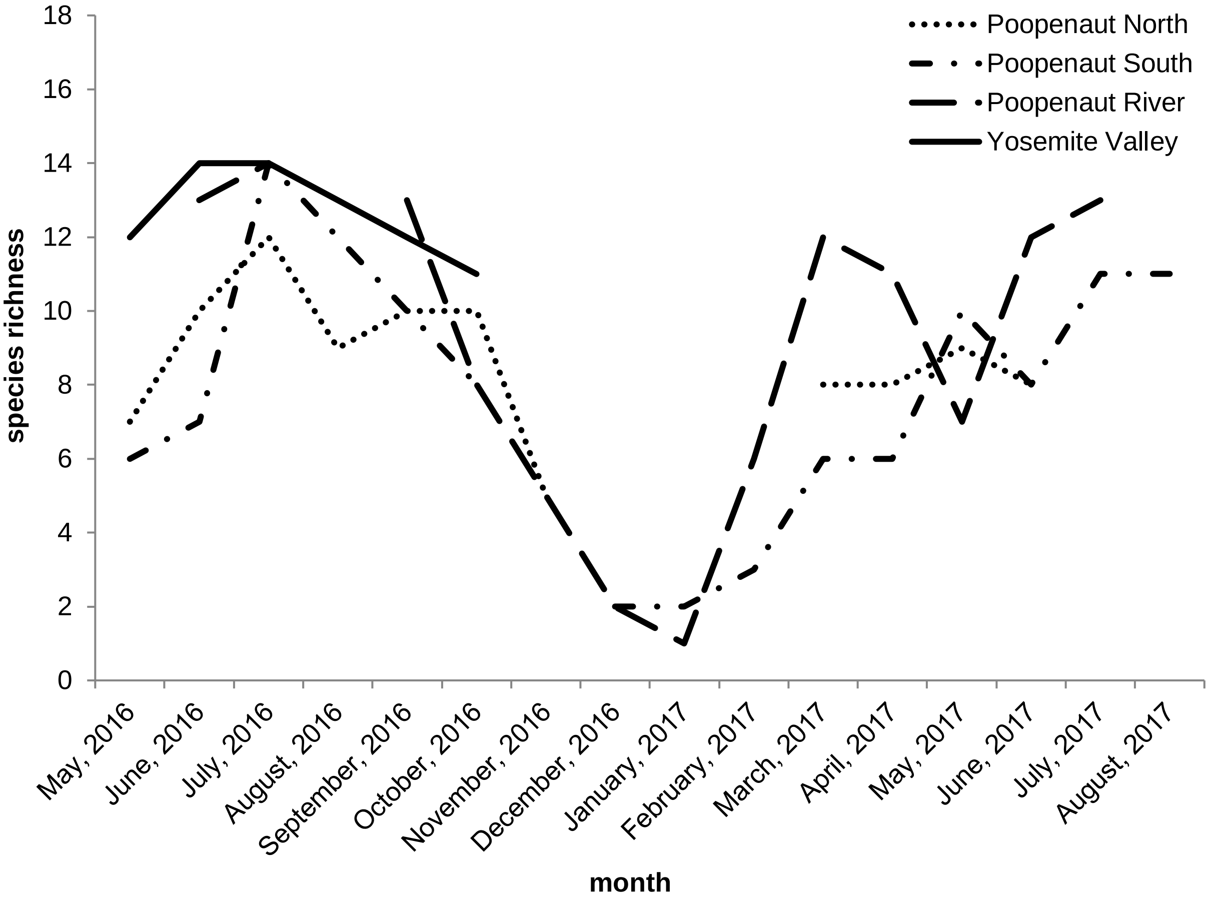


Figure 5-18. Species richness at the four study locations monitored in 2016 and 2017 by month. Broken lines indicate a gap in monitoring for a given location.

Table 5-6. Summary statistics for estimates of δ^{15}N, δ^{13}C, reliance on aquatically derived energy, and trophic position generated from all blood samples collected from bats in 2016 from Poopenaut and Yosemite Valley sampling locations.

	n	δ^{15}N				δ^{13}C				% aquatic				trophic position			
Month/Site/Species		min	$\bar{x}$	SD	max	min	$\bar{x}$	SD	max	min	$\bar{x}$	SD	max	min	$\bar{x}$	SD	max
May																	
Poopenaut																	
MYYU	4	6.4	7.3	0.68	7.9	-24.1	-23.7	0.33	-23.5	0.68	0.74	0.05	0.78	3.44	3.67	0.19	3.85
MYCA	2	5.9	6.0	0.13	6.1	-24.8	-24.0	1.05	-23.3	0.56	0.61	0.07	0.66	3.30	3.32	0.03	3.34
MYTH	1	7.3	7.3	-	7.3	-23.6	-23.6	-	-23.6	0.75	0.75	-	0.75	3.67	3.67	-	3.67
LANO	1	5.7	5.7	-	5.7	-23.0	-23.0	-	-23.0	0.64	0.64	-	0.64	3.22	3.22	-	3.22
All	**8**	**5.7**	**6.6**	**0.82**	**7.9**	**-24.8**	**-23.6**	**0.42**	**-23.0**	**0.56**	**0.69**	**0.07**	**0.78**	**3.22**	**3.47**	**0.23**	**3.85**
Yosemite																	
MYYU	3	6.0	6.4	0.51	7.0	-25.9	-24.6	1.12	-23.8	0.54	0.62	0.08	0.70	3.32	3.45	0.14	3.60
All	**3**	**6.0**	**6.4**	**0.51**	**7.0**	**-25.9**	**-24.6**	**1.12**	**-23.8**	**0.54**	**0.62**	**0.08**	**0.70**	**3.32**	**3.45**	**0.14**	**3.60**
June																	
Poopenaut																	
MYCA	1	5.9	5.9	-	5.9	-24.3	-24.3	-	-24.3	0.59	0.59	-	0.59	3.29	3.29	-	3.29
MYEV	1	4.8	4.8	-	4.8	-24.2	-24.2	-	-24.2	0.52	0.52	-	0.52	2.98	2.98	-	2.98
All	**2**	**4.8**	**5.4**	**0.76**	**5.9**	**-24.3**	**-24.2**	**0.08**	**-24.2**	**0.52**	**0.56**	**0.05**	**0.59**	**2.98**	**3.14**	**0.22**	**3.29**
Yosemite																	
MYCA	1	6.5	6.5	-	6.5	-24.8	-24.8	-	-24.8	0.61	0.61	-	0.61	3.47	3.47	-	3.47
MYYU	3	6.4	7.9	2.33	10.6	-25.0	-24.4	0.56	-24.0	0.62	0.73	0.17	0.92	3.44	3.87	0.66	4.63
MYTH	2	6.3	6.3	0.01	6.3	-24.1	-23.8	0.47	-23.4	0.63	0.65	0.02	0.67	3.39	3.39	0.01	3.40
All	**6**	**6.3**	**6.9**	**0.90**	**10.6**	**-25.0**	**-24.3**	**0.54**	**-23.4**	**0.61**	**0.66**	**0.06**	**0.92**	**3.39**	**3.58**	**0.26**	**4.63**

Table 5-6 Continued.

September																	
Poopenaut																	
MYYU/YULU/MYLU	23	5.5	7.8	2.68	17.7	-26.1	-22.7	1.83	-19.5	0.59	0.76	0.11	0.98	3.16	3.84	0.77	6.70
All	**23**	**5.5**	**7.8**	**2.68**	**17.7**	**-26.1**	**-22.7**	**1.83**	**-19.5**	**0.59**	**0.76**	**0.11**	**0.98**	**3.16**	**3.84**	**0.77**	**6.70**
Yosemite/Cascade																	
MYYU	27	5.5	8.3	2.69	15.6	-27.8	-22.9	2.28	-19.4	0.53	0.77	0.14	0.97	3.16	3.98	0.78	6.09
MYTH	1	4.8	4.8	-	4.8	-22.9	-22.9	-	-22.9	0.59	0.59	-	0.59	2.98	2.98	-	2.98
TABR	1	4.8	4.8	-	4.8	-22.4	-22.4	-	-22.4	0.61	0.61	-	0.61	2.98	2.98	-	2.98
EPFU	1	3.6	3.6	-	3.6	-21.3	-21.3	-	-21.3	0.61	0.61	-	0.61	2.60	2.60	-	2.60
All	**30**	**3.6**	**5.4**	**2.04**	**15.6**	**-27.8**	**-22.4**	**0.77**	**-19.4**	**0.53**	**0.65**	**0.08**	**0.97**	**2.60**	**3.13**	**0.59**	**6.09**

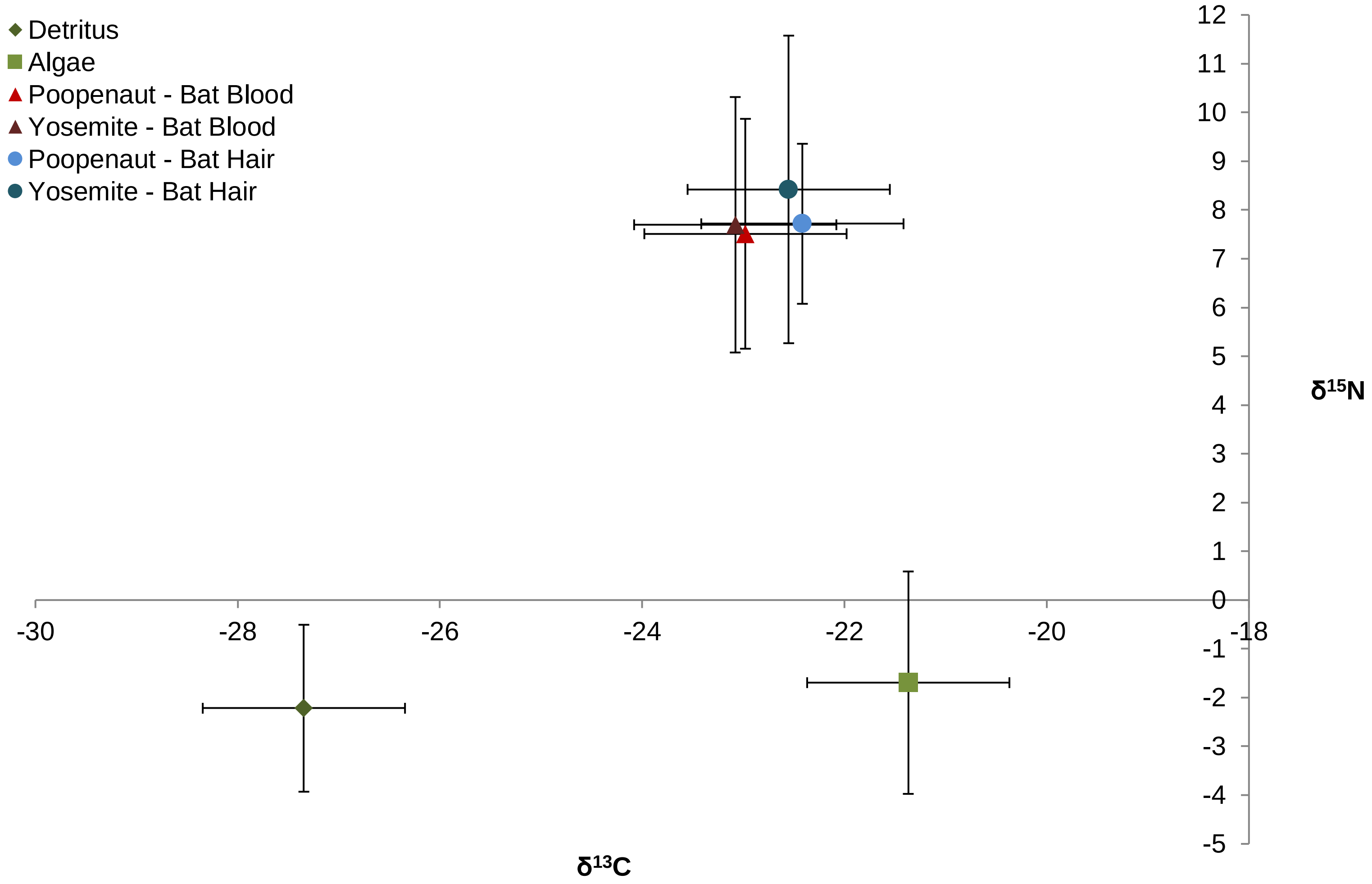


Figure 5-19. Bi-plot of δ^{13}C and δ^{15}N values for detritus, algae, bat blood, and bat hair from Yosemite and Poopenaut Valley. Markers indicate mean, bars are one standard deviation from the mean. All sites and dates are included. Algae and detritus estimates are those measured by Jackson and Sullivan (2017) from 77 locations along the Merced, Tuolumne, and the South Fork of the Merced Rivers and their tributaries.

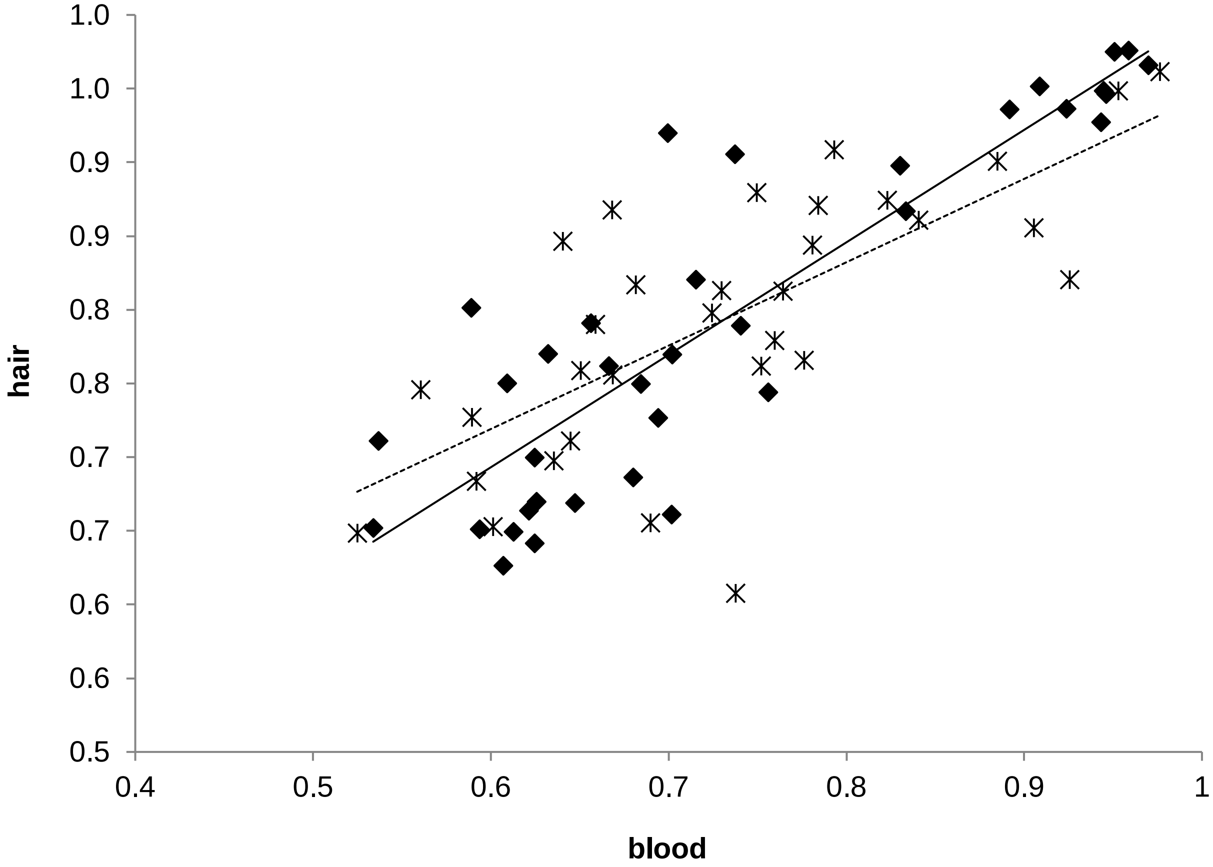


Figure 5-20. Linear relationship between bat reliance on aquatically derived nutritional subsidies estimated from blood and hair samples. Diamonds represent bats sampled in Poopenaut Valley (R^2 = 0.52), and asterisks represent bats sampled at Cascade (R^2 = 0.77). Estimates from blood give an indication of diet from the last few days, while estimates from hair indicate diet over months. The positive correlation indicates that bats have a high degree of diet fidelity over time and that they are more reliant on an aquatic energetic pathway at other times of the year than in September when the samples were collected.

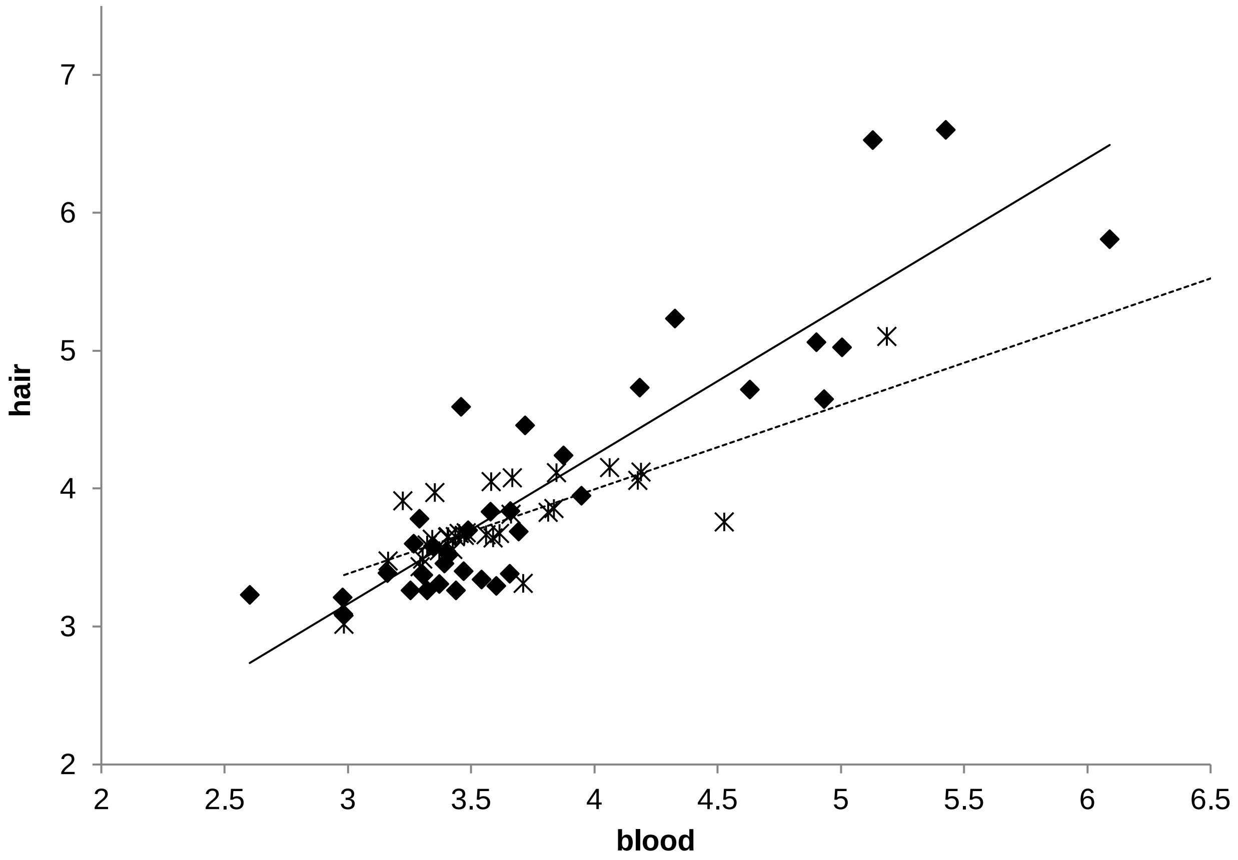


Figure 5-21. Linear relationship between bat trophic position estimated from blood and hair samples. Asterisks represent bats samples in Poopenaut Valley (R^2 = 0.79), and diamonds represent bats samples at Cascade (R^2 = 0.80). Estimates from blood give an indication of diet from the last few days, while estimates from hair indicate diet over months. The positive correlation indicates that bats have a high degree of diet fidelity over time and that occupy and higher trophic position at other times of the year than in September when the samples were collected.

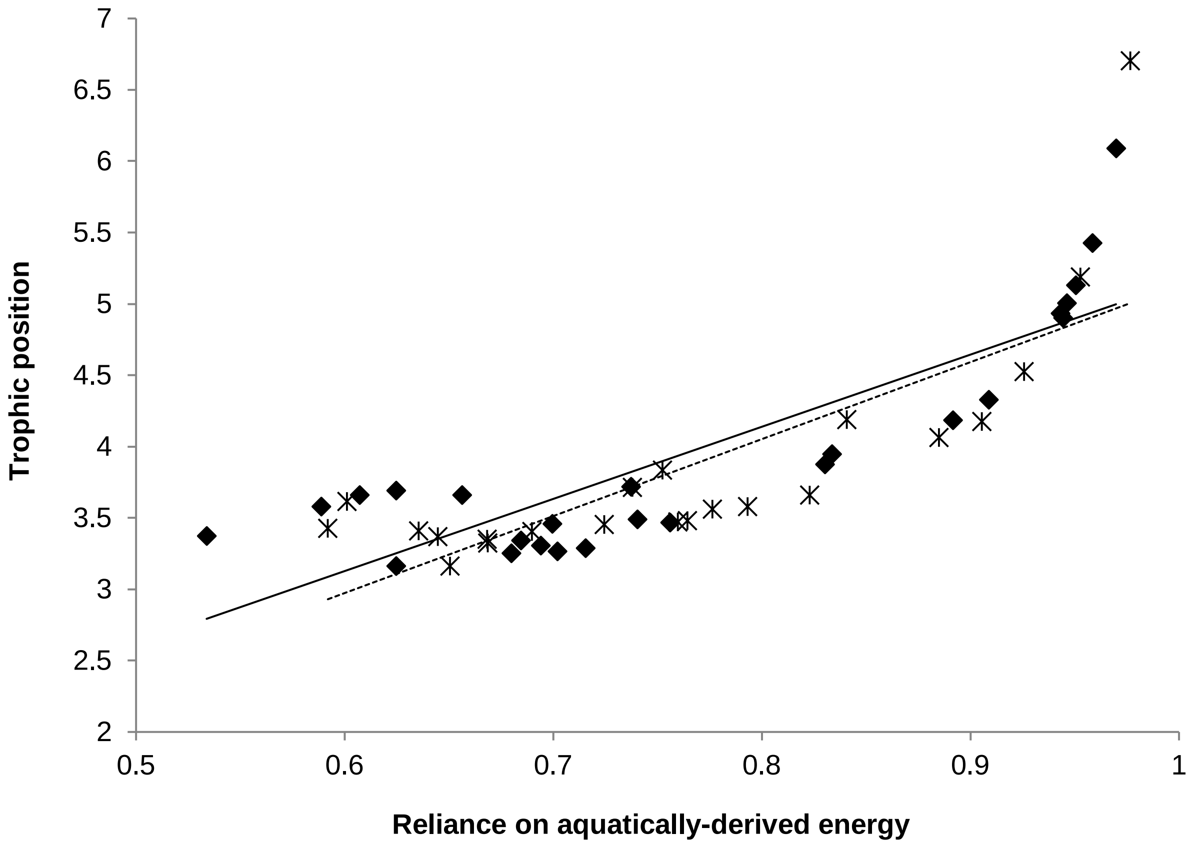


Figure 5-22. Linear relationship between reliance on aquatically derived energy by bats and trophic position estimated from blood samples. Asterisks represent bats samples in Poopenaut Valley ($R^2 = 0.61$), and diamonds represent bats samples at Cascade ($R^2 = 0.74$) in September 2016.

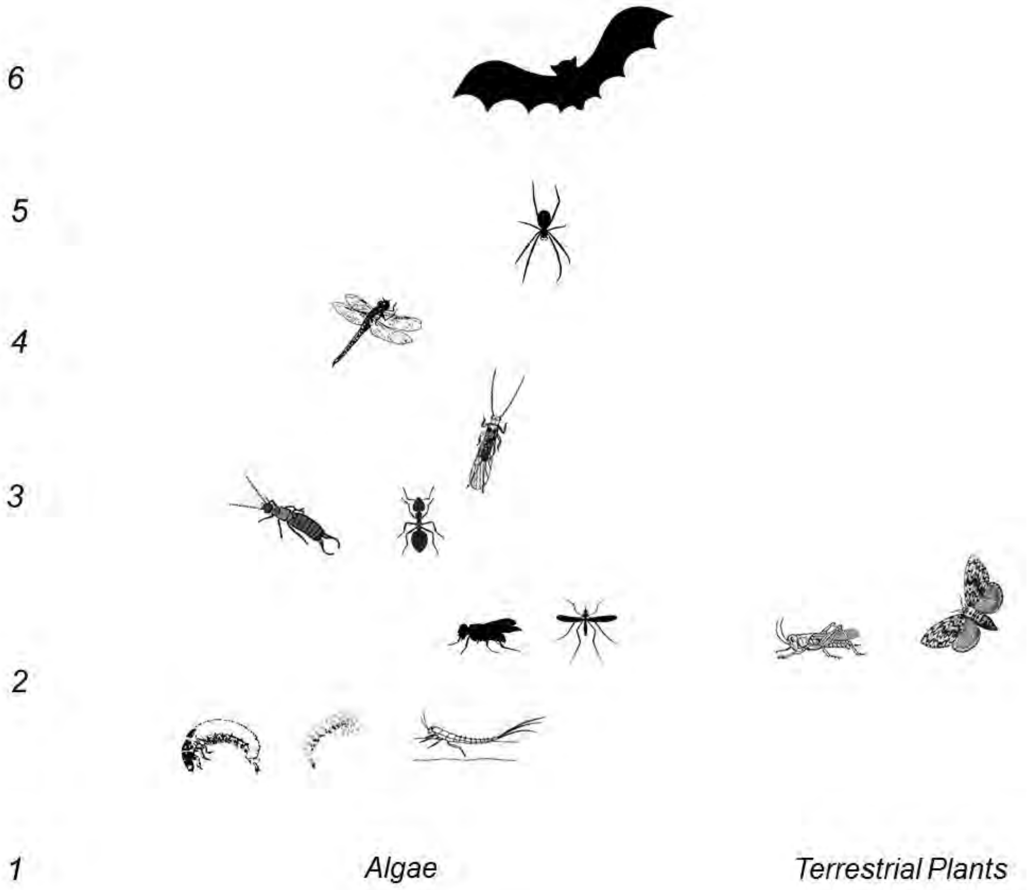


Figure 5-23. Potential food web leading to bats. Trophic position is indicated on the left. Organisms represented at each trophic level include: 1. Primary producers which include algae, macrophytes, and terrestrial plants; 2. Aquatic and terrestrial insects that primarily eat plant material or algae (e.g., Diptera, Tricoptera, Ephemeroptera, Lepidoptera, Hemiptera, and Orthoptera); 3. Aquatic and terrestrial insects that primarily eat other invertebrates (e.g., Plecoptera, Megaloptera, Hymenoptera, and Coleoptera); 4. Aquatic and terrestrial invertebrates that can eat other predators (e.g., Odonata, Araneae); 5. Invertebrates predators that eat other predators and/or cannibalize (e.g., Araneae); 6. Top consumer (e.g., insectivorous bats). Note that aquatic primary consumers likely feed on both algae and stream conditioned leaf litter, any insectivore including bats and invertebrates can forage at any trophic level, and that omnivory is common. Results from this study indicate the bats studied generally rely more heavily on a food chain supported by primary production by algae and occupy a mean trophic position near 3.5.

5.4 Discussion

An impressive biodiversity of bat species inhabits Poopenaut Valley, with at least one species, the Mexican free-tailed bat, present year-round. Out of five special status species documented, two are the first (spotted bat) and second (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 across all study sites 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 are 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 warmer than is expected under an unregulated scenario (Figure 5-16). 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. 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 and after the Rim Fire compared to the summer months leading up to the fire in 2013. We detected California myotis in record numbers during and after 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 and immediately after 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. An increase in activity levels of spotted and western mastiff bats and concomitant decreases in activity levels of California myotis and Mexican free-tailed bats were significant drivers of this change (Figure 5-14). 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). However, over a longer time period (one year) invertebrate abundance may have increased. In addition, restructuring of riparian vegetation can benefit some bats. For example, we observed increased activity levels of large, high-flying species that may benefit from simplified riparian forest structure combined with decreased activity of species that prefer clutter (i.e., California myotis and Mexican free-tailed bat). Further, 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 consistently recorded more species of bats known to occur in Yosemite, suggesting that a more diverse array of bats utilize the river corridor than adjacent pond or meadow habitats (Figure 5-18). Further, we found significant differences in bat community composition among study sites, suggesting that pond, meadow, and river habitats each attract a distinct cohort of bats. Further inquiry into patterns at the population level will be useful to tease out exact mechanisms driving these differences.

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. In September, bat activity was at the highest levels observed all summer (Figure 5-16). The south side detector recorded almost twice as many bat passes in September compared to July, the north side detector recorded eight times as many, and the river detector recorded six times as many (600 per night!) (Figure 5-17). Concurrently, bat activity in Yosemite Valley was highest in May and June and decreased significantly from July onward – the opposite pattern (Figure 5-17). 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 compared to 6,500 cfs) and the descending limb more gradual. Therefore, the flood conditions in Yosemite may not have had the same power to extirpate temporarily benthic invertebrates. Other factors including differences in pond hydrology between the Camp 6 pond in Yosemite Valley and the north-side pond in Poopenaut Valley also may have contributed to this pattern and deserve further inquiry.

The addition of the food web component of our study allowed us to measure bat dependence on aquatic productivity directly. We found that the bats we sampled relied heavily on an aquatic-energetic pathway leading to their preferred prey. Bats in this study derived 52% to 98% of their energetic demand from an aquatic-energetic pathway (Table 5-6). Estimates of bat reliance on an aquatic-energetic pathway derived from blood samples were positively correlated with estimates derived from hair samples (Figure 5-19). This suggests that bats rely even more heavily on an aquatic-energetic pathway throughout the season because hair samples reflect diet over the course of months, whereas blood samples reflect diet over days. This pattern was consistent between the Poopenaut and Yosemite systems (Table 5-6, Figure 5-19). To our knowledge, no other study has measured the aquatic contribution to bat energetic demand. However, other studies have estimated the aquatic contribution to other riparian insectivores including Tetragnathid spiders (40% to 90%; Jackson and Sullivan 2015, 2017), riparian swallows (23% - 54%, Kautza and Sullivan 2016), and riparian rove beetles (14% to 46%, Kautza and Sullivan 2016). It is remarkable that bats in this study rely much more heavily on an aquatic energetic pathway than perhaps any other organism studied. This suggests that bats selectively prey on emergent aquatic insects *and* that those insects primarily feed on benthic algae. Given that reliance on an aquatic-energetic pathway by emergent aquatic insects can range from 10% to 97% (Jonsson and Stenroth 2016, Kautza and Sullivan 2016, Jackson and Sullivan 2015), it is not impossible that these estimates are correct. However, if the basal resources we are using in our models (i.e., algae and stream-conditioned leaf litter) are not representative of the most important primary producers in this system, our estimates could be incorrect.

Trophic position of bats in this study ranged from 2.98 to 6.70 with a mean near 3.5 (Table 5-6). If bats occupy a trophic position of three, this suggests a food chain consisting of a primary producer, a secondary consumer, and the bat itself (Figure 5-23). Therefore, the food chain leading to bats in this study usually includes at least one predatory invertebrate, and can include up to *three* intermediary predators or omnivores (Figure 5-23). Estimates of trophic position of bats derived from blood samples was positively correlated with those estimated from hair samples (Figure 5-21). This evidence suggests that bats occupy a higher trophic position throughout the season. In addition, these results indicate consistent dietary selection throughout the season among the bats studied, and shows a range of selective preferences among individuals, even within the same species. Further bat reliance on an aquatic-energetic pathway was positively correlated with trophic position (Figure 5-21). Bats that relied more heavily on an aquatic energetic pathway generally fed at a higher trophic position, suggesting that aquatic-to-terrestrial food webs leading to bats are more complex than terrestrial food webs, include more predators or omnivores, and are perhaps more resistant or resilient to disturbance (Downing and Leibold 2010).Together these results indicate that the bats captured in these riparian systems rely disproportionately on food webs supported by photosynthesis occurring within rivers and streams, therefore emphasizing the importance of intact aquatic ecosystem processes to these bats. We recently collected additional basal resources (i.e., algae, stream-conditioned leaf litter, and riparian plant materials) during the summer in order to check that the primary producers we are using in our models are those of actual importance in the ecosystem.

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