Impacts of Hydropeaking Flows on Aquatic Insect Populations and Bats

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Introduction

In Yosemite National Park, 17 species of bats are known to occur (Sears 2011, Stock 2015). Of these 17 species, 5 are of special status due to documented population declines (Pierson 1998). These declines have mainly been attributed to anthropogenic impacts outside the park, but the conservation of park habitat as a refuge for bats contributes to thriving bat populations. Bats are known to forage on numerous types of insects (Naidoo 2012, McWilliams 2005, Clare 2011) which change in respect to location, seasonality, and habitat conditions. Numerous species of bats, including the majority of the species known to occur in and near Yosemite National Park, have foraging strategies that are closely associated with bodies of water (Seidman 2001). Riparian areas and adjacent forested areas provide critical habitat for bats for not only foraging, but also for roosting and mating as well (Brigham 1997). The diverse riparian vegetation and seasonal backwaters attract a variety of insects on which bats forage (Clare 2011, Seidman 2001).

The presence of bats along riparian corridors can serve as an indicator of ecosystem health. Bats are considered indicator species due to the fact they must consume 30-50% of their body weight in insects each night in order to survive (Esbérard 2008). Thus, in order for healthy populations of bats to persist in an area, there must not only be sites for roosting and open spaces for foraging, but also must have plentiful insects in the area. The presence of insects near a stream can be influenced by numerous environmental and anthropogenic factors, including changes in water height and changes in water temperature, thus they are sensitive to the management practices of the park. Our review paper seeks to address the question of how do hydropeaking flows on Tuolumne River affect aquatic insect populations on which bats forage? We hypothesize that hydropeaking flows negatively impact bat populations due to the reductions in aquatic insect abundance.

Impacts of Hydropeaking

The construction of dams are feats of human ingenuity, allowing us to store water and generate hydroelectricity power. Although they provide many benefits to society, dams also have environmental impacts. Hydropeaking is a term used to describe the pulsated flows of a river resulting from water periodically released from a powerhouse. Hydropeaking affects the volume, timing, and temperature of flows (Person 2013). The water released in a pulsed flow comes from the bottom of an upstream reservoir and is typically colder than the average river temperature (Griffith 2013). Additionally, the stage of the water downstream fluctuates depending on the magnitude and frequency of the hydropeaking flows. The frequent fluctuations in water level and temperature creates rapidly changing riparian habitat conditions and threaten insect populations that depend on stable water height and temperatures for reproduction and growth.

Aquatic insects are sensitive to the discharge and thermal changes caused by hydropeaking. Specifically, they are sensitive to both the timing and magnitude of downstream flows, as well as the temperature of the water releases. A large discharge downstream from a powerhouse can cause a disturbance known as catastrophic drift. This occurs when a large flow flushes away the fine detritus and individuals living in it, leaving the remaining individuals exposed to predators (Bruno 2013). Additionally, the temperature difference between the water being released and water already downstream changes the overall temperature, which causes behavioral drift. This results in aquatic insect species relocating to areas where the temperatures are more favorable (Bruno 2013). Therefore, by monitoring water level through measuring gauge height and recording water temperature, we can predict whether catastrophic drift or behavioral drift will affect the downstream ecology.

As seen in many studies monitoring the feeding and roosting sites of bats, water plays a critical role in the ecology of bats (Miller 2003, Seidman 2001). As recorded in the National Park Service's survey of Poopenaut Valley, most bats within the park forage directly over or adjacent to the water (Stock 2015). Open and closed canopy areas are also used by bats in various ways. The abundances of bats can be correlated with the amount of space available in the canopy, depending on each species' needs (Esbérard 2008). Thus, changing height of the water and changes in water quality and turbidity have effects on bats, even when not observed immediately following hydrologic changes.

Methods for Sampling Bats

Bats are extremely difficult to monitor and there are several methods that can be deployed. The classic method is to mist net- where a thin net is set up in an area where bats are known to occur. The bats fly into the net, and are collected, identified, then released. Mist netting can be somewhat dangerous for the bats, because there is a chance they can be physically harmed in the process. Mist nets also have to be set in open spaces, which limits researchers to only a few species (Seidman 2001). Telemetry can be used, but it still involves mist netting and is time and labor intensive. Bats are also known to abandon an area when the environmental pressures overwhelm them or make the habitat no longer suitable – whether it be a lack of roosting sites or a depletion in their food sources (Seidman 2001). Bats are not active during the day, so one highly effective but labor intensive method is to map roosts while they are sleeping. Roost mapping can be an effective monitoring technique, but bats do not always use the same roosts each night (Brigham 1997).

Recent technology enables the acoustic detection of bats. Collected recordings can be run through a specialized software program which identifies the bat to species. The one problem to this method is the detector's inability to differentiate calls from more than one bat, making it difficult to determine abundance of a single species, but allows for species richness to be calculated. Among these methods, no one is better than the other, but when deployed together, bat species abundance and species richness in an area can be determined.

Analysis

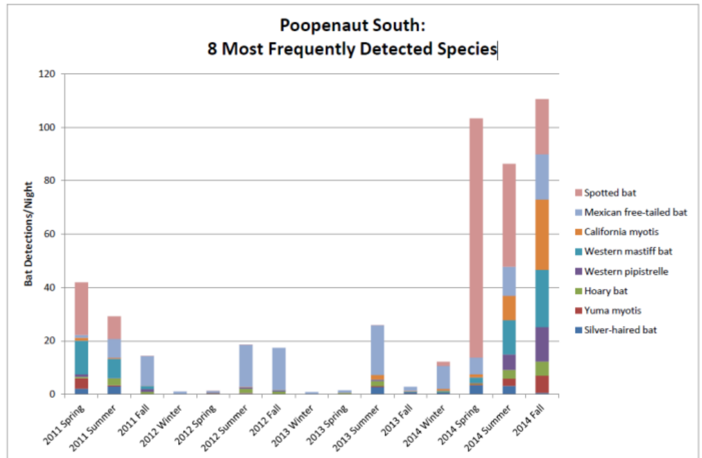
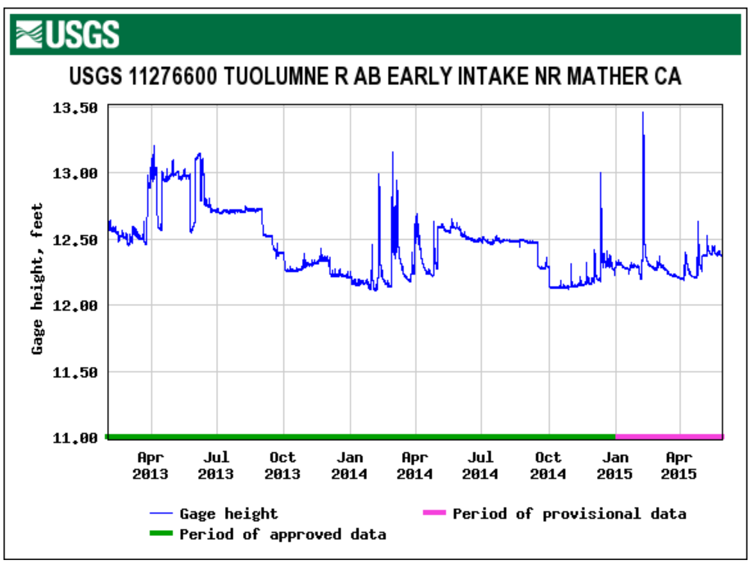


Figure 5-6. Bat detections by season of the 8 most frequently detected species at the south detector from 14 April 2011 to 10 September 2014. The vertical axis is number of bat detections/number of recording nights.

Figure 1 shows the abundance of the 8 most frequently detected species in the South Poopenaut Valley (Stock 2015). Figure 2, generated from USGS data above Tuolumne River Early intake near Mather, CA shows two periods of relative gauge height stability around July 2013 and 2014. Figure 1 shows an abundance of bat detections in the Poopenaut Valley during Summer 2013 and 2014. This analysis across both figures and dates is congruent with the prediction that bat distributions are affected by dynamic water levels, which cause a catastrophic drift of insects. In Figure 2, October 2013 shows a dramatic drop in water height, and in Figure 1, in Fall 2013 there was a significant reduction in the amount of bat sightings in the area. This change could be attributed to the Rim Fire, which began in August 2013. The fire most likely killed a majority of the local insect populations, suggesting that bats would need to search for food elsewhere. It is difficult to determine if the changing water level was the sole driving force of bat movement in 2013, but there is timely evidence that the water level change between January 2014 and April 2014 are associated with an astonishing amount of detections of bat species in Spring 2014. This abundance could be evidence of the effects of catastrophic drift. The rapid fluctuation and large flow of discharge upstream can cause the water



to flush insect populations downstream. As a result, the bats will be able to feast on the new arrival of prey who got washed away. These observations show that there could be a correlation between hydropeaking releases and bat detections based on the catastrophic and behavioral drift demonstrated by insect responses to flows. However, these conclusions may exhibit several sources of error due to monitoring technical difficulties.

Conclusion

Fluctuating water levels coupled with changing water conditions affect the lowest level of the trophic cascade - the insects - along the Tuolumne River. The effects on the insects can be categorized by the response seen in the distribution of invertebrates along the river. Insects respond to the discharge level or the temperature of the flow released from the dam. The changes in magnitude and timing cause catastrophic drift - which displaces the insects leaving them exposed to predators. Sudden changes in water temperature cause behavioral drift. The change in temperature makes the microhabitat of the river uninhabitable. In order to survive, the insects move themselves, and indirectly their larvae to a more suitable habitat with better temperature conditions. These events result in not only a change in the distribution and location of the insects, but they also alter the presence of bats. The bats will relocate themselves accordingly to areas with ample prey. By examining the hydrographs, with respect to the changing height of the river and fluctuating temperatures, we can determine the displacement of the insects, and predict the presence of bats in an area. The changes along the river due to releases from upstream powerhouses have widespread effects on the ecology of the river. Minimum instream flows do not allow for backwater to build up in areas, which causes a loss in foraging areas for bats. It is important to consider the effects of hydropeaking flows on insects because their presence determine the abundance of bats because of their large part in ecosystem health.

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