Impacts of Managed Flow on Habitat in the Mainstem of the Tuolumne River

Lindsay Floyd

GEL 136, 2018
University of California, Davis

Introduction

The Tuolumne River is a 6th order stream whose headwaters begin near the crest of the Sierra and flow westward approximately 130 miles towards the confluence with the San Joaquin River (USGS, 2018). In the early 1900's construction began on the Tuolumne River and by 1934 O'Shaughnessy Dam, Hetch Hetchy Reservoir, New Don Pedro Reservoir and La Grange Dam had been constructed. Water then began to be delivered as part of the Hetch Hetchy Aqueduct system which was built to supply water to the city of San Francisco, Bay Area municipalities and farmers in the Central Valley (SFPUC, 2005). Today the Tuolumne Reservoir supplies water to three million people across 29 counties in California and is an important source of irrigation water for farmers in Modesto and Turlock Irrigation Districts (Water Education Foundation, 2018). The San Francisco Public Utilities Commission (SFPUC), for example, diverts an average of 244,000 acre feet of water per year to supply 2.4 million people in the Bay Area, an amount that is roughly 14% of total flows in the Tuolumne (SFPUC, 2005). However, along with the creation of critical water resources, the construction of reservoirs and dams along the river has had serious consequences for native ecosystems in and along the river.

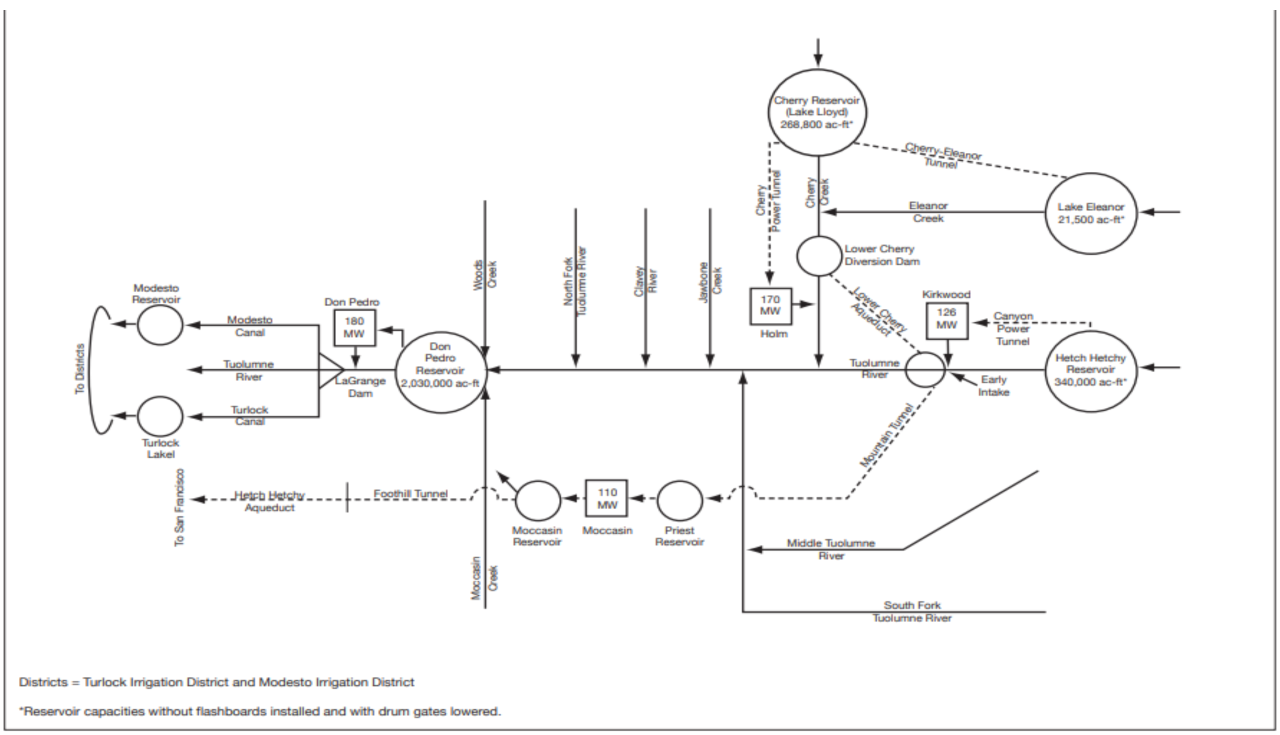

Figure 1: Schematic of Tuolumne River (Source SFPUC, 2005.)

Flow Alteration

Due to its Mediterranean climate, unmanaged rivers in California typically have asynchronous flow regimes, experiencing seasonal flooding and drought events. The Tuolumne River is primarily sourced from snowmelt and glaciers in its upper reaches. Precipitation falls almost exclusively in the winter and late spring months and collects mostly as snow. A typical hydrograph for this type of river experiences a peak in flows during spring as the snowpack melts and runoff flows into the river, and a dry season in late summer into autumn as the winter runoff has ended and fall storms have yet to occur (Figure 2).

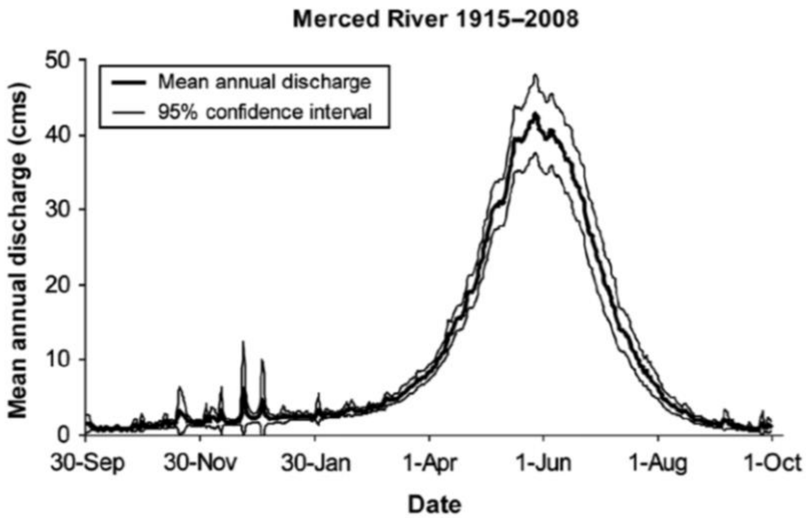

Figure 2: Typical hydrograph of a snow-sourced river in California. (Source Yarnell et al 2010)

When the main branch of the Tuolumne River began to be heavily managed, its hydrology drastically changed. Dams require controlled releases of water to ensure that proper amounts are stored in reservoirs and can be supplied to water users (Postel and Richter, 2003). The managed regime of flows creates a more homogeneous annual pattern, generally eliminating large pulses or minor droughts that were natural characteristics of an unmanaged flow regime (Postel and Richter, 2003). Reservoir storage is released during the dry months to ensure water deliverance to consumers and provide enough flows for recreation, thus eliminating minor seasonal low flows. Similarly, flows do not get excessively high during winter and spring months, as the peak flows in the hydrograph partly go into reservoir reserves for future release and use. Albeit, these generalizations do not hold true in years of extreme drought or wetness.

Managed and Unmanaged Flow Comparison

Above Hetch Hetchy Reservoir, there is little construction on the river, thus flows are more similar to those of an unmanaged snow-driven regime. Flows fluctuate daily to release more water in the afternoons to accommodate a larger electricity demand. The figure below compares two hydrographs over a 30-day interval in spring, showing the differences in flow rates (Figure 3).

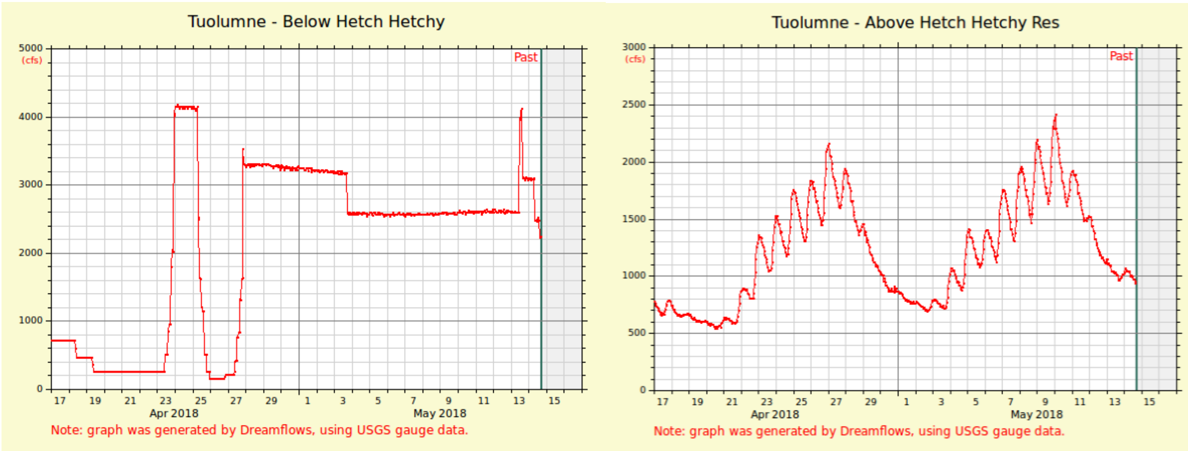

Figure 3: 30-day hydrographs taken below Holm Powerhouse (left) and above Hetch Hetchy Reservoir (right) (Source: Dreamflows, 2018)

The flows for the station below the Hetch Hetchy Reservoir show a direct influence from dam releases. The sharp increases and decreases of discharge over a short period of time, such as the flux between April 23 and April 25, reflect an immediate release of dam water and is a key characteristic of a managed system. Contrastingly, the discharge of the station above Hetch Hetchy is more subtle with smaller fluxes based on diurnal snowmelt variations.

Below are two hydrographs, one below Cherry Creek and one above Hetch Hetchy Reservoir, providing comparisons for the central section of the Tuolumne River. Flows below Holm Powerhouse during summer months experience cyclical pulses as water is carefully managed for recreational use and hydropower generation.

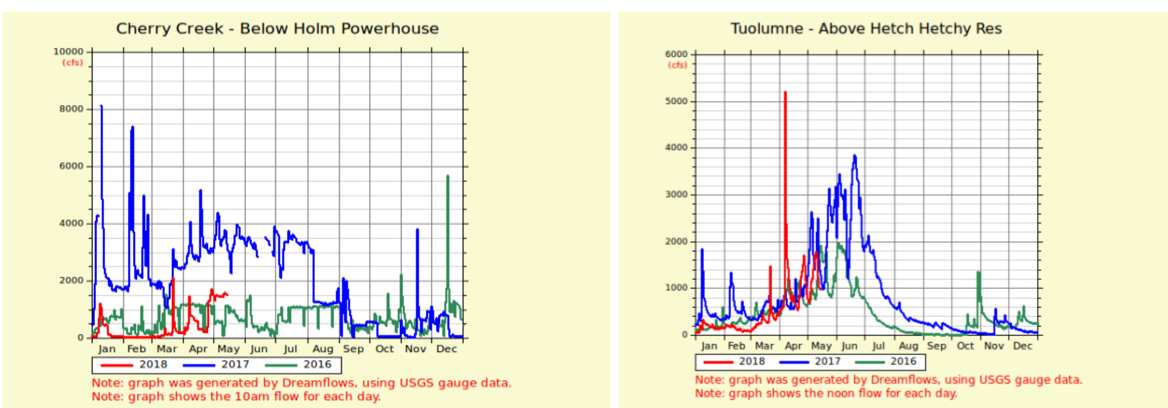

Figure 4: Annual hydrographs of Tuolumne from 2016-present taken at two locations along the river. The right figure represents the heavily managed middle section of the watershed, whereas the right is a more natural flow regime in upper Tuolumne. (Source: Dreamflows, 2018)

Habitat Alteration

Hydrology, which is influenced from underlying geology, ultimately dictates the ecology of a river. Stream flows directly influence what species will inhabit an area based on a multitude of factors including stream depth, flow velocity, carbon sources and water quality. When flows are significantly altered, like those following construction and operation of a reservoir system, habitats inevitably will undergo change. More homogenous flows often lead to a more homogenous biota composition and promote the success of non-native species (Mount and Moyle, 2007).

The operation and subsequently homogenized flows lead to altered sediment deposits, but more importantly, it changes the annual flow patterns of a river. Water temperature, dissolved oxygen content, nutrient concentration and pH all depend on the velocity, stream depth, and stream width among many factors, which can all be manipulated with sustained alteration of flow patterns. Many native species depend on the natural flow regime as part of their life cycle. For example, cottonwoods depend on scouring flows, wet gravel bars and gradual flow recession for successful establishments of seeds (Yarnell et al., 2010). These conditions are often present in an unaltered flow regime, but the homogeneity and constant flows from a dammed system prevent the ideal cottonwood conditions from occurring, thus inhibiting recruitment in the ecosystem. Additionally, controlled flows result in constant, shallow flows that become warmer than unmanaged flows with more depth. Warmer temperatures alter the habitat needed for macroinvertebrates such as mayflies and stoneflies that depend on cool water conditions (UC Davis Center for Watershed Sciences, 2009). Fish like Chinook salmon and rainbow trout, both found in throughout the Tuolumne, are also affected as they rely on cold, gravelly streambeds to lay their eggs. When the water is too warm or sediment is redistributed and washed away, their ideal breeding ground is threatened.

Contrastingly, non-natives tend to thrive in managed watershed systems (Mims and Olden, 2013). Exotic vegetation tends to grow close to river channel banks in a managed system, as there are fewer extreme high flow disturbances to clear the new recruits. This has resulted in an increase in nonnative riparian vegetation such as Eucalyptus, Giant reed, Tree of heaven and Fig trees (Stillwater Sciences, 2013). In addition to vegetation, non-native critters tend to thrive in the dam-controlled system of the Tuolumne. Warmer waters and habitat loss result in the loss of native fishes and macroinvertebrates. The decline in native species presents the opportunity for non-native fishes, like bluegill and smallmouth bass, to establish in the ecosystem, as there is less competition for resources (NPS, 2017).

Case Study: Clavey River and Tuolumne Below New Don Pedro Reservoir

The Clavey River, which enters the Tuolumne about five miles below Meral's Pool is a tributary of the main stem of the Tuolumne but has an unmanaged flow regime. It is one of only a few rivers in California to be unimpaired by humans (UC Davis Center for Watershed Sciences, 2009), and it serves as a useful comparison to track flow changes that result from construction along the Tuolumne. The Clavey is a primarily snow-driven river but has a greater input from rain precipitation that the Tuolumne and a mean annual discharge of 50,000 acre-feet. The Clavey experience annual scouring events from large pulses in the springtime. These large pulses also have enough strength to remove large amounts of vegetation, even trees. As a result woody debris collects along the Clavey River on eddies or turns in the river, providing habitat for critters like fish, beavers or insects in the crannies of the woody debris (UC Davis Center for Watershed Sciences, 2009). The cool, fast-moving flows also provide ideal habitats for a diverse assemblage of macroinvertebrates such as mayflies and stoneflies. These flows often have fast-flowing riffle and cascades which offer ample area for macroinvertebrates and fish breeding.

Contrastingly, the flows of the Tuolumne below the New Don Pedro Reservoir and La Grange Dam are relatively homogenized and simplistic. Flows need to be maintained year round to ensure ideal storage in reservoirs and the most economical distribution of water for users (Lee et al. 2011)**.** These constant flows that lack large pulses or seasonal droughts often have encroachment of invasive plants along the banks as there are few disturbances on the ecosystem. Additionally, there is a lack of sediment diversity, as sediment and debris tend to accumulate behind dams as opposed to being distributed throughout the stream. This removes habitat that otherwise could be used by insects and fishes. Many native fish species in California are adapted to flows of an unmanaged system. This includes the colder water and variable hydrographic patterns. Invasive species like carp and sunfish prefer the constant, managed flows with warmer water temperatures (Epke et al. 2010).

Concluding Discussion

While the Hetch Hetchy system is an important water supplier for the state, its modification of the natural flow regime has had detrimental effects on native habitats. Biota that relied on historical flow conditions are now threatened by habitat alteration and presence of invasive species. Management practices for dams could help mitigate some effects of a dammed river system while still serving the needs of its anthropogenic users. For example, the “Functional Flow” strategies of Yarnell et al. (2015) involves altering flow patterns to provide a more seasonal and focused flow regime to provide varied flows for species that rely on specific water conditions for their life cycle (e.g., Escobar-Arias and Pasternack, 2010). This release strategy may result in some economic loss for hydropower utilities that manage the dams, but it would provide some relief to habitats that are threatened under a managed river system. While flow negotiations are often a costly and lengthy process, they could prove to be largely beneficial to reducing the impact managed flow regimes have on an ecosystem. Navigating these nuanced environmental and societal water needs is an integral component in functional river management (Chen and Olden, 2018).

References

Chen, W., and J. D. Olden. 2017. Designing flows to resolve human and environmental water needs in a dam-regulated river. Nature Communications 8.

Escobar-Arias, M. I., and G. B. Pasternack. 2010. A hydrogeomorphic dynamics approach to assess in-stream ecological functionality using the functional flows model, part 1-model characteristics. River Research and Applications 26:1103–1128.

Fish. 2017. . U.S. Department of the Interior. https://www.nps.gov/yose/learn/nature/fish.htm.

Lee, Y., T. Yoon, and F. A. Shah. 2011. Economics of integrated watershed management in the presence of a dam. Water Resources Research 47.

Moyle, P. B., and J. F. Mount. 2007. Homogenous rivers, homogenous faunas. Proceedings of the National Academy of Sciences 104:5711–5712.

Postel, S., and B. Richter. 2003. Rivers for life: managing water for people and nature. Island PressWashington, DC.

Shackleton, C. 2018. Dreamflows Home Page. http://www.dreamflows.com/.

Suddeth et al. 2018. Natural History Guide to the Tuolumne River. https://watershed.ucdavis.edu/tuolumne/resources/TuolumneNaturalHistory GuideV1.0.pdf.

SFPUC. 2005. Tuolumne River System and Downstream Bodies. SFPUC. http://sf-planning.org/sites/default/files/FileCenter/ Documents/7941-2005.0159E_vol3_sec5-3_wsip_finalpeir.pdf.

UC Davis Center for Watershed Science. 2009. The Clavey River. https://watershed.ucdavis.edu/tuolumne/resources/Final_Clavey.pdf.

USGS. 2018. GNIS Detail - Tuolumne River. USGS. https://geonames.usgs.gov/apex/f?p=gnispq:3:0::NO::P3_FID:255171.

Water Education Foundation. 2016. Hetch Hetchy Reservoir and Water System. http://www.watereducation.org/aquapedia/hetch-hetchy-reservoir-and-water- System.

Yarnell, S. M., J. H. Viers, and J. F. Mount. 2010. Ecology and Management of the Spring Snowmelt Recession. BioScience 60:114–127.

Yarnell, S. M., G. E. Petts, J. C. Schmidt, A. A. Whipple, E. E. Beller, C. N. Dahm, P. Goodwin, and J. H. Viers. 2015. Functional Flows in Modified Riverscapes: Hydrographs, Habitats and Opportunities. BioScience 65:963–972.