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Individual Paper

Invasive Fish Species in the Lower Tuolumne River

Introduction

Intentional and accidental introductions of non-native species frequently occur in freshwater ecosystems. The need for management practices come in when these species become invasive, negatively impacting the ecosystem. The lower portion of the Tuolumne River has been effected by invasive fish species and now requires intervention in order to prevent further influences to native organisms or their habitat. Analyzing features of the stream system that make invasions possible, as well as the characteristics of invasive fish species that make them able to invade the lower Tuolumne River can aid in creating effective management plans to protect the native ecosystems.

Stream Characteristics Promoting Invasions

Homogenization of the lower Tuolumne River from anthropogenic alterations to flow regime and habitat provides conditions favorable to invasive fish species. Water supply allocations, diversions, and dams are the main contributors to the altered flow regime. Lower summer flows, particularly from storing water from the spring snowmelt, have created constant flows instead of the extreme flood events that used to occur. Many invasive species thrive in this type of environment where streams are more static, especially in reservoirs (Poff & Ward, 1989). The flow regime within a stream influences the habitat throughout the system, which ultimately determines the assortment of organisms able to inhabit the area (Vannote et al., 1980). Alterations to habitats, particularly from dams, have reduced sediment transport. New Don Pedro

Dam, for example, traps sediment upstream, which negatively impacts native fish that require heterogeneous sediment for spawning, feeding, or avoiding predation (Poff et al., 1997). Dams also prevent migration paths that native fish used, making the river more hospitable to species that do not move great distances. These abiotic factors combined with life history strategies of the organisms play a crucial role in allowing invasive fish species to survive and ultimately replace many native fish.

Invader Characteristics

Non-native fish of the lower Tuolumne River share characteristics that make them successful invaders. Unlike native species that have specific niches and habitat types, invasive fish tend to be generalists, which aid in them being prosperous at establishing themselves throughout the river. These species are highly fecund and commonly live for short periods (Grabowska & Przybylski, 2015). In general, they all are opportunistic feeders; most will feed on multiple species of fish, invertebrates, and crustaceans, or forage in different niches throughout the stream (Moyle, 1976). Many of these species possess phenotypic plasticity and can survive in a wide array of environmental conditions and habitats (Valiente et al., 2010). Also, invasive fish are often aggressive and display territorial behavior, making it easy for them to outcompete and predate on native fish. These characteristics allow invasive species to have a higher reproductive rate partially because they aggressively defend nest sites, which increases the likelihood of egg survival (Gozlan et al., 2003).

Management Options

Understanding why non-native fish have been able to thrive in the lower Tuolumne River provides insight into where management efforts should be directed. Since fish are adapted to the environment which they evolved in, returning the habitat and flow regime to its natural state are

possible solutions to promote an increase in native fish populations. Habitat restoration would reestablish historic environments that invasive fish would be less likely to survive in, and allow native fish to recolonize areas. Habitat degradation is a problem for native species, so this method would help with other conservation goals and benefit more than just the organisms negatively effected by the invasive fish. Some of these plans already exist in this stream, including the Dos Rios restoration site, which focuses on riparian and floodplain restoration. Other attempts in the Tuolumne River focused on the issue of the influx of fine sediment downstream from dams posing problems for native organisms that rely on those areas for spawning, such as salmon (Kondolf et al., 1996). Restoring the area by adding in gravels or sediment that was historically available before dams can encourage native species to return. Although this method could work in the short term, without addressing the underlying issue of dams, fine sediment will most likely return to cover the gravel. Habitat restoration can be costly and time consuming, so it may not be the most efficient method if it is only a temporary solution.

However, restoring the flow regime can tackle the fundamental problem that the environmental was altered to a state that made it easy to invade and could provide permanent solutions, including habitat repair. A number of rivers regulate flows, and a couple have been successful at reducing invasive fish. One success story occurred in Putah Creek, where portions previously featured a large abundance of non-native fish. The flows were adjusted, and in a short period of time there was a decrease in invasive fish and increase in native species (Kiernan et al., 2012). Since flows are fairly constant within the lower Tuolumne River, manipulating them to include variation that used to occur historically would create an environment no longer suitable for invasive fish. Despite the challenges of having to negotiate with multiple parties that have

different motives when dealing with water management, this method will address other conservation concerns, similar to habitat restoration (Richter et al., 2003).

Many other management options that do not intentionally alter the physical system exist, however most are too risky to use in water because there is a lack of confinement. Biological control, which is deliberate introductions of a specie's natural enemy, or poison are commonly used to eradicate invasive species. Without sufficient knowledge on the diet and life history of the biological control species, there can be unintentional results, given that introducing an organism or chemicals into a system is potentially irreversible (Hoddle, 2004). Nevertheless, there is an up and coming method for invasive fish removal motived by the infamous lionfish that has been successful with no known inadvertent effects. Starting off small scale in communities on the waters where the lionfish invaded, a market for the species was created (Chapman, 2016). The fish started to be sold in food stores and restaurants, and motivated fishers to target this species. This approach is growing even to San Francisco, where a couple of restaurants now serve invasive carp from the area. Encouraging people to fish for the invasive fish and promoting a market for them can be a method to help keep populations down (Chapman, 2016). For example, centrarchids, such as bluegill (*Lepomis macrochirus*) are consumed across the country; encouraging this within the lower Tuolumne River can be a way to help keep numbers low. Taking into account characteristics of the invasive fish already mentioned can help fishermen target areas where they are likely to occur. In general, understanding a fish's life history and basic biology is what help fishermen be successful, so applying that to invasive fish should work. Although this method would not lead to complete eradication, it can be a way to help manage populations and get the public involved as a way to educate others on the harms of invasive species.

Knowing how hard it is to deal with removal of invasive fish puts more pressure on increasing preventative measures to ensure no more invasive fish enter the Tuolumne River. Since the more disturbed habitats benefit invasive fish over native ones, protecting pristine parts of the lower river can help promote native fish. Addressing how these species became introduced in the first place is another aspect to consider. Eliminating the vectors for the introductions can reduce the threat of more species becoming invasive.

Conclusion

Although many invasive species management options exist, focusing on the flow regime appears to be the most impactful, in this case. Given that non-native species have behavioral and physiological adaptations, as well as life history strategies to thrive in the disturbed environment, focusing on restoration or reconciliation will be most effective. And since flow will influence habitat, flow regime management can be efficient at addressing underlying problems and helping more than just the organisms negatively effected by the invasive fish. Creating a market for the invasive fish can also be a way to control populations and get more people involved in invasive species management, however this method will not solely fix the problem. Given that the Tuolumne River has already faced anthropogenic activities like dams and water diversion that have altered natural habitat for native species, addressing the issue of invasive species is vital at this point to prevent any further decline in native fish populations. Though some invasive fish might be too well established across a large range to implement complete eradication, management and preventative actions are still possible.

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