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Native fishes in the Truckee River: Are in-stream structures and patterns of population genetic structure related?

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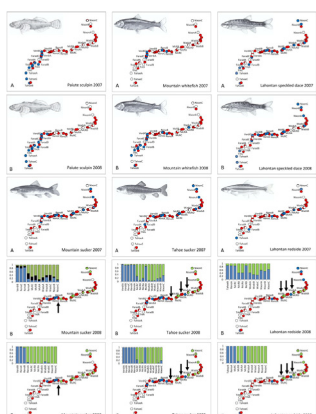
HIGHLIGHTS

- Impact of in-stream structures assessed for a suite of native fishes.
- Microsatellite markers and Bayesian genotype clustering were applied.
- Population subdivision was not observed a year after high flow conditions.
- Population subdivision was observed during low flow conditions for three species.
- Impacts to movement by in-stream structures can be mitigated by flow management.

GRAPHICAL ABSTRACT



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ABSTRACT

In-stream structures are recognized as significant impediments to movement for freshwater fishes. Apex predators such as salmonids have been the focus of much research on the impacts of such barriers to population dynamics and population viability however much less research has focused on native fishes, where in-stream structures may have a greater impact on long term population viability of these smaller, less mobile species. Patterns of genetic structure on a riverscape can provide information on which structures represent real barriers to movement for fish species and under what specific flow conditions. Here we characterize the impact of 41 dam and diversion structures on movement dynamics under varying flow conditions for a suite of six native fishes found in the Truckee River of California and Nevada. Microsatellite loci were used to estimate total allelic diversity, effective population size and assess genetic population structure. Although there is spatial overlap among species within the river there are clear differences in species distributions within the watershed. Observed population genetic structure was associated with in-stream structures, but only under low flow conditions. High total discharge in 2006 allowed fish to move over potential barriers resulting in no observed population genetic

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structure for any species in 2007. The efficacy of in-stream structures to impede movement and isolate fish emerged only after multiple years of low flow conditions. Our results suggest that restricted movement of fish species, as a result of in-stream barriers, can be mitigated by flow management. However, as flow dynamics are likely to be altered under global climate change, fragmentation due to barriers could isolate stream fishes into small subpopulations susceptible to both demographic losses and losses of genetic variation.

1. Introduction

Many freshwater fish species are highly impacted by anthropogenic mediated alterations to river ecosystems (Rowe et al., 2009; Strayer, 2010; Branco et al., 2012, Matono et al., 2013; Van Haverbeke et al., 2013; Walters et al., 2014). Not the least of these are dams and water diversions for municipal and agriculture use, which fragment large flowing systems into smaller isolated reaches reducing habitat size, habitat diversity, and fish populations. Smaller less diverse habitats limit the ability of individuals to fulfill all life history requirements, thus negatively affecting population viability (Alexiades et al., 2012; Cooney and Kwak, 2013; Keefer et al., 2013; Santos et al., 2013; Van Haverbeke et al., 2013). In many instances anthropogenic impacts have resulted in listings under the United States Endangered Species Act (ESA) or the International Union for Conservation for Nature (IUCN). For most species, ESA listing has been concomitant with losses of genetic variation, and thus, evolutionary potential (Garrigan et al., 2002; Hurt and Hedrick, 2004; Dowling et al., 2012; Peacock and Dochtermann, 2012). As the impacts of global climate change intensify, human pressure on water resources, for example, in the western United States will undoubtedly increase, escalating both conservation concerns and challenges to maintain functioning aquatic ecosystems, their native species, and the ecosystem services they provide.

Native fishes that are not of commercial or recreational interest have few data to assess their status in large parts of their ranges precluding informed decisions regarding extinction vulnerability (Cooke et al., 2005; Quist et al., 2006). However, the ESA single species listing approach may ignore important ecosystem processes critical to population persistence for suites of interacting species (Franklin, 1993; Orians, 1993; Franklin, 1994; Tracy and Brussard, 1994; Whiteley et al., 2006). A more “ecosystem based” approach would be to assess the ecological viability of multiple species with multiple potential environmental stressors with the aim of managing for properly functioning ecosystems that support biotic communities (Kviberg and Craig, 2006; Edgar et al., 2016). Recent examples of an ecosystem based approach include Teichert et al.'s (2016) work on the impact of nine anthropogenic stressor categories on 90 estuary fisheries in the Northeast Atlantic and McDonald-Madden et al.'s (2016) use of food-web theory to guide ecosystem management of species networks.

Here we focus on the movement dynamics of a suite of native fishes found in the Truckee River in western Nevada and eastern California in the face of anthropogenic barriers. As with many watersheds in western North America, the Truckee River has been highly impacted by anthropogenic perturbations over the 20th and 21st centuries. A series of in-stream dam structures and water diversions on the river impound water for the urban centers of Reno and Sparks, Nevada and provide water for irrigation. Construction of a large in-stream dam diversion as part of the Newlands Reclamation Act of 1902 (P.L. 57-161) in 1905 and channelization by the Army Corp of Engineers in the late 1960′s greatly impacted flow dynamics, reduced recruitment in riparian cottonwoods stands in the lower river, and altered invertebrate community structure (USFWS Truckee River Recovery Implementation Team, 2003).

Despite the fact that the native fish species found in the Truckee River watershed are fairly common throughout their respective ranges, there is little known about their population ecology in general and almost no information available for populations found within the Truckee River watershed specifically (Baker, 1967; Vondracek et al., 1982; Marrin et al., 1984; Johnson, 1984; Vinyard and Yuan, 1996; Light, 2005; Dauwalter and Rahel, 2008; Taylor et al., 2012; Benjamin et al., 2014). Therefore the impact of anthropogenic disturbance, including the role that in-stream structures play in restricting movement, on the long-term population viability for many of these species, which range in size from small cyprinids, Lahontan speckled dace (*Rhinichthys osculus robustus*), Lahontan redside (*Richardsonius egregious*) and cottids, Paiute sculpin (*Cottus beldingi*) to larger catostomids, mountain sucker (*Catostomus platyrhynchus*), Tahoe sucker (*Catostomus tahoensis*) and salmonids, mountain whitefish (*Prosopium williamsoni*) remains unknown.

In this study we characterize the spatial distribution of the six fluvial, native fish species found in the main stem Truckee River from its origin at Lake Tahoe, California to its terminus at Pyramid Lake, Nevada (Fig. 1). Hypotheses concerning both flow dynamics, which are highly variable both temporally and seasonally in this watershed, and the presence and type of potential barriers on movement dynamics of these fishes were tested. All fish species are not uniformly distributed throughout the river due to differing ecological requirements such as water temperature, flow and foraging needs. Additionally the type of in-stream structure varies throughout the watershed. All in-stream structures were recently evaluated for fish passage by United States Fish and Wildlife Service (USFWS) (Table 1), and these designations were used to generate predictions regarding potential barriers and individual species.

Patterns of fish genetic structure in a riverscape can provide information with which to assess potential barriers to movement and the impact of flow conditions. We predict that population substructure will be present for those species whose distributions overlap with structures classified as complete in-stream barriers. Additionally, temporal and seasonal barriers are likely to impact smaller, less mobile fishes such as Paiute sculpin, Lahontan redside, and Lahontan speckled dace, during protracted low flow conditions leading to additional population substructure and small isolated groups of individuals. Smaller fishes are likely to be impacted disproportionally by seasonal and temporal barriers as studies on movement dynamics show that fish length can play an important role in determining home range size and movement patterns. Although none of the species from this study were included in a meta-analysis of dispersal patterns in fluvial fishes, Radinger and Wolter (2014) found fish length to be positively correlated with movement distances. The cottids had among the shortest movement distances and a narrower total range of distances moved (1–100 m), followed by cyprinids, salmonids, and catostomids (Radinger and Wolter, 2014).

Because many more barriers classified as seasonal and temporal are found on the Truckee River, they have the potential to impact movement dynamics for the smaller fish species whose distributions largely overlap with them. Only during periods of high flow could fish move downstream over complete in-stream barriers, but larger fish species may be able to negotiate other in-stream structures during low flows thereby reducing the impact of such structures on movement, gene flow, and population size. Barrier height can also be an impediment to movement especially for smaller fish species. In-stream structures with perch height > 15 cm represented barriers to upstream movement for the prickly (*Cottus asper*) and coastrange (*Cottus aleuticus*) sculpins both small species (70–300 mm; 60–170 mm respectively) (LeMoine and Bodensteiner, 2014). Small populations of fish isolated between temporal and seasonal barriers are more susceptible to demographic