Food Habits of Sculpin Spp. in Small Idaho Streams: No Evidence of Predation on Newly Emerged Steelhead Alevins

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Abstract

Recent declines of anadromous salmonids in the Pacific Northwest have prompted a need to understand the factors limiting populations across habitats and life stages. In the weeks following emergence from the spawning gravel, juvenile salmonids have limited swimming capacity and can be particularly vulnerable to predation by piscivores, such as sculpins (Cottus sp.) which are widespread in Pacific Northwest streams. The objective of this study was to investigate the extent to which sculpin prey on newly emerged steelhead (Oncorhynchus mykiss) in a threatened population in Idaho. Three species of sculpin were present in the watershed, including Paiute (C. beldingii), mottled (C. bairdii), and torrent (C. rhotheus) sculpin. Gut content analyses of 360 sculpin showed that invertebrates were the dominant food source (> 85% of all sculpin preyed mainly on invertebrates), and piscivory was rare (< 2%). None of the samples contained steelhead alevins. We conclude that there was no indication of predation during emergence in our study system, but note that future studies should incorporate stable isotope analyses or directly investigate the extent to which sculpin prey on salmonid eggs.

Keywords: Cottus, diet, Oncorhynchus mykiss, population, trophic

Introduction

Recent population declines of anadromous salmonids have led to the listing of several species and evolutionary significant units in the Pacific Northwest (Nehlsen et al. 1991, NRC 1996). An important step towards recovery is to examine the factors limiting populations, both to better understand their ecology and to inform management strategies (Nehlsen et al. 1991). This is not a trivial undertaking because anadromous salmonids utilize a wide variety of habitats throughout their life cycles. The potential effects on population vital rates should therefore be assessed at each of these life stages.

One potential factor that can limit the cohort size of salmonids is predation. Predation is a fundamental mechanism that shapes the evolution of life-history variation in fish species, structures entire ecological communities, and affects the abundances of both predators and prey (Reznick and Endler 1982, Polis et al. 1989, Tonn et al. 1992, Mittelbach and Persson 1998). Predator-prey relationships in fishes are highly dynamic,
and vulnerability to predation is a function of both taxonomy and size (Werner and Gilliam 1984, Rice et al. 1997). Stream salmonids are often considered top predators, but during their early life stages these species are vulnerable to predation by conspecifics and other stream fishes (Patten 1975, Foote and Brown 1998).

Sculpin (Cottus sp.) inhabit headwater streams in the Pacific Northwest, where several species of salmonids spawn. Both sculpin and steelhead (Oncorhynchus mykiss) are native to the Columbia River Basin and frequently coexist in similar habitats (Johnson et al. 1983, Linden 1970, Phillips and Claire 1966). Most sculpin are considered to be invertivores, feeding on a variety of aquatic insects, snails, and zooplankton (Johnson 1985, Wallace and Zaroban 2013, Wydoski and Whitney 2003). In some instances, sculpin can be piscivorous, feeding cannibalistically (Johnson 1985) or on other species such as shiners, northern pikeminnow, and salmonids (Swain et al. 2014, Tabor et al. 2007, Wallace and Zaroban 2013).

Some studies have found that predation by sculpin can be substantial during the phase when alevins are emerging from the gravel (Hunter 1959, Phillips and Claire 1966, Berejikian 1995, Swain et al. 2014), whereas other studies have found predation by sculpin to be of lesser importance (Johnson et al. 1983, Tatara et al. 2009). Here we investigate the taxonomic representation of sculpin and their diets in a North-Central Idaho watershed. The study took place during the early free-swimming phase of juvenile steelhead (Oncorhynchus mykiss) in a population listed as threatened under the Endangered Species Act. Our primary objective was to investigate the extent to which sculpin prey on steelhead alevins.

**Methods**

**Study Area and Population**

The Lapwai Creek watershed (694 km²) in North-Central Idaho drains into the Clearwater River and consists of four main tributaries—Lapwai Creek, Mission Creek, Sweetwater Creek, and Webb Creek (Figure 1). The watershed designated as critical habitat for threatened Snake River steelhead (NMFS 2006). The watershed is located on the boundary between the Columbia River Plateau and Northern Rockies ecoregions (McGrath et al. 2002), and is dominated by canyon topography through a mix of coniferous forest at higher elevations and grasslands at lower elevations. The hydrograph is driven by snowmelt and spring rain from early March through late May, and warm, dry summers with baseflow conditions starting in July. There is no hatchery supplementation for steelhead in the watershed. Steelhead spawn in March–April and eggs hatch in mid- to late-May.
Study Design

As part of an effort to study the ecology of juvenile steelhead, nine study sites were monitored in 2012 (Figure 1). The study sites were chosen to cover a gradient of habitat conditions and stream fish communities throughout the watershed and were approximately 100 m in length. Each site was abbreviated based on its location within the tributary (first letter—Upper, Middle, or Lower), name of tributary (second letter), and section within each segment (last letter—Upper, Middle, or ‘X’). For example, UMM is located on the Upper segment of Mission Creek, and is found in the Middle portion of said segment.

We monitored the presence of steelhead redds and alevins in May 2012 to inform our collections. Free-swimming alevins (25–30 mm total length) were first observed during the week of 28 May 2012. We conducted alevin counts and sculpin collections twice in each study site. The first visit occurred from 05 June to 07 June 2012, and the second visit occurred from 18 June to 28 June 2012. This ensured that we covered the temporal range of emergence, and that we captured the potential functional response of sculpin to steelhead recruitment.

Field Methods

We used a Smith-Root LR-24 electrofisher (Smith-Root Inc., Vancouver, Washington) to enumerate steelhead alevins and collect sculpin. During the first visit we conducted a single electrofishing pass to avoid harming alevins and trampling potentially remaining redds. We set the voltage to 100 V at 30 Hz and a 15% duty cycle. Alevins were found in shallow stream margins with structural complexity, likely to seek refuge from high current velocities (Bjornn and Reiser 1991), and we consequently targeted this type of habitat in our sampling. We enumerated alevins and immediately released them back to the stream margins. During the second visit we conducted a three-pass removal effort, which allowed us to calculate densities of both sculpin and steelhead. Densities were calculated using Carle and Strub’s (1978) maximum weighted likelihood estimator of removal data. We removed 20 sculpin from each study site during each visit, totaling 180 individuals from the first visit and 180 from the second visit. Sculpin were selected based on observed size class distributions after each electrofishing event. We therefore selected individuals that spanned the size range of captured sculpin (based on a bin size of 10 mm) and were reflective of each size class density (e.g. if half of fish sampled were 60 mm, we collected about 10 sculpin in the 60 mm size class). Sculpin were euthanized using tricaine methanesulfonate (MS-222) and immediately frozen for gut content analysis.

Lab Methods

Each sculpin was identified to species, measured to the nearest millimeter (total length), and weighed to the nearest decigram. Species identification was based on the presence or absence of palantine teeth, separation or connection of dorsal fins, preopercular spine count, and peduncle shape (Wallace and Zaroban 2013). We were interested in the dominant prey group in each stomach. Stomach contents were removed, identified under a microscope, and prey type sorted categorically into fish, macroinvertebrates, and unidentifiable material. The categories were then weighed to the nearest 0.0001 g. Ten samples were empty, and 329 contained only one prey category. We therefore assigned each sculpin to one of the three prey categories or as empty. The remaining 21 samples had more than one prey category, but the contribution by weight of one category exceeded the other by more than 10% in all cases. We therefore assigned the 21 samples to the category with the most contribution by weight.

Results

We identified three species of sculpin in the Lapwai Creek watershed (Table 1). Paiute sculpin (C. beldingii) was the most numerous (62%), followed by mottled sculpin (C. bairdii; 26%), and torrent sculpin (C. rhotheus; 12%). The three species appeared in similar size distributions in our sample, with average length and weight 64 mm and 4.0 g, respectively. Their combined densities in the study sites had an average of 0.74 fish per m². The density ratio between sculpin and steelhead on the second sampling occasion varied
considerably between study sites, from 0.80 to 76 sculpin per steelhead, hence covering a range of predation potential (Table 2). Site USU had the highest ratio of sculpin to steelhead alevins. Site ULU had the lowest ratio, but harbored the most steelhead alevins compared to other sites.

Across the sampled size range, and over the two sampling visits, we found that sculpin preyed almost exclusively on macroinvertebrates (Figure 2). Out of 360 samples, 310 sculpin consumed macroinvertebrates. Only sculpin larger than 90 mm had fish in their diets. This size category comprised six percent of the total sample (20 out of 360). Out of these 20 individuals, six had fish in their stomachs, and all contained only one fish. Five samples (four Paiute, one mottled) contained sculpin and one sample (torrent) contained longnose dace (*Rhinichthys cataractae*). Since we found that a small percentage of sculpin consumed fish, we did not compare other factors (e.g., stream

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characteristics, other fish species densities, habitat types) to sculpin predation. None of the samples contained steelhead alevins.

Discussion

We found no evidence of predation by sculpin on free-swimming steelhead alevins, although sculpin occurred in large numbers relative to steelhead in some study sites. The predominant diet by sculpin across their size distribution was macroinvertebrates, and only the largest sculpin had fish in their diets. Our results suggest that sculpin in the Lapwai Creek watershed are primarily invertivores, and larger sculpin can be piscivorous, often feeding on the most abundant fish species. These results are consistent with previous studies and published literature (Johnson 1985, Johnson et al. 1983, Wallace and Zaroban 2013, Wydoski and Whitney 2003). Our study adds to the body of literature that has found no evidence of predation by sculpin on salmonid eggs and alevins, and hence calls for a more nuanced perspective of the feeding ecology of this genus.

Studies on the extent of predation by sculpin on salmonid eggs, alevins, and fry have reported conflicting results. Multiple studies have documented sculpin predation on salmonid eggs, alevins, and fry (Ricker 1941, Hunter 1959, Phillips and Claire 1966, Berejikian 1995, Foote and Brown 1998, Tabor et al. 2007, 2012; Swain et al. 2014). On the contrary, Tatara et al. (2009) found little evidence of predation after steelhead emerged from the spawning gravel. Johnson et al. (1983) documented that shorthead sculpin in an Idaho stream with resident salmonids fed primarily on macroinvertebrates in the spring and fall.

We think there are two main reasons for the spread of results. First, sculpin species, although similar in physical appearance and habitat use at first glance, utilize different resources and have specific traits that restrict their ability to prey on fishes (Wallace and Zaroban 2013). Second, salmonids are a diverse group with different life history strategies and physical abilities among, and even within, species (Quinn 2005), such as spawning time, post-emergence dispersal and habitat use, and swimming ability. Collectively, these two concerns indicate that further investigation of the functional traits of both predator and prey may be warranted.
Several studies have found predation by prickly (C. asper) and coastrange (C. aleuticus) sculpin on salmonids in both running water and lakes (Ricker 1941, Hunter 1959, Phillips and Claire 1966, Berejikian 1995, Tabor et al. 2007, 2012; Swain et al. 2014). Gape size limitations often prevent some predators from utilizing potential prey (Northcote 1954, Phillips and Claire 1966, Pasch and Lyford Jr. 1972, Johnson et al. 2012). In the Lapwai Creek watershed, torrent sculpin is the species that functionally most resembles these two species, based on its relatively larger gape size than Paiute and mottled sculpin (Wydoski and Whitney 2003, Zaroban and Wallace 2013). Torrent sculpin is known to opportunistically prey on salmonids (Tabor and Chan 1996, Tabor et al. 2012), and could hence represent a potentially important predator in the system. However, torrent sculpin occurred in the lowest density in our study (approximately 10% of all sculpin). Given the relatively short early critical period following emergence, potential predation by torrent and other sculpin are likely of lesser importance than starvation, displacement and adverse abiotic factors in the Lapwai system. Also worth noting is that opportunistic predators could show numerical as well as functional responses given enough access to prey resources (Begon et al. 1996). With the reduced quantity and diversity of salmonid runs relative to historic conditions (Nehlsen et al. 1991) we speculate that the overall sculpin density may have decreased, and that species composition may also have changed.

Although we found no evidence of sculpin predation during the first free-swimming weeks of juvenile Steelhead, we note that we did not investigate predation on eggs. Sculpin are known to consume salmonid eggs (Phillips and Claire 1966, Foote and Brown 1998, Swain et al. 2014), but due to the protected status of the study population (NMFS 2006), we could not risk trampling redds to investigate whether this occurred in the Lapwai Creek watershed. Phillips and Claire (1966) found that 70–84 mm coastrange sculpin fed on eggs, but individuals smaller than 70 mm did not. Approximately 36% of sampled sculpin in our study were ≥ 70 mm, which suggests that they were large enough to consume salmonid eggs. However, sculpin that do feed on eggs generally select for unburied eggs (Wallace and Zaroban 2013). To fully investigate whether egg predation occurs, future studies should incorporate stable isotope analyses or direct observation in experimental redds that are not at odds with the spawning success in listed populations.

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