Cutthroat Trout in Saltwater: Spawn Timing, Migration Patterns and Abundance of Anadromous Coastal Cutthroat Trout

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Abstract—Despite being one of the most widely distributed salmonids along the Pacific coast, the Coastal Cutthroat Trout *Oncorhynchus clarkii clarkii* is one of the least understood. In 2007 we began a multidisciplinary project to clarify the spawn timing, spawner abundance, redd morphology, marine migration, and genetic population structure of anadromous Coastal Cutthroat Trout in Puget Sound. Using PIT (Passive Integrated Transpoder) tags, genetic stock assignment and scale analysis combined with redd surveys, we have documented important insights into the biology of anadromous Cutthroat Trout. The majority of "sea-run" Cutthroat Trout enter marine waters at age 2, exhibit high site fidelity to nearshore beaches as juveniles and adults and return to natal tributaries in the spring to spawn (February through June). Migration distances are limited with observations of high site fidelity year-round for juveniles and adults but interestuarine movements were common. Together, this new information provides fisheries managers with improved tools to maintain healthy populations of anadromous Cutthroat Trout across their range.

Introduction

The Cutthroat Trout *Oncorhynchus clarkii clarkii* has been described as the ancestral salmonid in the Pacific Northwest (Trotter 2008), and through thousands of years of probing inland and southward, this species has evolved into at least 11 other subspecies and more than five life history types, including anadromy (Behnke 1979). The subspecies Coastal Cutthroat Trout is not an important commercial species and so is understudied relative to other salmonids on the west coast of North America. Although general life cycle information has been documented for anadromous Coastal Cutthroat Trout (Wenburg 1998; Trotter 2008), their spawn timing, migration patterns and status are poorly understood. Without this information, biologists may be unable to evaluate management plans or ensure the long-term stability of a population.

In the absence of definitive information on the status of Coastal Cutthroat Trout, managers have relied on conservative management approaches to minimize fishing mortality in hopes of maintaining or increasing the number of Cutthroat Trout while continuing to offer fishing opportunity. While harvest is permitted in selected rivers in Washington State, current sport fishing regulations for Cutthroat Trout in marine waters require barbless hooks and prohibit harvest year-round. Unlike harvest fisheries, where the majority of fish captured are removed from the population, catch-and-release fisheries assume that the majority of fish captured are successfully returned to the water alive and thus remain part of the population. Hooking mortality associated with catch-and-release fisheries is thought to be low (Schill et al. 1986), however, mortality rates may vary widely depending on a variety of factors (e.g., gear type, angler experience and environmental conditions; Gresswell and Harding 1997). Under a high mortality rate scenario and where stocks of concern are frequently encountered by anglers, fishing pressure could conflict with conservation concerns, regardless of special angling regulations such as catch and release.

In marine waters Cutthroat Trout are managed assuming a mixed-stock management type, but the degree of mixing and general migrations patterns are unknown. Cutthroat Trout exhibit high site fidelity during spawning (Wenburg and Bentzen 2001), forming genetic stock structure organized at the stream level. Results from tagging studies in Hood Canal, a large fjord of Puget Sound, suggests that Cutthroat Trout rarely migrate far from their natal stream in the marine environment (Moore et al. 2010). It is unknown, however, whether or not the fidelity Cutthroat Trout exhibit to their natal inlet in Hood Canal is characteristic of Cutthroat Trout throughout

Puget Sound. If so, the popular sport fishery concentrated near estuaries adjacent to Cutthroat Trout spawning streams may be best managed as a series of inlet-specific terminal fisheries where angling regulations can be applied to marine waters based on the status of the associated population. Conversely, if longer distance migrations that are common for other species of anadromous trout (i.e. Bull Trout *Salvelinus confluentus*, Brown Trout *Salmon trutta*, Arctic Char *Salvelinus alpinus* etc.; Quinn and Myers 2004) are observed for Cutthroat Trout, inlets of Puget Sound may be best characterized as mixed stock fisheries. In this case, angling regulations applied across a broad geographic region may be appropriate to protect small, independent populations mixed with larger ones.

The goal of this work was to characterize Cutthroat Trout found in the marine and freshwater environments of south Puget Sound and provide fisheries managers with tools to improve monitoring and management activities. Specifically, we sought to describe the (1) spawn timing and abundance, (2) size and age, and (3) migration patterns of anadromous Cutthroat Trout in South Puget Sound Washington. Combined, this new information may assist managers in designing fisheries to address stocks of concern and promote the long term viability of anadromous Cutthroat Trout.

Methods

Study Area

Puget Sound, Washington, is characterized by numerous fjord-like inlets each fed by one or more streams draining into it. As a whole, Puget Sound has water chemistry properties resembling partially mixed estuaries (Sutherland et al. 2011). The current study was conducted in freshwater and nearshore marine waters of South Puget Sound that represent high-use fishing areas for those targeting Cutthroat Trout (Lothrop and Losee 2016). The marine study areas comprised Skookum, Totten and Eld inlets as well as the area where these three inlets meet (Squaxin Passage, Figure 1). The aspects of the study carried out in freshwater included the three major streams draining the marine study area, Skookum Creek, Kennedy Creek, and McLane Creek.

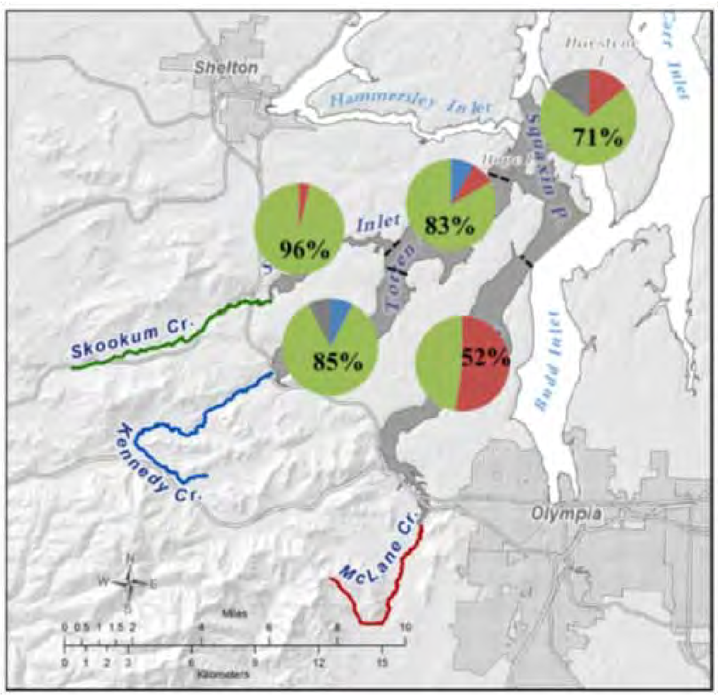

Figure 1. Study area in South Puget Sound, Washington, U.S.A and proportional contribution of genetic assignment of Coastal Cutthroat Trout by sampling region. Colored lines indicate streams included in baseline samples for genetic stock assignment. Colors within pie graphs indicate natal stream assignment; Skookum Creek:green, Kennedy Creek: blue, McLane Creek: red and unidentified source population: grey. Percentages indicate stock with greatest contribution by region.

Spawning and Abundance

To evaluate spawning timing of Coastal Cutthroat Trout the Skookum Creek index area (RKM 8.9 to 12.1) was surveyed from October to June 2008–2014 using standardized salmonid redd survey methodology described by Gallagher and Gallagher (2005). Each redd was flagged with the date, the surveyor's initials, and other descriptive details as needed. The same two trained individuals were assigned to survey redds for the life of the study, with few exceptions, thus reducing interobserver error and allowing for a comparison of relative abundance across various time scales (i.e., days, months, and years).

Measurements of redd size and sediment type were collected in 2014. Pit length was the total length of the pit as measured parallel to the streamflow. Pit width was the maximum width of the pit as measured perpendicular to the streamflow. The tail spill is the sediment that is excavated by spawning fish and elevated above the stream bed immediately downstream of the pit; its length was measured as the total length parallel to the streamflow. The diameters of substrate particles adjacent to each redd were measured with a metric rod to evaluate substrate composition.

To estimate escapement we sought to convert total redd counts to an estimate of mature Cutthroat Trout. To estimate the number of fish per redd, we tagged fish > 200 mm (FL) with PIT tags in the marine study area and intercepted a proportion of those fish in the Skookum Creek spawning index area during the spawning season using fixed PIT tag antennas. Fish detected on antennas in the index area represented a proportion of the total number of fish entering the index area. An estimate of the total number of fish entering Skookum Creek was produced by estimating the proportion of total Skookum Creek Cutthroat tagged through monthly sampling of Cutthroat Trout in the Skookum Creek Estuary using a beach seine. We expanded the number of tagged Cutthroat Trout detected on fixed antennas by the estimate of the proportion of tagged fish from monthly marine sampling to achieve an estimate of the total number of Cutthroat Trout entering Skookum Creek. This number was then divided by the total number of redds, producing the estimated fish per redd. We then multiplied the number of fish per redd by the total number of redds in the Skookum Creek drainage to produce an escapement estimate for Skookum Creek.

Collection of Fish and Age Analysis

Fork lengths (FL), scales and tissue samples were collected from Cutthroat Trout throughout the study area using hook and line and beach seine. To determine age, scales collected from the preferred area above the lateral line midway between the dorsal and adipose fins were analyzed for age and saltwater entry at the Washington Department of Fish and Wildlife (WDFW) marine aging lab. The scales were mounted on scale cards, lightly dyed for visibility and analyzed under 40× magnification. We defined juveniles as those without an annulus on their scales and adults as those with no annulus or ≥1 annuli after marine entry.

Marine Movements

To describe both broad and fine scale movements, we used genetic methodologies as described by Losee et al. (2017). To document broad patterns of stock-specific movements and identify the degree of "mixing" of various populations, we sampled Cutthroat Trout throughout the study area using hook and line and assigned catch to their population of origin using genetic stock identification. To describe fine-scale movements of Cutthroat Trout, we evaluated site fidelity by sampling the same location in Eld Inlet monthly, using a beach seine while recording the number of times individual Cutthroat Trout were recaptured at this location. Recaptures were identified using genetic tags; samples with matching genotypes were assumed to be the same individual.

Results

Spawning and Abundance

During 2009–2014, we observed 544 Coastal Cutthroat Trout redds and 148 live Coastal Cutthroat Trout. Coastal Cutthroat Trout redds were observed in the index area as early as February 2 and as late as May 27 (Figure 2). The observed Coastal Cutthroat Trout spawning period ranged from a minimum of 47 d in 2009 to a maximum of 114 d in 2012 (mean ± SD = 79.9 ± 21.0 d). Mean pit length was 0.48 ± 0.14 m (mean ± SD), and mean pit width was 0.43 ± 0.14 m. Coastal Cutthroat Trout redds tended to be constructed in habitat that was dominated by small gravel (~69%;) but large gravel and small cobble were also common.

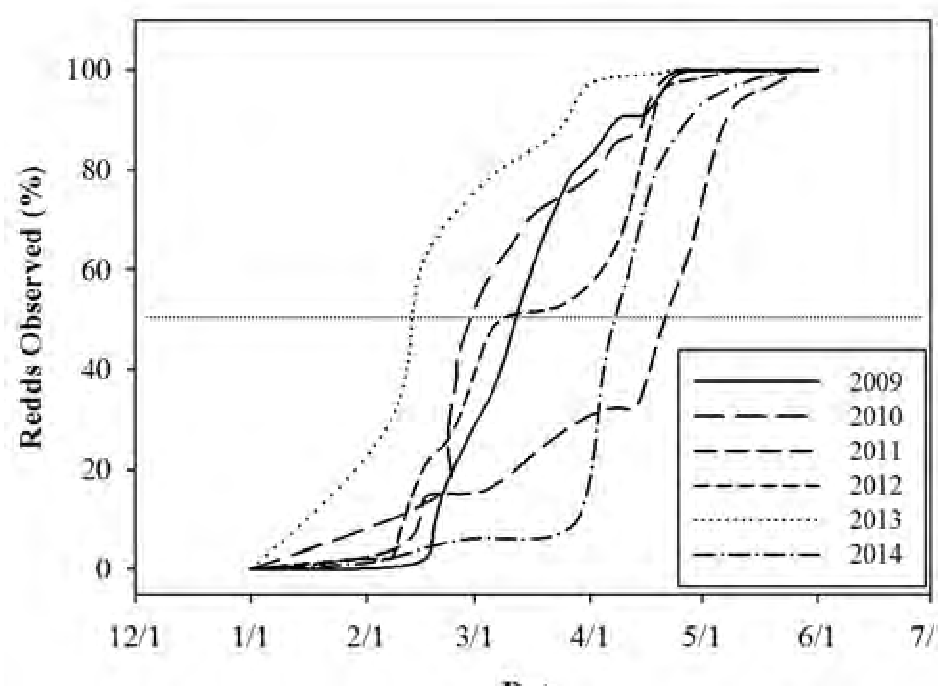

Figure 2. Cumulative percentage of anadromous Coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii*) redds observed in Skookum Creek by date. Data points from surveys are joined by a smoothed line. Horizontal dotted line identifies the date by which 50% of redds had been observed.

Using Passive Integrated Transponder (PIT) tags in the spring of 2017, we estimated that 91 adult Cutthroat Trout entered the index area of Skookum Creek. During the same time period, we enumerated 74 redds. With one year of data, the preliminary estimate of number of fish per redd is 1.23. Using this estimator and expanding redd counts to include spawning habitat in Skookum Creek outside the index area, we estimated an average escapement of anadromous Cutthroat Trout for Skookum Creek during the study period (2008-2015) of 132 (± 39.5 S. D.). The estimate of fish per redd will be further evaluated in 2018 and 2019 allowing for a robust estimate of fish per redd and total escapement of Cutthroat Trout for the entire study period.

Age Distribution

Based on scale analysis, mature Cutthroat Trout sampled in the marine environment were dominated by 3 year olds (35.0%, Figure 3). Nine separate life history strategies were identified with juveniles entering marine water at age 1, 2, and 3. Few fish demonstrated a spawning check (N=4) at the time of capture in marine water and three of these Cutthroat Trout spawned 2 years after entering the marine water while one individual had spawned after only 1 year in saltwater.

Marine Movements

Inlets of South Puget Sound were comprised of multiple genetically distinct populations in all months. The majority (71.6%) of Cutthroat Trout captured using hook and line in the marine environment were less than 15 km from the mouth of their natal stream while 14.1% were captured greater than 30 km from their natal stream. Average migration distance was greatest in summer months when marine temperatures are greatest and spawning season has ended.

Following the initial sampling event in January, we identified genetic matches (recaptures) in every month of the study with the exception of the month of June when no Cutthroat Trout were captured (Figure 4). Overall, 21% of Cutthroat Trout sampled in this study were encountered during subsequent sampling events. Highest recapture rates occurred on March 26, 2015. On this sampling event, all adults captured had been sampled previously (N=24) and 86% of total catch (juveniles + adults) had been captured previously (25/29). During the course of the study. 13.1% of known juvenile Cutthroat Trout captured at the study site were captured more than once and 30.8% of adult Cutthroat Trout were captured more than once.

Discussion

We documented that Coastal Cutthroat Trout spawning activity was protracted over an extended time period and exhibited a high degree of interannual variability relative to other salmonids. Numerous studies have used mark–recapture methods and/or trap counts to describe the timing of the Coastal Cutthroat Trout migration into freshwater for populations across the subspecies' range. Although this information is valuable for estimating the time of adult freshwater entry and for describing habitat use, generating definitive information on the spawn timing of Coastal Cutthroat Trout is imperative for successful management. By comparing weekly counts of Coastal Cutthroat Trout redds to estimates of abundance using PIT tags, we were able to provide an accurate estimate of spawn timing and estimate the number of fish present during the construction of redds within the index area. A logical next step would be to replicate this work across other systems in Puget Sound and beyond. However, information reported here should serve as a starting point to allow managers and volunteers to estimate abundance of Cutthroat Trout across their range.

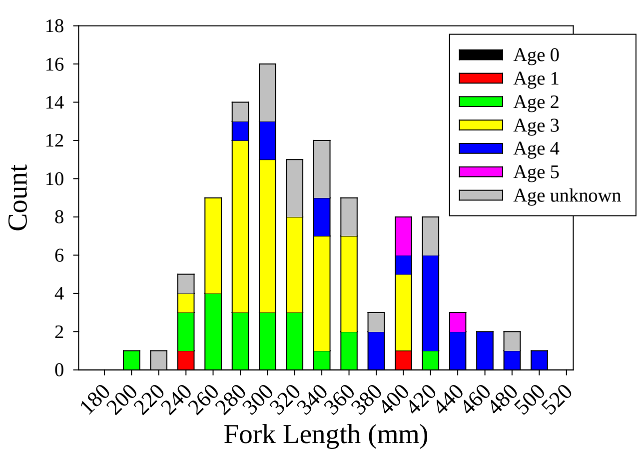

Figure 3. Length frequency distribution and age composition (stacked bars) of Coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii)* captured in marine water of South Puget Sound, Washington.

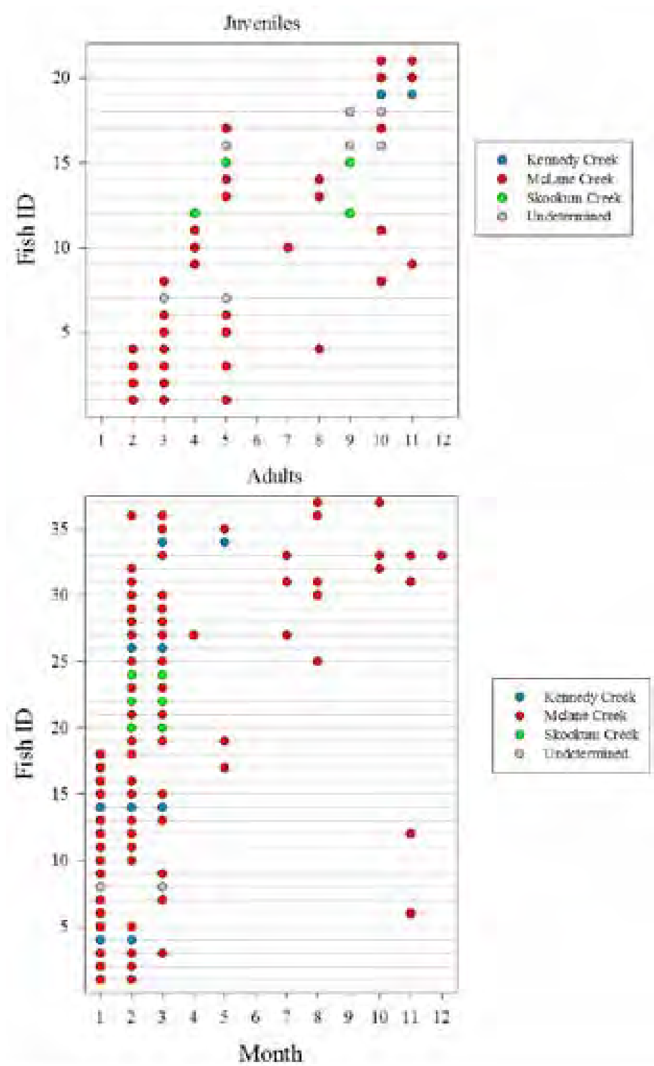

Figure 4. Month of recapture for Coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii*). Each horizontal line represents an individual Coastal Cutthroat Trout (Fish ID) captured more than 1 time in Eld Inlet, South Puget Sound Washington in 2015. Dots indicate months of capture (x axis). Colors indicate genetically assigned stream of origin.

With genetic stock identification, we showed that anadromous Coastal Cutthroat Trout regularly made marine migrations outside of natal inlets. Anadromous trout exhibit a variety of different migration patterns from transoceanic migrations of Steelhead (Quinn and Myers, 2004) to short interbasin migrations of Dolly Varden *Salvelinus malma* (Spares et al. 2015) and Brown Trout *Salmo trutta* (Eldøy et al. 2015) as well as partial expression of anadromy in Dolly Varden and Rainbow Trout (Bond et al. 2015). While studies specifically focused on Cutthroat Trout in the marine environment are limited, the majority of what is known suggests that Cutthroat Trout make relatively short distance marine migrations (Goetz et al. 2013), do not migrate across large bodies of water (Jones and Seifert 1997) and are unlikely to leave their natal inlet (Moore et al. 2010) ; however, longer migrations have been documented, e.g., Pearcy et al. (1990). In the current study, the majority of fish were assigned to their nearby natal streams <15 km away from the capture location; however, a second mode of longer migrating fish was observed. Fish originating from Skookum and McLane creeks were recovered in high proportions on the margins of the study area, suggesting that it is likely that the full extent of the marine distribution of our study populations was not observed. These results are consistent with those of Goetz et al. (2013) where most fish underwent short marine migrations (residents) while others exhibited longer migrations (migrants). Overall, information reported here suggests that, unlike Cutthroat Trout observed in Hood Canal (Moore et al. 2010), Cutthroat Trout in South Puget Sound regularly leave their natal inlet and exhibit a high degree of variability in migration distance.

Along with interestuarine migrations, we found that Cutthroat Trout exhibited high site fidelity in an area where they are easily accessible to anglers. Recent work by WDFW has identified challenges in management of anadromous Cutthroat Trout due to their mixed stock composition in marine water (Losee et al. 2017), unpredictable migratory patterns (Moore et al. 2010), variability in spawn timing (Losee et al. 2015), and increasing effort by sport anglers targeting them. As a result of much of the uncertainty surrounding anadromous Cutthroat Trout, Washington State manages them conservatively, relying on catch-and-release regulations to minimize fishing mortality. Results of the current research clarify movement patterns of this species and add additional support for conservative regulations to protect Cutthroat Trout from overharvest in areas where remaining nearshore habitat overlaps with fishing access sites. Additionally, catch-and-release regulations most likely provide the greatest economic benefit by maximizing catch rates over the long term for relatively small population sizes.

It is now understood that sport fishers targeting Coastal Cutthroat Trout in marine waters of South Puget Sound encounter a variety of distinct stocks, each made up of less than 300 fish. It is also known that large bodied (>350mm) individuals that had spawned previously were uncommon. Depending on the goals of fish managers, considerations for more fecund, larger females and those stocks that are limiting should be made when designing regulations, consistent with a mixed-stock management strategy. While this may not be feasible due to limited funds and federally mandated recovery efforts for higher priority, Endangered Species Act listed stocks, methodologies for estimating abundance of Coastal Cutthroat Trout in-river are now available and can be implemented with little cost. Finally, by gaining additional information on the movements, age structure, and life history of anadromous Cutthroat Trout relative to historical information, managers may be better able to evaluate the impact sport fisheries have on Coastal Cutthroat Trout in the marine and freshwater and design fisheries to maximize long-term fishing opportunity on abundant stocks.

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