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North American Journal of Fisheries Management

ISSN: 0275-5947 (Print) 1548-8675 (Online) Journal homepage: http://www.tandfonline.com/loi/ujfm20

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To cite this article: James P. Losee, Larry Phillips & William C. Young (2016) Spawn Timing and Redd Morphology of Anadromous Coastal Cutthroat Trout Oncorhynchus clarkii clarkii in a Tributary of South Puget Sound, Washington, North American Journal of Fisheries Management, 36:2, 375-384

To link to this article: http://dx.doi.org/10.1080/02755947.2015.1129001

Published online: 31 Mar 2016.

North American Journal of Fisheries Management 36:375–384, 2016

ISSN: 0275-5947 print / 1548-8675 online
DOI: 10.1080/02755947.2015.1129001

ARTICLE

Spawn Timing and Redd Morphology of Anadromous Coastal Cutthroat Trout *Oncorhynchus clarkii clarkii* in a Tributary of South Puget Sound, Washington

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Abstract
Spawn timing information for Coastal Cutthroat Trout *Oncorhynchus clarkii clarkii* is typically limited to counts of adult fish at traps and tagging studies based on few samples. These types of data have suggested a protracted spawning period that occurs between November and March. We sought to determine the spawn timing and describe the redd morphology of anadromous Coastal Cutthroat Trout in a typical coastal stream of southern Puget Sound, Washington. Skookum Creek was surveyed for live and dead Coastal Cutthroat Trout and redds once weekly from early October to early June during six spawning season (2008–2014). In total, 148 live adults and 544 redds were observed. The timing of redd construction was highly variable among years, with 50% of redd detections occurring by as early as February 13 or as late as April 27. Measurements were collected from individual redds to describe redd morphology and the habitat type utilized by spawning Coastal Cutthroat Trout. Redds were typically found in substrate composed of small gravel (1.3–3.8 cm) and large gravel (3.8–7.6 cm) and in water with an average velocity of 0.60 m/s. The pit within redds averaged 0.43 m wide × 0.48 m long. Information from this study may provide new insights that will allow fisheries managers to begin developing a species-specific approach to monitoring anadromous Coastal Cutthroat Trout.

Coastal Cutthroat Trout *Oncorhynchus clarkii clarkii* exhibit numerous life history forms. The Cutthroat Trout *O. 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 Coastal Cutthroat Trout is not an important commercial species and so is understudied. Although general life cycle information has been documented for anadromous Coastal Cutthroat Trout (Trotter 1989; Wenburg 1998), their spawn timing and redd morphology (size and shape) are poorly understood.

An understanding of the timing, location, and abundance of spawning fish is basic to the management of any fish species. Without this knowledge, biologists may be unable to estimate annual abundance, evaluate management plans, or ensure the long-term stability of a population. Spawn timing and the mechanisms controlling the return to freshwater have been extensively studied for the majority of anadromous salmonids (Leider et al. 1984; Heggberget 1988; Bond and Quinn 2013; Vadas and Beecher 2014). Spawn timing for Pacific salmon is partly a product of recent environmental conditions driving growth and maturation as well as interactions with sympatric species but is controlled primarily by genetic responses to long-term averages in abiotic conditions,

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Received July 2, 2015; accepted December 2, 2015

such as stream temperature and streamflow (Hodgson et al. 2006). This offers some explanation for the predictable nature of spawn timing in the majority of salmonids. In an effort to describe the spawn timing of Coastal Cutthroat Trout, state and federal fishery managers have relied on generalized spawning times from existing low-resolution empirical data collected over a broad geographic area (Johnson et al. 1999); trap counts (e.g., Joe Peters, Squaxin Island Indian Tribe, unpublished data); and anecdotal information (reports from anglers). In Washington, spawn timing for Coastal Cutthroat Trout has historically been defined as extending from late winter to spring (January–March; WDFW 2014). Although this time period may encompass much of the likely spawning period, the diversity of habitat types within the range of most populations suggests that spawn timing is more diverse and flexible than has been assumed by state fishery managers. The current understanding of Coastal Cutthroat Trout is that the majority of returning adults enter freshwater during one of two periods: early entry fish are associated with large river systems and return to freshwater as early as August, whereas late-entry fish are associated with small, independent drainages and return to freshwater during winter or spring (Johnston and Mercer 1976; Michael 1989). These studies indicate that spawning occurs between early fall and late spring—outside the period currently defined by fishery managers—and that spawn timing may vary widely between drainages within a management area depending on a variety of conditions. However, the relationship between the timing of freshwater immigration and spawn timing is unknown.

Fisheries managers have relied primarily on the number of live Coastal Cutthroat Trout collected at traps to estimate the timing of spawning, the number of adults on the spawning grounds, or both (Michael 1989; Pauley et al. 1989). Trapping data alone, however, may not provide reliable spawn timing data. Results from several studies suggest that the timing of freshwater entry does not coincide with spawn timing (Wyatt 1959; Trotter 1997; Saiget et al. 2007), resulting in unreliable estimates of spawn timing or adult abundance. To describe the freshwater movement of adult Coastal Cutthroat Trout, Saiget et al. (2007) tracked five anadromous adults in a tributary of the Copper River delta, Alaska. Results demonstrated that although redd construction occurred during a relatively short time period (25 d), adult freshwater entry extended over a period of 4 months (Saiget et al. 2007). Similarly, Wenburg (1998) documented that freshwater entry occurred over a much longer time period than adult out-migration (>6 months versus <4 months), suggesting that upstream migration takes place over a relatively long time period prior to spawning. In addition to high variability in the interval between freshwater entry and spawning by adult Coastal Cutthroat Trout, the accuracy of trapping data may also be in question because many of the Coastal Cutthroat Trout returning to freshwater for the first time do not spawn (Trotter 1997). These potential sources of error, along with an apparent trapping bias toward larger fish, highlight the need for definitive information on the spawn timing of anadromous Coastal Cutthroat Trout.

One alternative to trapping adults to determine spawn timing is the enumeration of redds via spawning ground surveys. Redd survey methodology has been validated as a reliable tool with which to estimate the number of spawners for many salmonid species (Gallagher and Gallagher 2005; Gallagher and Knechtle 2005), including fluvial and adfluvial Cutthroat Trout (Magee et al. 1996; McMillan et al. 2014; Vadas and Beecher 2014). In addition, redd morphology, sediment size, and mesohabitat characteristics associated with redds have been described for other Cutthroat Trout subspecies, including Colorado River Cutthroat Trout *O. clarkii pleuriticus*, Bonneville Cutthroat Trout *O. clarkii utah*, Westslope Cutthroat Trout *O. clarkii lewisi*, and Yellowstone Cutthroat Trout *O. clarkii bouvieri* (Thurow and King 1994; Keeley and Slaney 1996; Bennett et al. 2014). However, little is known about the size and shape of redds built by anadromous Coastal Cutthroat Trout or the number of adults involved in the construction of a redd.

The purpose of the present study was to document the spawn timing of anadromous Coastal Cutthroat Trout in a coastal tributary that is representative of the Puget Trough Ecoregion (Landscope America 2014). We measured the morphology of Coastal Cutthroat Trout redds as well as the substrate and hydraulics at redd locations in Skookum Creek, Washington. In addition, we quantified interannual variability in the timing of redd construction by Coastal Cutthroat Trout in the creek during six spawning seasons (2008–2014), and we provide several descriptive metrics from spawning sites to aid managers in distinguishing between the redds of Coastal Cutthroat Trout and the redds of sympatric fish species.

METHODS

Study Area

Skookum Creek is a 14-km-long independent tributary of south Puget Sound near Shelton (Mason County), Washington (Figure 1). With an upstream catchment area of approximately 20 km^2 and a long-term mean annual discharge of 734 L/s, Skookum Creek has the characteristics of a typical Coastal Cutthroat Trout spawning stream (Johnson et al. 1999; Buehrens 2011; Ptolemy 2013). The creek exhibits high intra-annual variability in spring streamflows. During a period of continuous measurements in 1953, discharge between February and May ranged from 198 to 17,705 L/s (mean = 1,807 L/s; USGS 2015). Several annual and semiannual tributaries (e.g., Little and Reitdorf creeks) enter Skookum Creek over its length. Skookum Creek and its tributaries drain approximately 4,917 ha of commercial forest, agricultural areas, and residential areas (USGS 2015). The lower approximately 8 km of Skookum Creek are characterized by low-gradient, highly disturbed agricultural land with relatively poor-quality riparian area and widely

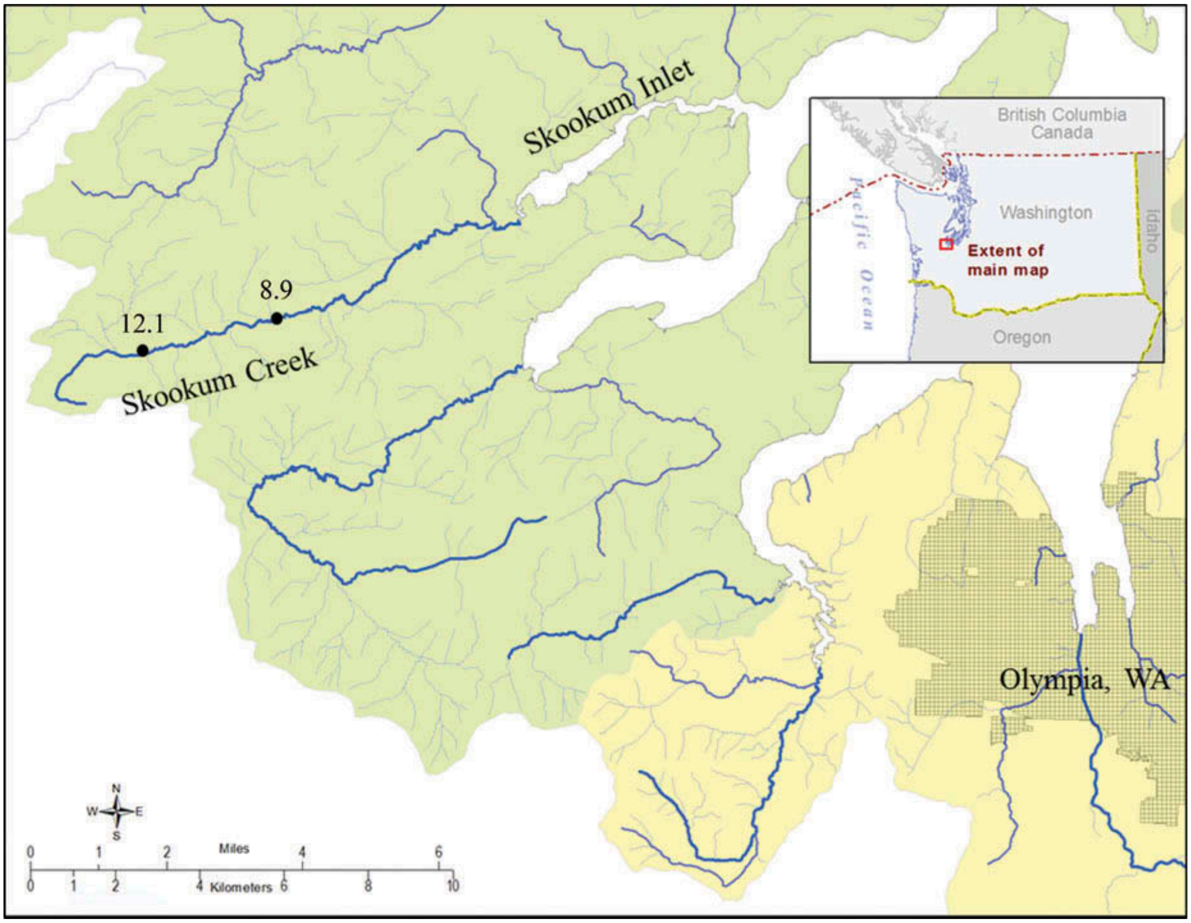

FIGURE 1. Study area in Skookum Creek, Mason County, Washington, where redd counts for anadromous Coastal Cutthroat Trout were conducted. Limits of the index area (river kilometer 8.9–12.1) are indicated with black dots.

dispersed, sparse patches of gravel. In contrast, alluvial gravel and cobble are the dominant substrates upstream of river kilometer (rkm) 8 (H. Beecher and S. Boessow, Washington Department of Fish and Wildlife [WDFW], unpublished data), where the present study took place.

Skookum Creek was surveyed for the presence of Coastal Cutthroat Trout redds along an index section between rkm 8.9 and rkm 12.1 (Figure 1). This area was chosen based on a recent Physical Habitat Simulation Model (PHABSIM) evaluation of Skookum Creek. Results from the PHABSIM study suggested that the index area encompassed over 80% of the suitable spawning habitat available to salmonids (Beecher and Boessow, unpublished data) and is representative of a typical Coastal Cutthroat Trout stream in the Puget Trough Ecoregion (Landscope America 2014). Cutthroat Trout redd density at the reach scale has been correlated with the quantity and quality of available spawning habitat (Magee et al. 1996); therefore, we expected that our study area would account for a large proportion of the total number of redds in Skookum Creek.

The entire length of Skookum Creek is accessible to anadromous salmonids. In addition to Coastal Cutthroat Trout, it supports populations of Coho Salmon *O. kisutch* and Chum Salmon *O. keta*. Genetic analysis of juvenile lampreys in Skookum Creek during the study period suggested that Western Brook Lamprey *Lampetra richardsoni* are also present there in low numbers (Hayes et al. 2013). Steelhead *O. mykiss* have not been observed in Skookum Creek since hatchery releases ceased in 1989.

Survey Methods

The Skookum Creek index area was surveyed from October to June 2008–2014 by using standardized salmonid redd survey methodology described by Gallagher and Gallagher (2005). Surveyors wore polarized sunglasses and caps to reduce glare. 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). No surveys were conducted during January 2010 due to staff limitations; however, no live salmonids or redds were observed in January during any other year of the study period.

Redd observations.—Each redd was flagged with the date, the surveyor's initials, and other descriptive details as needed. We assumed that redds were those of anadromous Coastal Cutthroat Trout. This assumption was based on several factors: (1) the absence of other salmonids during the sampling period; (2) the presence of adult Coastal Cutthroat Trout; and (3) the relatively small size of observed redds relative to those of Coho Salmon and Chum Salmon. We distinguished Coastal Cutthroat Trout redds from those of lampreys *Lampetra* spp. based on published descriptions of salmonid redds (Gallagher and Gallagher 2005) and field observations. Redds that are constructed by salmon typically include a well-defined depression (pit) immediately upstream of a mound (tailspill), whereas those constructed by lampreys do not (Stone 2006; Brumo et al. 2009). These assumptions were further evaluated in situ and are reported in the Results.

We recognize the possibility of misidentifying the redds of nonanadromous Cutthroat Trout as redds constructed by the sea-run variety; however, Skookum Creek is unlikely to support many resident fish that would be large enough to dig redds of the sizes observed in this study. To investigate the relative number of nonanadromous Cutthroat Trout in Skookum Creek, scale samples were collected from juvenile and adult Cutthroat Trout in-stream and during freshwater emigration in 2014 and were analyzed as described by Ericksen (1999). Results from scale analysis revealed that all of the mature (age > 2) Cutthroat Trout sampled in Skookum Creek had scale patterns that were consistent with previous entry into the marine environment.

Redd Location and Morphology

Water velocity and depth.—Reiser and Wesche (1977) reported that the depth and velocity measured immediately upstream of redd pits were representative of conditions experienced by Brown Trout *Salmo trutta* and Brook Trout *Salvelinus fontinalis* prior to spawning. In 2010 and 2011, water velocity (m/s) and water depth (nearest 1 cm) were measured at the front edge of the pit for each redd (Figure 2). Depth measurements were collected with a top-setting wading rod. Flow was measured at 60% depth by using a Swoffer Model 2100 flowmeter. For velocity and depth measurements, only redds that had been constructed within the previous 7 d were included, which allowed us to describe stream conditions near the time of spawning. However, statistical noise is likely present given the variability in streamflow at the 7-d interval of observation.

Substrate.—In 2010 and 2011, the diameters of substrate particles adjacent to each redd were measured with a metric rod to evaluate substrate composition. Substrate was categorized at each redd site by using a modified Wentworth scale (Bovee and Milhous 1978; Bovee et al. 1998). Substrate categories included category 3 (pea gravel: 0.3–1.3 cm), category 4 (small gravel: 1.3–3.8 cm), category 5 (large gravel: 3.8–7.6 cm), and category 6 (small cobble: 7.6–15.2 cm; Appendix Table A.1). Substrate is presented as the dominant particle size category, the subdominant particle size category, and the associated percentages of those categories (e.g., 70% category 3 and 30% category 4).

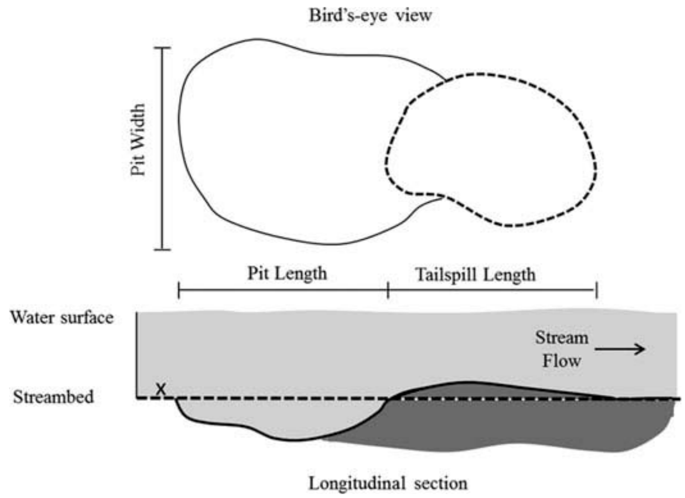

FIGURE 2. Diagram of descriptive measurements collected from the redds of anadromous Coastal Cutthroat Trout in Skookum Creek (× = location of velocity and depth measurements).

Redd dimensions.—Measurements of redd size (nearest 2 cm) were collected in 2014 using two poles (0.914 m [3 ft] long) fixed with a thumb screw at the apex (representing an enlarged mathematical compass), which served to transfer measurements from the redd to a meter stick. Pit length was the total length of the pit as measured parallel to the streamflow (Figure 2). Pit width was the maximum width of the pit as measured perpendicular to the streamflow. The tailspill 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. We used the Shapiro–Wilk test for normality to identify which metrics, if any, were normally distributed, thus serving as reliable characters to identify the redds of Coastal Cutthroat Trout in the field.

Redd life.—Redd life is defined as the length of time for which a redd remains visible (Smith and Castle 1991); it is the product of a variety of factors, including streamflow, sunlight, turbidity, redd superimposition, and periphyton accumulation (Gallagher and Gallagher 2005). We classified redds as either "identifiable" or "not identifiable." In this study, surveys were conducted every 7 d, limiting our interval of inference to a range of 1 week. For this reason, newly observed redds ranged in age from 0 to 6 d and were assigned an average redd life of 3 d. Similarly, redds that were identifiable 7 d after the initial observation had ages ranging between 7 and 13 d; thus, they were assigned a mean redd life of 10 d. All mean redd life values were used to calculate the overall average redd life in days.

Fish observations.—Live and dead adult salmonids observed in the index area were visually identified to species based on their size and color. We noted the presence of live adult Coastal Cutthroat Trout occupying redds versus those not occupying a redd.

The trapping of out-migrating salmonids by the Squaxin Island Indian Tribe during the study period suggested that the maximum size of Coastal Cutthroat Trout parr and smolts migrating to the marine environment was approximately 24.0 cm TL (Peters, unpublished data). Therefore, only fish that were visually estimated from the bank as exceeding 25 cm TL were included in counts of live fish; these counts served as estimates of the number of Coastal Cutthroat Trout that had returned from the marine environment. To understand whether observations of live Coastal Cutthroat Trout could serve as a proxy for the relative number of spawners across years, we used Pearson's product-moment correlation analysis (after conducting the Shapiro–Wilk test for normality) to test the relationship between interannual variability in the total count of live Coastal Cutthroat Trout and interannual variability in the redd count.

Variability in spawn timing.—A Kolmogorov–Smirnov (K–S) two-sample test was used to investigate whether the temporal distribution of redd counts differed significantly ($P < 0.05$) between years. We applied a Bonferroni correction to α (i.e., $\alpha = 0.05/6 = 0.008$) to achieve a P-value of 0.05 as a realized experimentwide error rate across multiple comparisons. We estimated the date by which 50% of the total number of Coastal Cutthroat Trout redds had been observed by using a smoothed line drawn between the total number of redds versus time for each survey in each year.

RESULTS

During 2009–2014, we observed 544 Coastal Cutthroat Trout redds, 148 live Coastal Cutthroat Trout, and no dead Coastal Cutthroat Trout in the 3.2-km study reach within Skookum Creek (Table 1). Less than 3% (25/544) of the observed redds had one or more Coastal Cutthroat Trout occupying them. Observations of live adults ranged from 4 individuals in 2011 to 47 individuals in 2013. Interannual variability in the total number of live Coastal Cutthroat Trout observed was not significantly related to the interannual variability in total redd counts (Pearson's $r = 0.610$, $P = 0.20$). Other salmonids observed during the study period included Chum Salmon and Coho Salmon; peak counts for both species occurred in November, and a minimum of 25 d elapsed between the last observation of a live Chum Salmon or Coho Salmon and the first observation of a Coastal Cutthroat Trout redd. No live lampreys or lamprey redds were observed during the study period.

Redd Location and Morphology

Water velocity and depth.—Water velocity at the upstream edge of Coastal Cutthroat Trout redds ranged from 0.34 to 0.96 m/s (mean ± SD = 0.60 ± 0.13 m/s; Table 2), and water depth ranged from 0.06 to 0.37 m (0.18 ± 0.06 m).

Substrate.—Coastal Cutthroat Trout redds tended to be constructed in habitat that was dominated by small gravel (~69%; Table 2); large gravel was the subdominant substrate type in 40% of the redds. However, substrate type was highly variable, with a smaller percentage of redds (26%) also containing small cobble as the subdominant substrate type.

Redd dimensions.—Mean pit length was 0.48 ± 0.14 m (mean ± SD), and mean pit width was 0.43 ± 0.14 m. Pit length and pit width were normally distributed (Shapiro–Wilk test, pit length: $W = 0.982$, $P = 0.712$; pit width: $W = 0.983$, $P = 0.738$; Figure 3a, b). In contrast, mean tailspill length (0.64 m) exhibited a relatively high SD of 0.46. Tailspill length data were nonnormally distributed (Shapiro–Wilk test: $W = 0.820$, $P < 0.001$; Figure 3c).

Redd life.—The majority of Coastal Cutthroat Trout redds (56%) were visible for more than 7 d after initial observation, and the mean redd life was 13.4 ± 4.0 d (mean ± SD; Table 2).

TABLE 1. Number of new redds, number of live anadromous Coastal Cutthroat Trout, and estimated date by which 50% of the redds had been observed in the index area of Skookum Creek, Washington.

	Month of observation for new redds						
Year	Feb	Mar	Apr	May	Total	Live fish total	50% of redds observed (month and day)
2009	29	72	27	0	128	30	Mar 11
2010	45	29	29	0	103	39	Feb 28
2011	13	1	35	32	81	4	Apr 20
2012	12	12	21	1	46	17	Mar 7
2013	66	34	12	0	112	47	Feb 13
2014	1	5	51	8	65	11	Apr 7
Total	166	153	175	41	535	148	NA
Mean ± SD	28 ± 22.1	25.5 ± 24.0	29.1 ± 12.1	6.8 ± 11.6	89.2 ± 28.1	24.7 ± 15.3	Mar 10 ± 16 d

TABLE 2. Characteristics of redds constructed by anadromous Coastal Cutthroat Trout in Skookum Creek, Washington. Substrate type is given as the dominant or subdominant particle size category (Wentworth scale; see Table A.1 for category descriptions), with the percentage shown in parentheses.

Statistic	Water velocity (m/s)	Water depth (m)	Substrate type (Wentworth scale) Dominant particle size category (%)	Substrate type (Wentworth scale) Subdominant particle size category (%)	Pit length (m)	Pit width (m)	Tailspill length (m)	Redd life (d)
Mean ± SD	0.60 ± 0.13	0.18 ± 0.06	4 (70)	5 (30)	0.48 ± 0.14	0.43 ± 0.14	0.64 ± 0.46	13.4 ± 4.0
Minimum	0.34	0.06	3 (60)	5 (40)	0.19	0.12	0.11	<12
Maximum	0.96	0.37	6 (50)	5 (50)	0.75	0.77	2.32	14–20
n	44	91	35	35	45	45	45	54
CV	0.22	0.33	–	–	0.29	0.33	0.72	–

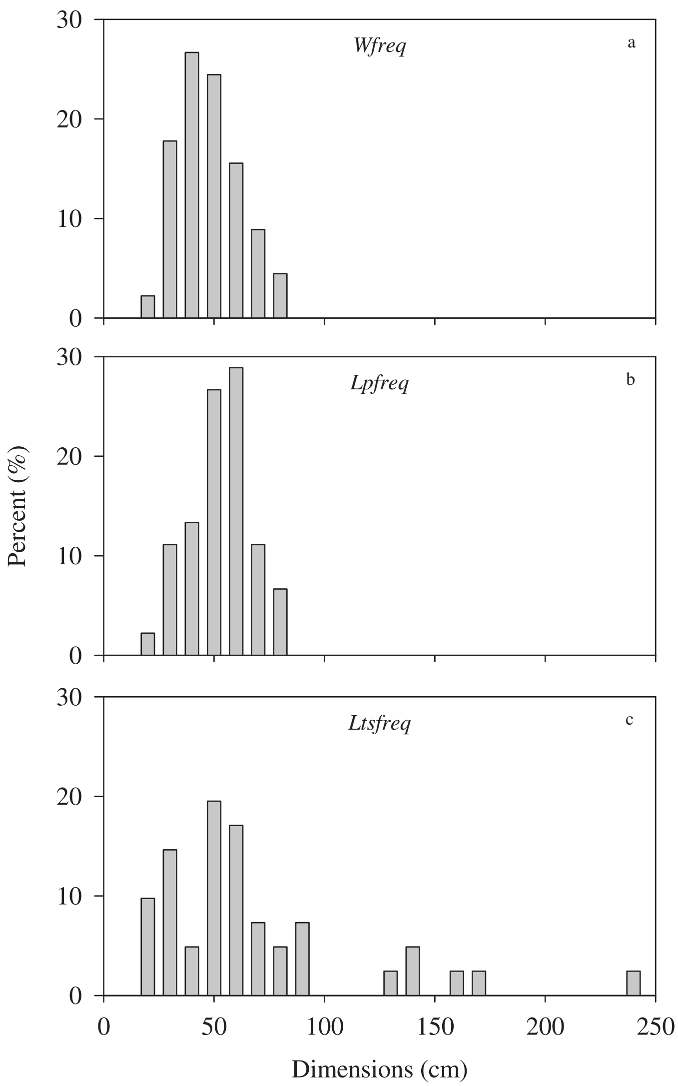

FIGURE 3. Length frequency distribution of **(a)** pit width, **(b)** pit length, and **(c)** tailspill length of redds constructed by anadromous Coastal Cutthroat Trout in Skookum Creek.

No redds were detectable beyond 14 d (redd life between 14 and 20 d) after initial observation.

Variability in Spawn Timing

Coastal Cutthroat Trout redds were observed in the index area as early as February 2 and as late as May 27 (Figure 4). Pairwise comparisons of spawning distributions revealed that the spawn timing of Coastal Cutthroat Trout was significantly different (K–S test: $P < 0.05$; Table 1; Figure 5) for each pair of study years except (1) 2009 versus 2012; and (2) 2010 versus 2012 (K–S test: $P > 0.05$; Table 1; Figure 5). Across all years, the overall mean date by which 50% of redds were observed was March 10, but annual values varied by more than 2 months (February 13, 2013, versus April 20, 2011; Table 1; Figure 5). 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).

DISCUSSION

The January–March spawn timing previously described for Coastal Cutthroat Trout in Washington does not accurately depict the potential spawning period for Coastal Cutthroat Trout in Puget Sound. We documented that spawning activity was protracted over an extended time period and exhibited a high degree of interannual variability. 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 in the absence of sympatric salmonids, we were able to (1) provide an accurate estimate of spawn timing and (2) demonstrate the potential for anadromous

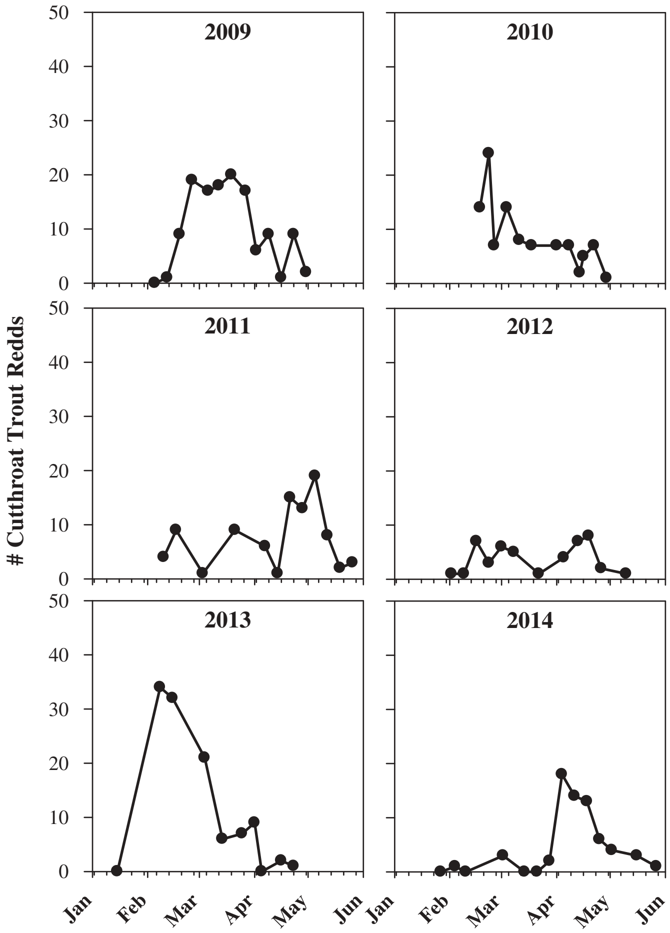

FIGURE 4. Number of anadromous Coastal Cutthroat Trout redds observed in Skookum Creek, 2009–2014.

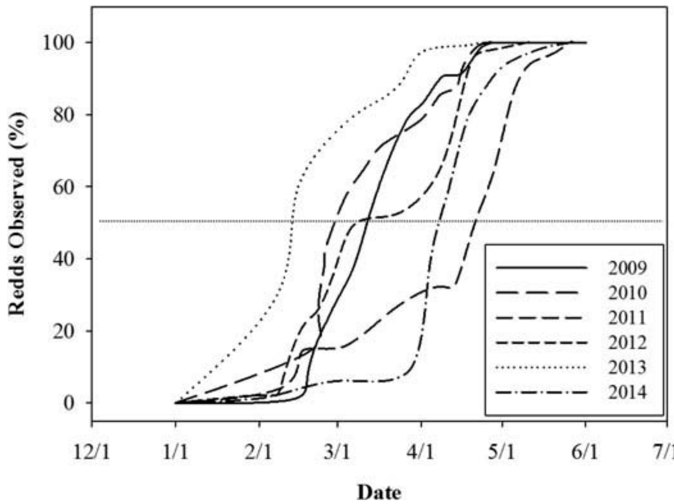

FIGURE 5. Cumulative percentage of anadromous Coastal Cutthroat Trout redds observed in Skookum Creek by date. Data points from surveys are joined by a smoothed line. Horizontal dotted line identifies the date by which 50% of redds had been observed.

Coastal Cutthroat Trout to exhibit a high degree of variability in spawn timing.

Results from the current study suggest that Coastal Cutthroat Trout exhibit a broader spawning period than other salmonids in the same watershed. In a synthesis, Trotter (2008) reported that Coastal Cutthroat Trout spawn throughout the winter and spring, with peak spawning occurring in April–May for northern populations (Alaska) and in February for southern populations. Data reported herein suggest that spawn timing is more variable than described by Trotter (2008) and others and that it cannot be explained solely by latitude. In Skookum Creek, located near the center of the known distribution of Coastal Cutthroat Trout, spawning took place between February 2 and May 27 and was highly variable among years. The median date of redd counts for Coastal Cutthroat Trout varied by more than 2 months. Our study was not designed to identify the specific factors that drive the spawn timing of Coastal Cutthroat Trout, but it does highlight the need for fishery managers to re-evaluate assumptions about this subspecies and to explore the factors that influence spawn timing.

In Skookum Creek, the variable spawn timing—with a duration of up to 4 months—took place in the spring, when south Puget Sound streams exhibit variable flow patterns (USGS 2015). Although the relationship between Coastal Cutthroat Trout spawning and local environmental conditions is not well understood, this relationship should be further studied, as it may have implications for the persistence of this subspecies if faced with sudden changes (urbanization, hydropower, etc.) or long-term changes (climate) in environmental conditions. Additional work aimed at identifying the specific factors that influence the spawning of anadromous Coastal Cutthroat Trout would improve accuracy in predicting spawn timing and habitat use across a variety of environmental gradients.

To our knowledge, observations of Coastal Cutthroat Trout redds are not being used to estimate the total number of anadromous spawners or to predict the standing population size of Coastal Cutthroat Trout. It could be assumed that each redd represents one female Coastal Cutthroat Trout, but the lack of information on how many individuals (males and females) are involved in the construction of a redd limits the utility of such data for estimating the total number of spawners. In addition, redd data may not serve as an accurate representation of the true number of redds present due to (1) error associated with redd counting (Dunham et al. 2001) and (2) the inability to distinguish “test digs” from redds that contain eggs (Holecek and Walters 2007). In a study of the error associated with counting Bull Trout *Salvelinus confluentus* redds, Dunham et al. (2001) suggested that the number of redds observed may vary substantially depending on the surveyor’s experience and level of training. As suggested by Dunham et al.

(2001), we controlled for this source of error by assigning two trained individuals to survey redds for the life of the study with few exceptions, thus allowing for a comparison of relative abundance across various time scales (i.e., days, months, and years). Future studies that identify the sources and degree of error associated with Coastal Cutthroat Trout redd counts and that compare the number of adults on the spawning grounds to the number of redds produced would increase the value of redd counts beyond their use as estimates of spawn timing.

Interannual variability in the number of live Coastal Cutthroat Trout observed in the study area was not related to variability in the number of redds counted, suggesting that fish counts alone do not serve as a good indicator of population size or relative abundance. However, counts of live salmonids during the study period supported the assumption that the redds observed in Skookum Creek between February and June were those of anadromous Coastal Cutthroat Trout rather than other salmonids. In fact, there was a minimum of 25 d between the final observation of a live Chum Salmon or Coho Salmon and the first observation of a Coastal Cutthroat Trout redd. Anecdotal reports suggest that Skookum Creek historically supported winter steelhead, which would have spawned within the same time frame as Coastal Cutthroat Trout (February–April; Chuck Baranski, WDFW, personal communication). However, steelhead have not been documented in Skookum Creek since 1984 (WDFW, unpublished data). In addition, no steelhead out-migrants were captured in a smolt trap operated below the index area (rkm 3) in Skookum Creek during the study period (2002–2014; Joe Peters, Squaxin Island Indian Tribe, personal communication). Collectively, this information suggests that any steelhead population that did exist in Skookum Creek has been extirpated and should not be considered a factor in the present results.

The lack of temporal or spatial overlap between Coastal Cutthroat Trout and other salmonids in Skookum Creek allowed for an accurate estimate of spawn timing and redd morphology for this subspecies. Although the present data provide Coastal Cutthroat Trout spawn timing information that may be useful to fisheries managers, the accuracy in applying these results to other systems is unknown. Results from previous studies suggest that at the juvenile and adult life stages, Coastal Cutthroat Trout hold a competitive disadvantage relative to sympatric salmonids, such as Coho Salmon and steelhead (Giger 1972; Glova 1986; Hearn 1987; Bisson et al. 1988). It is unknown whether the protracted 4-month spawn timing observed in Skookum Creek is characteristic of anadromous Coastal Cutthroat Trout populations across their range or has arisen due to this population's release from the competitive pressure exerted by other salmonids. The response of anadromous Coastal Cutthroat Trout to the presence of steelhead and/or Coho Salmon during the spawning period is not well understood and should be investigated further.

We have provided redd morphology data that may assist fisheries managers in distinguishing between the redds of Coastal Cutthroat Trout and the redds of sympatric species. Thurow and King (1994) demonstrated that the size of redds constructed by Yellowstone Cutthroat Trout was not related to environmental indices (flow, depth, etc.), thus suggesting that other factors (e.g., fish size) could be more important in determining redd dimensions. Furthermore, because redd size has been correlated with fish size, fisheries managers have used redd length as a tool to identify the species responsible for building nests of various sizes (Gallagher and Gallagher 2005). In contrast, it has been shown that stream conditions (flow, gradient, sediment size, and cover) can play a role in determining the size of completed redds—specifically, the length of the tailspill (Gallagher and Gallagher 2005). Consistent with the findings of Thurow and King (1994), our results suggest that tailspill length is highly variable, whereas the pit width, the pit length, and the depth and flow at the redd location were normally distributed across our samples. Overall, our results indicate that the length and width of the redd pit and the flow and depth at the pit's upstream edge may be reliable tools for distinguishing the redds of Coastal Cutthroat Trout from those of sympatric species.

We defined the spawn timing of anadromous Coastal Cutthroat Trout in a tributary of south Puget Sound. In addition, we described the morphology of Coastal Cutthroat Trout redds by reporting a host of descriptive characteristics in a system that was devoid of sympatric species. This information will allow fisheries managers to take additional steps toward understanding the factors that drive spawn timing in this relatively unstudied subspecies of Cutthroat Trout. Additional information is needed to accurately estimate Coastal Cutthroat Trout spawner abundance, but we have taken the logical first step by describing the period when anadromous Coastal Cutthroat Trout spawn. The variable spawn timing of Coastal Cutthroat Trout in Skookum Creek suggests that short-term monitoring projects used by fishery managers to define annual abundance and evaluate management plans may be insufficient for this subspecies. Management biologists should take a different approach relative to those used for other Pacific salmonids and should develop a management strategy aimed specifically at Coastal Cutthroat Trout.

ACKNOWLEDGMENTS

We thank Bill Evans (WDFW) for his expertise in all things anadromous. The quality of our data would have suffered without the consistency of Jack Havens; we also thank others who assisted with data collection, including Hal Beecher, Steve Boessow, Adam Couto, Kelly Cunningham, Riley Freeman, Tara Livingood, Kate Losee, John Rohr, Nick Ziackin, the Squaxin

Island Indian Tribe, and volunteers from South Sound Fly Fishers. Kenny Behen, Steve Caromile, Andrew Claiborne, Mark Downen, and Riley Freeman assisted with data analysis; Dale Gombert produced the map; and Ron Ptolemy, Paul Sekulich, Tom Quinn, and one anonymous reviewer provided thoughtful comments at various stages of manuscript preparation.

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Appendix: Scale for Stream Substrate Composition

TABLE A.1. Wentworth scale used to assess the stream substrate composition near Coastal Cutthroat Trout redds in Skookum Creek, Washington.

Category	Substrate type	Particle size (cm)
1	Silt/organic	<0.3, organic
2	Sand	<0.3, sink fast
3	Pea gravel	0.3–1.3
4	Small gravel	1.3–3.8
5	Large gravel	3.8–7.6
6	Small cobble	7.6–15.2
7	Large cobble	15.2–30.4
8	Boulder	>30.4
9	Bedrock	–