THE OREGON PLAN *for Salmon and Watersheds*

Life History Variability, Habitat Use, and Migratory Behavior of Coastal Cutthroat Trout in the Salmon River, Oregon

Report Number: OPSW-ODFW-2012-10

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INTRODUCTION

Coast basins in Oregon support resident and anadromous cutthroat trout (*Oncorhynchus clarki clarki*). Cutthroat trout isolated above barriers are stream resident, but those with access to river, estuary, and marine environments may express a variety of life history and migratory patterns. Past studies (e.g. Giger 1972, Sumner 1972, Tipping 1981) indicated that estuaries serve primarily as a migratory corridor or short-term rearing environment. However, recent advances in marking and tracking technology have permitted researchers to gain a better understanding of the complex migratory and habitat use patterns of cutthroat. Krentz (2007) conducted studies in Salmon River on the central Oregon coast to explore migratory patterns of cutthroat and examine the role of the estuary as a rearing environment.

Coastal cutthroat trout reared for extended periods of time throughout the available channel habitats in Salmon River estuary (Krentz 2007) during spring, summer, and fall. The estuarine resident population appeared to represent a significant portion of the migratory individuals, and included all older age classes. Estuary growth was similar to that of their ocean migrant counterparts, and survival in the estuary was high. Because cutthroat were collected and marked primarily within the estuary (Krentz 2007), it is unclear what portion of the migrant population reared in the estuary relative to the watershed or ocean, or whether the tagged group was representative of the migratory populations. The current study was designed to track a representative sample of the downstream migrant population, and assess the relative success (survival) of the estuary and ocean migrants.

Similar studies in the Columbia River documented directed and rapid migration through the estuary (Zydlewski et al. 2008, Hering et al. 2009). With rare exception, cutthroat trout were not observed to rear in the estuary. In addition, many fish disappeared before reaching the ocean and few of the ocean migrants returned to the natal tributary. In this study we replicated the study design used in the Columbia River studies to further comparisons of estuary migration and rearing strategies between the two estuaries.

The primary objective of our work in the Salmon River was to increase understanding of coastal cutthroat trout biology and the relationship between stream-resident and migratory, or "sea-run" cutthroat. Here we use the term "sea-run" to indicate migration into the tidally-inundated, or estuarine portions of the Salmon River watershed or to the ocean. Study objectives were to:

1. Estimate the distribution and abundance of coastal cutthroat trout in the Salmon River watershed
2. Quantify the proportions of the cutthroat populations that are migratory, identify which individuals migrate and describe the timing of migration
3. Describe estuary habitats used by sea-run migrants and characterize behavior within the Salmon River estuary

4. Estimate growth rate of stream and estuary resident cutthroat
5. Estimate estuary and ocean survival of sea-run individuals and document return to estuary and lower river.
6. Compare migratory behavior in Salmon River to that observed in the lower Columbia River

METHODS

Study Site

The Salmon River watershed is located on the north-central Oregon coast near Lincoln City (Figure 1). The basin is 195 km^2 in size, with an 800 hectare estuary that extends to river kilometer (rkm) 6.5. The estuary has extensive wetlands, many of which were restored during 1978, 1987, and 1996, and are labeled by year of restoration. Additional area where Rowdy Creek enters the southern edge of the estuary marsh at rkm 2.5 (i.e. 87 Marsh) and Frazier Creek were opened to tidal influence in 2010 and 2011 with the removal of a tide gate and associated dikes. One marsh system, labeled as "reference" was never diked. The basin has a diverse ownership and management: US Forest Service (USFS) Cascade Head Scenic Research Area in the estuary, USFS and private industrial forest in the uplands, Oregon State Parks in 3.2 km of stream corridor, and rural residential along the lower reaches of the mainstem Salmon River. ODFW operates a hatchery at rkm 7.9 (Figure 1) that was established in 1978 to supplement coho and Chinook salmon populations. Coho have not been released since May 2007. The hatchery releases 200,000 juvenile Chinook annually in late August or early September.

Watershed Population Estimates

Cutthroat trout abundance was estimated in 107 kilometers of wadeable stream in the basin that were presumed accessible to sea-run cutthroat trout, including both tributary and mainstem habitats. Within this sampling frame, 25 sites were selected annually using the Generalized Random Tessellation Stratified (GRTS) sampling methodology (Stevens and Olsen 2004). Abundance was estimated by multiple-pass removal (Zippin 1958) using backpack electroshockers. Each site was approximately 20 active channel widths in length, with a minimum of 50 meters and a maximum length of 150 meters. Blocknets were placed at the upstream and downstream end of each site, and we made multiple passes (minimum of three and maximum of five) through the site until a sufficient reduction in catch was achieved between subsequent passes. Depletion estimates of the number of fish at each site were derived from the program CAPTURE (White et al. 1982). The total number of cutthroat rearing in the basin was estimated using the local neighborhood (NBH) variance estimator (Stevens and Olsen 2003) and expanded to all accessible stream kilometers in the basin.

Cutthroat were enumerated and a subsample was measured (fork length), weighed, and PIT tagged. Trout <65 mm were classified as trout fry to minimize errors in identification between steelhead and cutthroat. Cutthroat trout 65-120 mm were tagged with 12 mm tags while those >120 mm were tagged with 23 mm PIT tags.

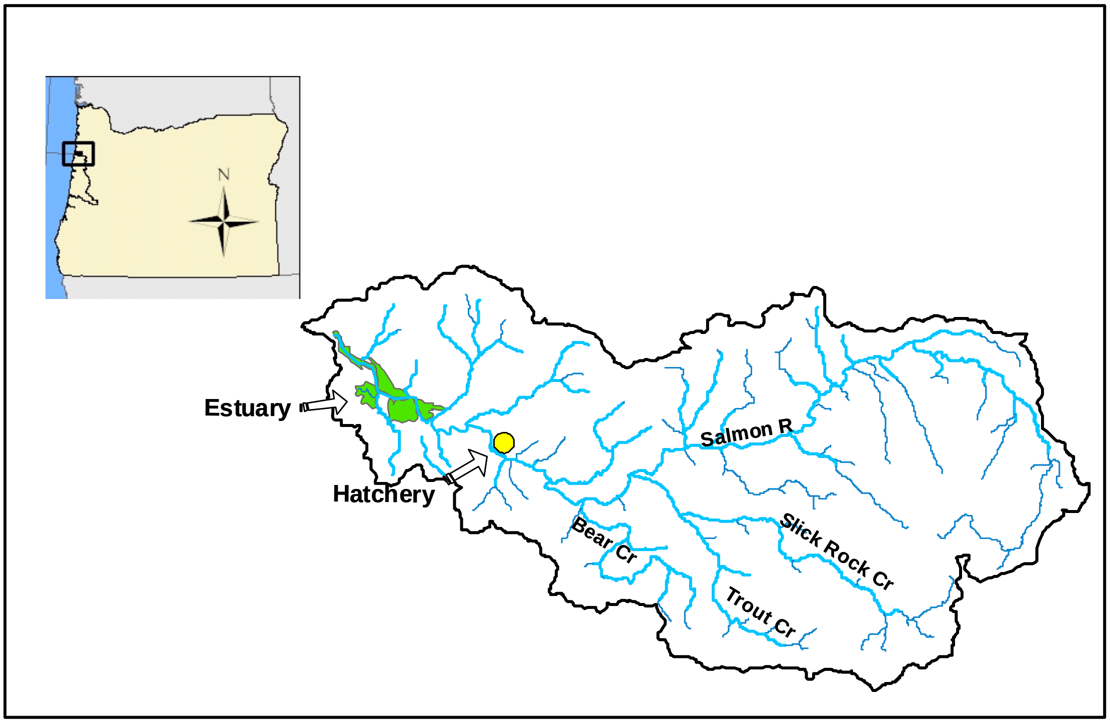

Figure 1. Salmon River basin on the north-central Oregon Coast. Cutthroat were captured in 2004, 2008, 2009, and 2010 by a 5-m diameter rotary screw trap operated from March to June each year at rkm 7.9 at the head of tidal influence.

Downstream Migrant Trapping

In 2004, we installed and operated a rotary screw trap from mid- March through late June on the Salmon River near the Salmon River hatchery solely for the purpose of collecting appropriately sized cutthroat to tag. No estimates of abundance were made, and only cutthroat with a fork length of >170mm were retained for acoustic tag implantation (n=22).

In 2008, 2009, and 2010, abundance, timing, and size distribution of downstream migrant cutthroat trout were monitored with a rotary screw trap (Figure 2) in the same location as in 2004, downstream of the Salmon River hatchery weir at river kilometer 7.9 (Figure 1). The trap was operated from mid-March to late June each year. All cutthroat captured in the screw trap were enumerated, measured, and weighed. A subsample of captured fish was marked with caudal fin clips (in addition to PIT tags) and released upstream of the trap to estimate trapping efficiency. Total abundance of downstream migrants was estimated as the number captured in the trap, adjusted by recapture efficiency. Efficiency was calculated on a weekly basis, and averaged over the season.

Cutthroat were tagged with a PIT tag, and in 2009, and 2010, all cutthroat >170mm in length also were implanted with an acoustic tag (n=11 and n=13 respectively).

Figure 2. Five meter diameter screw trap near the Salmon River Hatchery.

PIT Telemetry

Most coastal cutthroat trout >65mm that were captured during electrofishing in the watershed, at the Salmon River screw trap, or by beach seining in the estuary were marked with full duplex Passive Integrated Transponders (PIT-tags) (Table 1). Fish <120mm were internally implanted with 12mm tags ((Destron-Fearing model TX1411SST, 0.10 g dry weight), while those >120mm were tagged with 23mm full duplex (Destron-Fearing model TX1420SST, 0.37g dry weight). In 2008, 2009, and 2010 a total of 1254 were tagged in the upper watershed, 536 cutthroat were tagged at the screw trap, and 847 were tagged in the estuary. All cutthroat recaptured were measured and weighed.

Table 1. Number of cutthroat trout marked with PIT tags throughout the Salmon River basin in 2008, 2009, and 2010.

Upper Watershed/Electrofishing (August - September)	
2008	333
2009	465
2010	456
Mainstem River / Rotary Screw Trap (March - June)	
2008	125
2009	258
2010	153
Estuary/Beach Seine (January - December)	
2008	172
2009	287
2010	388

A PIT antenna array, consisting of three antennas, was placed in lower Salmon River on August 26, 2010 at rkm 8.0 adjacent to the Salmon River hatchery weir (Figure 3). The antenna array was placed on the north side of the river between the weir and shoreline. Fish generally are forced to the north side of the river to pass upstream. When the river raised high enough to completely submerge the weir, the antenna still operated and detected fish passing through, although we do not know what percentage of fish traveled on the north side of the weir. The antennas were powered by a multiplexing transceiver (Destron Fearing, Inc. model FS1001M), which in turn is powered by four 12V deep cycle batteries that are recharged through a 110 AC power line from the hatchery. PIT-tag interrogation and transceiver diagnostic data are downloaded directly from the transceiver memory via a wireless modem. The antenna records detections of tagged adult cutthroat, coho, and steelhead, and tagged juvenile fish passing downstream or upstream. Direction of movement could not be determined from detection data.

Figure 3. PIT antenna at Salmon River Hatchery weir. Left - low flow; center – moderate flow; right - high flow and still operating.

From April 22, 2010 to August 25, 2010, we operated a PIT tag antenna array in a brackish tidal marsh channel in the upper estuary at rkm 3.8 (i.e. 96 Marsh). The array consisted of five rectangular inductor coil antennas (3 were approximately 3.0 m x 1.2 m, 2 were 2.4m x 1.2 m) arranged in a line stretching across the channel (Figure 4). Antennas were powered by a multiplexing transceiver (Destron Fearing, Inc. model FS1001M). Power was provided by four 12V deep cycle batteries that were recharged with two 85-watt solar panels and a 10-amp, 24-volt charge controller. PIT-tag interrogation and transceiver diagnostic data were downloaded directly from the transceiver memory via a wireless modem.

Figure 4. 96 Marsh PIT tag antenna array.

Acoustic Telemetry

To evaluate estuarine habitat use, migration behavior, and survival of migrant coastal cutthroat trout, we tagged a sample of cutthroat captured at the migrant trap during 2004, 2009, and 2010 with individually coded hydroacoustic transmitters (Vemco, Ltd. Transmitters). Model V9 tags were used all three years. The V9 tags are 29m long x 9mm diameter, weigh 4.9g, and have a battery life up to 374 days. Prior to tagging, cutthroat were anesthetized (MS-222, ≤50 mg·L^{-1}), measured, and weighed. Tags were implanted in the peritoneum through a ventral incision using techniques similar to Zydlewski et al. (2008). Incisions were closed with two to four non-absorbable nylon monofiliament sutures. Tagged cutthroat were allowed to recover for at least four hours (2004) or overnight (2009, 2010) in an aerated 75L cooler, or a perforated 190L barrel anchored in the stream. The fish were released approximately 100 meters downstream of the trap. A total of 22, 11, and 13 cutthroat were tagged in 2004, 2009, and 2010, respectively (Table 2).

Table 2. Size and date of cutthroat trout implanted with acoustic tags in 2004, 2009, and 2010

Year	Tag Type	Sample Size	Length (mm)	Median (mm)	Dates
2004	V9-2L-R04K	22	173-388	216	4/13 - 6/04
2009	V9-2L-R04K	11	175-246	201	4/14 – 6/15
2010	V9-2L-R04K	13	175-320	221	3/26 – 6/10

Acoustic-tagged fish were detected with a network of stationary receivers (hydrophones) anchored above tide water, in the Salmon River estuary, and, in 2009 and 2010, at locations in the ocean near Three Rocks (Table 3, Figure 5). Receivers recorded the unique identification code of detected transmitters and the date and time of detections. Open water receivers were moored as described in Clements et al. (2005), and additional receivers were attached to stationary objects on the channel margins. Receivers were downloaded approximately monthly. In 2004, twelve receivers were deployed at locations between and including rkm 7.8 (i.e. Hatchery Hole) and rkm 1.3 (i.e. Crowley Creek). In 2009 thirteen receivers were deployed and eleven receivers were deployed in 2010. Several of the 2004 receiver locations were duplicated in 2009 and 2010, and we added a receiver directly upstream and downstream of the release site at the screw trap. We also had success maintaining receivers offshore in 2009 but were only able to retrieve one out of the three offshore receivers in 2010.

Table 3. Number and location of acoustic receivers in 2004, 2009, and 2010 placed above tide water, in the estuary, near the mouth and offshore

Year	N	Fresh water	Estuary	Mouth	Offshore
2004	12	2	10	0	0
2009	13	2	4	2	5
2010	11	2	4	2	3

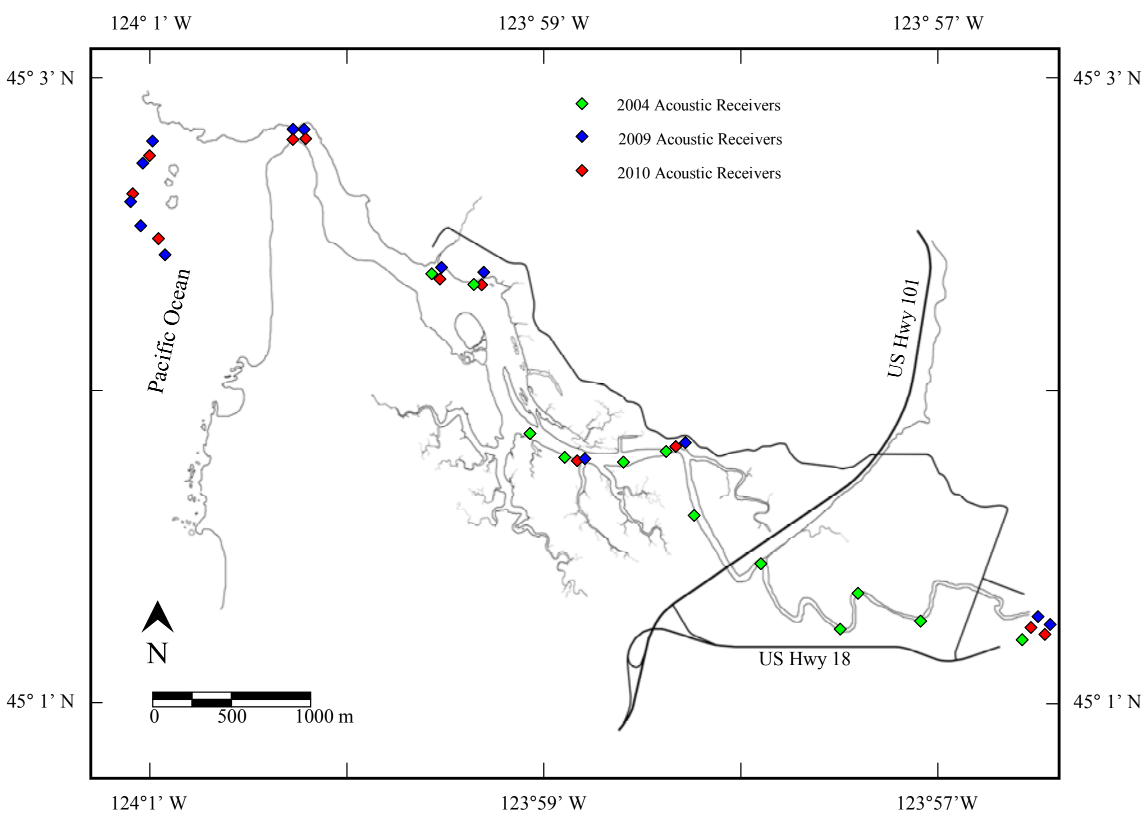

Figure 5. Acoustic receiver locations in 2004, 2009, and 2010 in the Salmon River estuary, near the mouth and offshore.

Estuary beach seine operations

We collected information on habitat use, residence time, and growth of cutthroat trout in the estuary. Beach seining is an effective means of capturing juvenile salmonids in the Salmon River estuary (Mullen 1979, Cornwell et al. 2001, Bottom et al. 2005), and catch-per-unit-effort seining is a reliable index of salmonid abundance in small Oregon estuaries (Reimers 1973, Pearcy et al. 1989). The main channel and wetland habitats of the estuary were sampled at least twice monthly using a 38m x 2.7m beach seine (1.9cm stretch mesh wings, reduced to 0.6cm stretch mesh in center panel). Site selection was representative of available channel and wetland habitat throughout the estuary from the 96 marsh to ocean entrance (Figure 6). The wetland habitats (natural and restored) are located along a salinity gradient from tidal-freshwater to marine zones (Bottom et al. 2005). We considered the mid-estuary to include the section from rkm 1.3 (i.e. Crowley Creek) to rkm 2.5 (i.e. 87 Marsh). The marsh sites were typically shallow and muddy, river channel sites were deeper with coarser substrate, and lower estuary sites were sandy and more saline. In 2008-2010, we conducted biweekly sampling throughout the year with weekly sampling from spring to early fall. Cutthroat were enumerated, measured, and scanned for PIT tags to estimate estuarine residence and growth. PIT tags were placed in untagged cutthroat (Table 1). We did not sample cutthroat in the estuary with a beach seine in 2004.

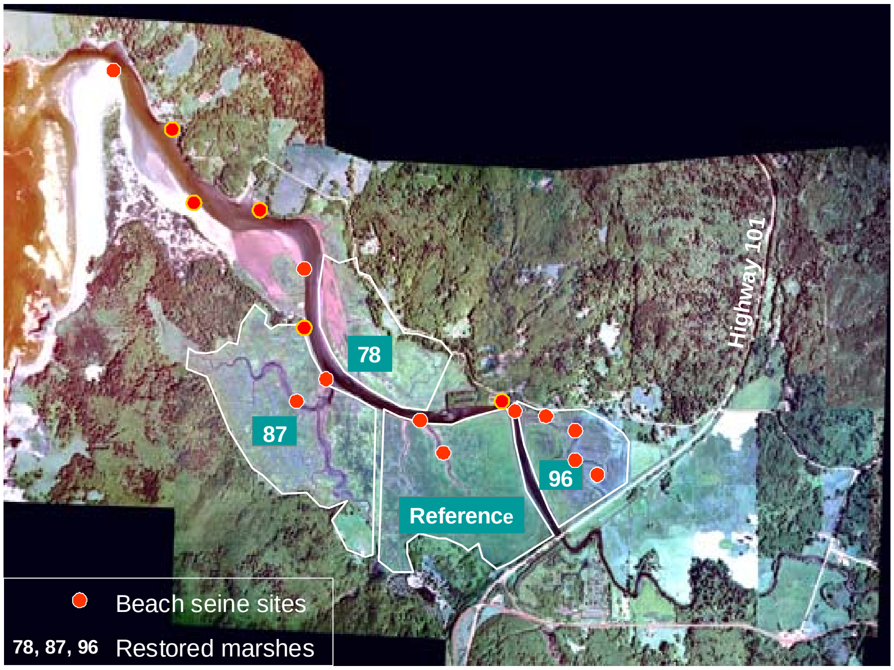

Figure 6. Beach seine sites in Salmon River estuary. Restored marshes are identified by year of restoration.

RESULTS

Watershed population

Population estimates of cutthroat in the basin ranged from 34,600 in 2008 to about 41,000 in 2009 (Table 4). Cutthroat trout were observed at all but one site, and were abundant in many of the tributaries (Figure 7). Sizes of cutthroat in streams during August and September ranged from 60mm to 274mm, with a mean length of 111mm and a median of 107mm (Figure 8).

Table 4. Population estimates (±95% confidence intervals), mean density per m^2, mean density per km, and percent of sites occupied, by cutthroat in streams of Salmon River watershed.

Year	Abundance (95% CI)	Density (m^2)	Density (km)	Occupancy
2008	34,610 (25%)	0.10	321	100%
2009	41,048 (13%)	0.15	382	100%
2010	35,849 (28%)	0.11	333	95%

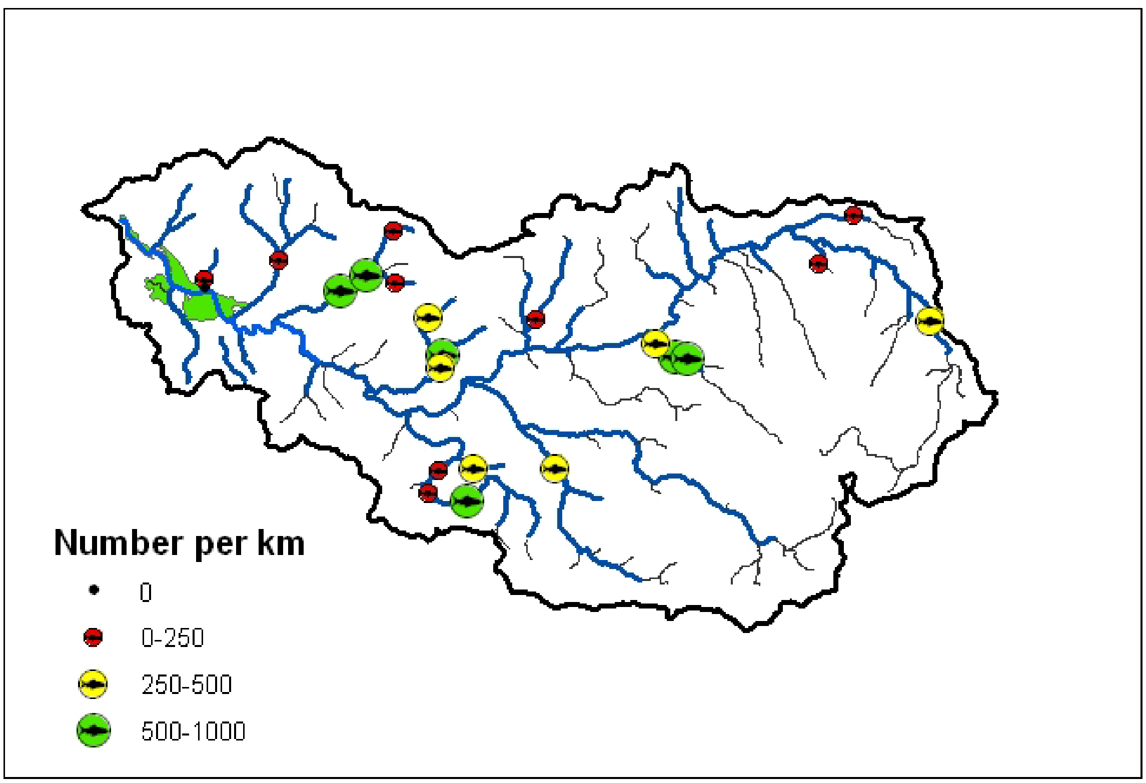

Figure 7. Density of juvenile cutthroat trout in 2010 at randomly selected sites (GRTS). Streams highlighted in thick blue represent streams accessible to sea-run cutthroat.

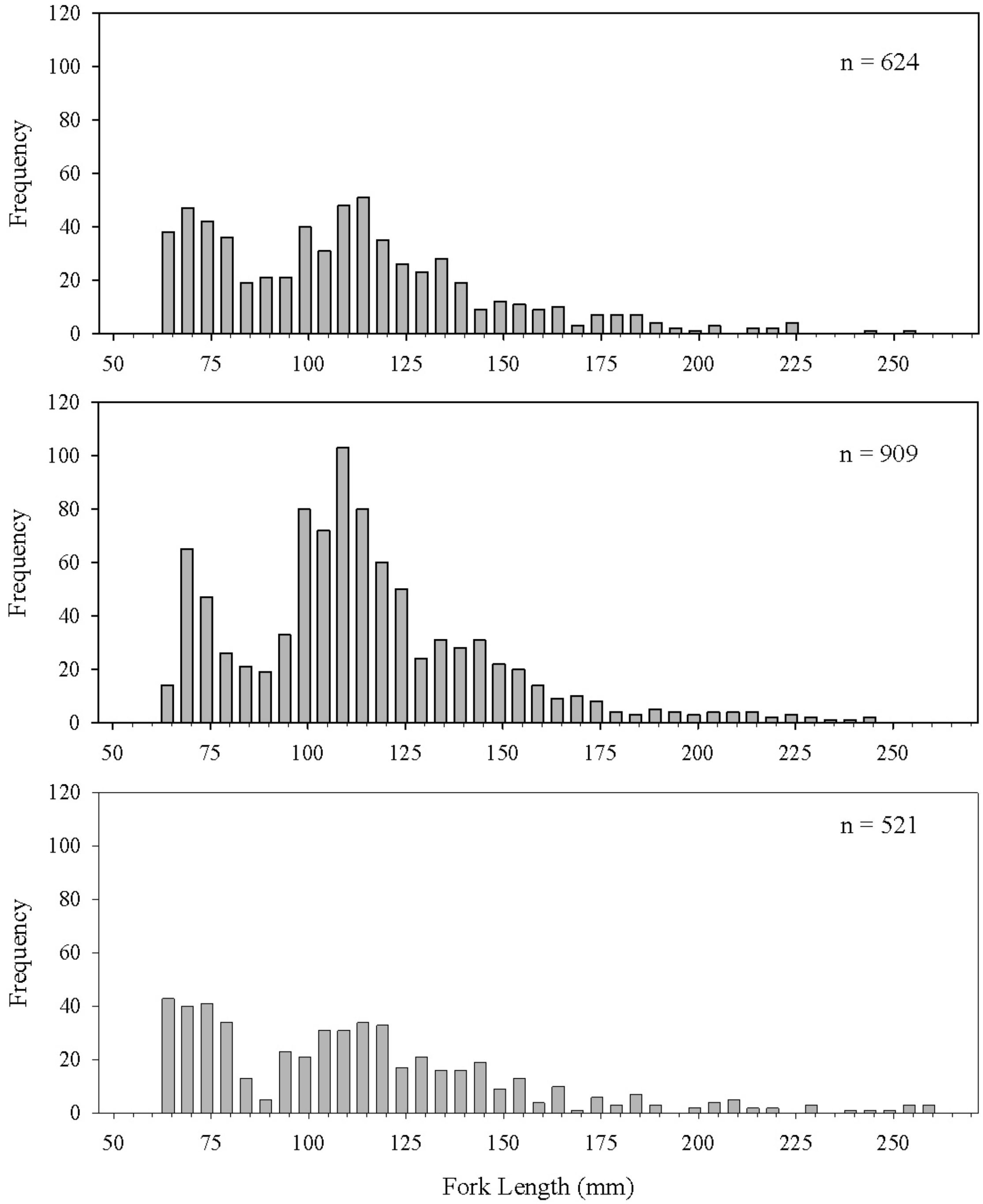

Figure 8. Length frequency histograms for a subsample of cutthroat trout captured in the upper watershed and tributaries of Salmon River in 2008 (upper graph), 2009 (middle), and 2010 (lower).

Size, timing, migration in Salmon River

In 2008, we operated our screw trap on the Salmon River from March 18 until June 20. Coastal cutthroat trout (n=136) were captured with 60% of the catch occurring between mid-April and mid-May (Figure 9). Fish ranged in size from 57mm to 265mm, with a median length of 131mm (Figure 10). Screw trap efficiency for cutthroat was low, averaging 1.5% for the 2008 sampling period.

In 2009, 274 cutthroat trout were captured in the Salmon River screw trap from March 13, 2009 until the trap was removed on July 2, 2009. Migrants ranged in size from 71mm to 365mm fork length, with a median length of 136mm (Figure 10). Ninety five percent of cutthroat captured in the screw trap were <200mm, and 79% were between 100mm and 170mm (Figure 10). Downstream migration in 2009 peaked in late April and early May (Figure 9). The screw trap efficiency averaged 6.4% for cutthroat in 2009. However, the trapping efficiency for larger cutthroat is probably lower than that estimated. Figure 11 displays the length frequency of cutthroat seined in the estuary during March through June which indicates an abundance of larger cutthroat that may not be effectively sampled by the screw trap.

In 2010 there were 157 cutthroat trout captured in the screw trap which operated from March 15 to June 30. The peak period for downstream cutthroat migration occurred from mid-April to mid-May when 70% of the fish were caught (Figure 9). Fish ranged from 88mm to 320mm with a median length of 144mm. The screw trap efficiency for cutthroat trout was low at 2% during the 2010 sampling season.

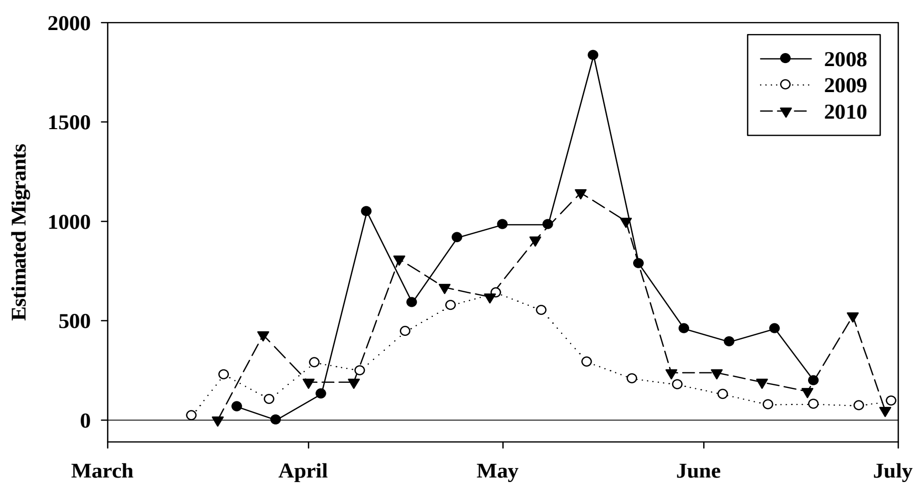

Figure 9. Estimated migration timing of cutthroat in Salmon River, 2008 – 2010.

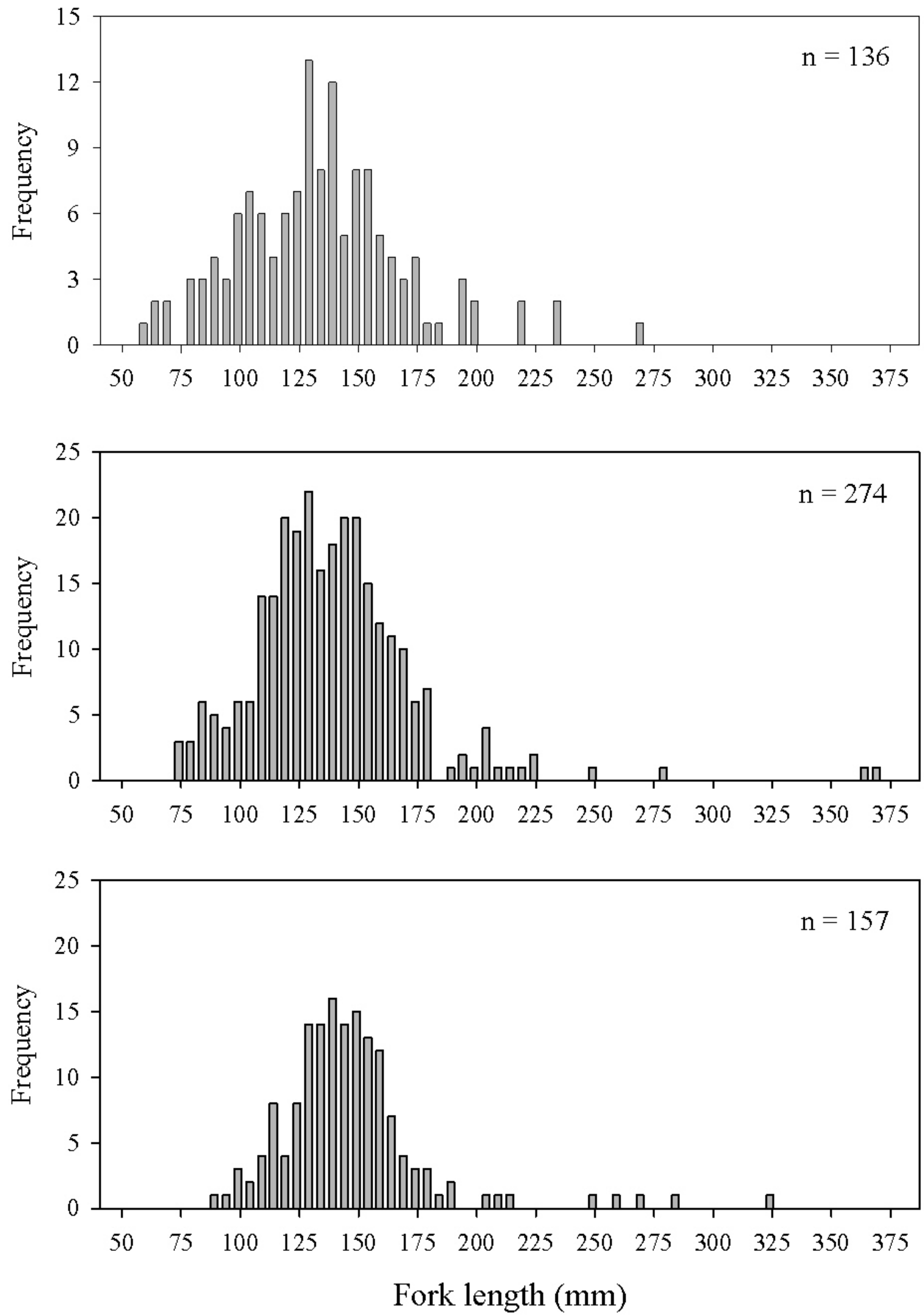

Figure 10. Fork lengths of cutthroat captured from March through June, 2008 (top), 2009 (center), and 2010 (bottom) at the Salmon River screw trap.

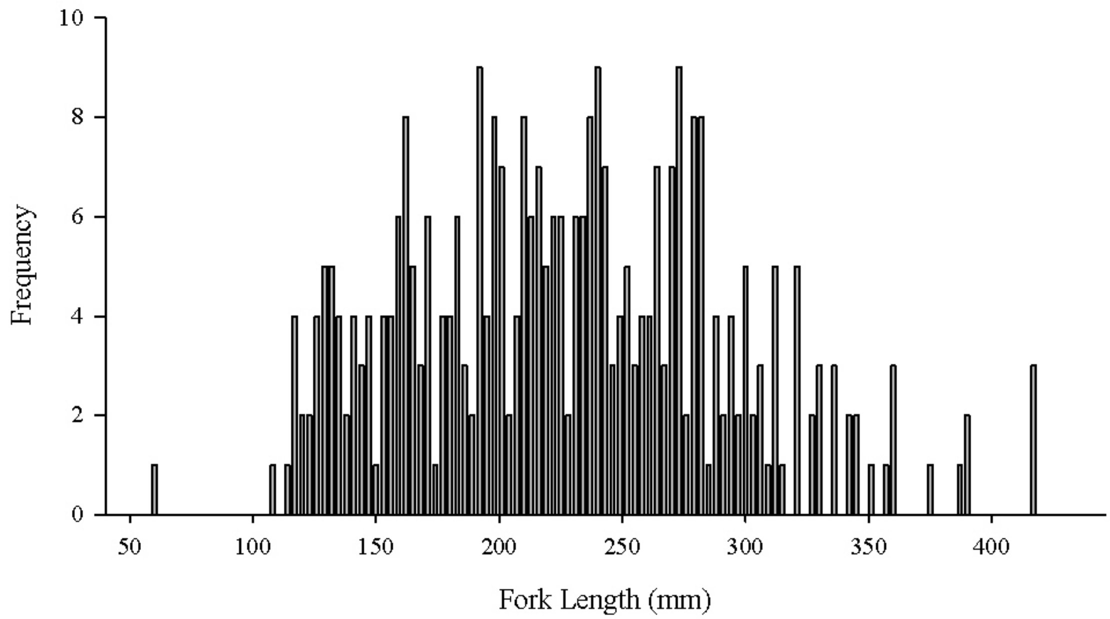

Figure 11. Length frequency of cutthroat captured by beach seine in the estuary from March through June.

Cutthroat migrated through the lower river from early April through June with the peak appearing in mid May (Figure 9). We estimated the number of migrants <120mm between 766 (2010) and 1950 (2009), and the number of those >120mm between 2100 (2009) and 8700 (2008) (Table 5). Confidence intervals are large due to low trap efficiency (average 3% during high river flows and 7% during low river flows).

Table 5. Annual estimate (±95% CI) of migratory cutthroat collected in a rotary screw trap in March – June, 2008, 2009, and 2010.

Species	Age or Size Class	2008	2009	2010
Cutthroat	<120	1150±137	1950±162	766±64
	≥120	8700±145	2098±62	4365±169

Estuarine habitat use, temporal distribution, size, and growth

We caught cutthroat in the estuary in all months of the year. In the mid-estuary (rkm 1.3 – 2.7) seining sites, we saw an early peak of cutthroat numbers in late spring and again in late summer (Figure 12).

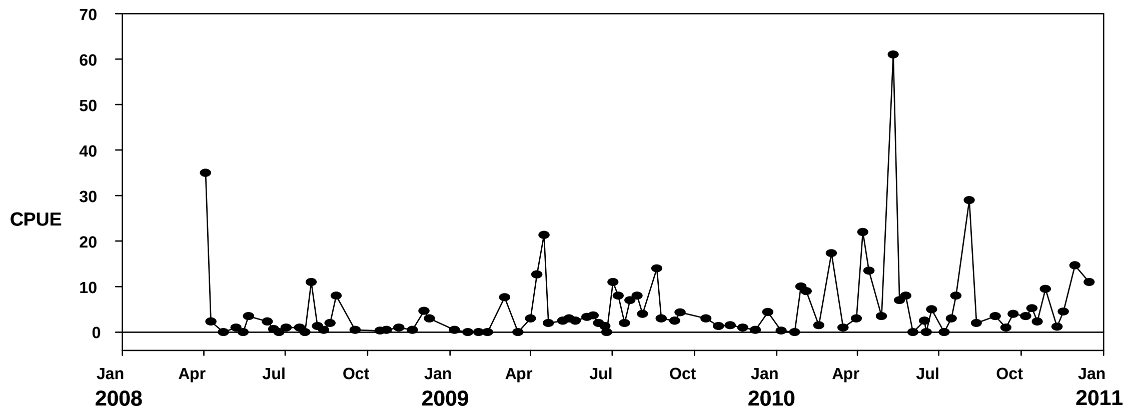

Figure 12. Catch per unit effort for cutthroat trout in the middle section of the Salmon River estuary, 2008 – 2010.

Ninety percent of cutthroat trout were caught in sites with deeper pools, while 9% of the total catch was in marsh channels and 2% in the lower estuary sites. The section of the estuary around Crowley Creek (rkm 1.3) had consistently the highest CPUE in our seine hauls, while the 96 marsh had the highest number of cutthroat of the three marshes (Figure 13).

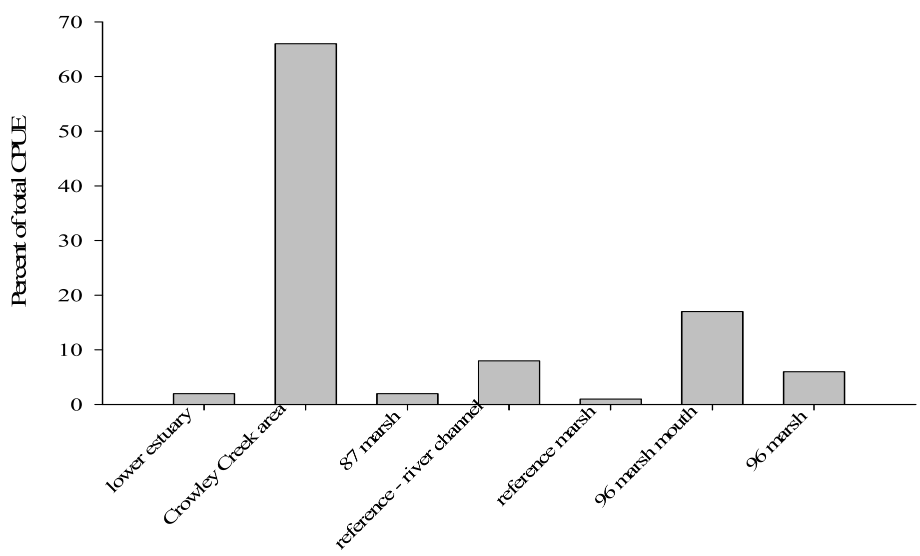

Figure 13. Distribution of cutthroat trout in the Salmon River estuary.

Cutthroat trout caught in the estuary ranged from 58 to 427 mm fork length. Those caught in marsh channels were typically smaller than those caught in the main estuary river channel, with an average fork length of 155mm compared to 243mm (Figure 14). The cutthroat observed in the estuary included larger, and presumably older, segment of the population than that observed in the freshwater streams in August and September or at the screw trap in the spring.

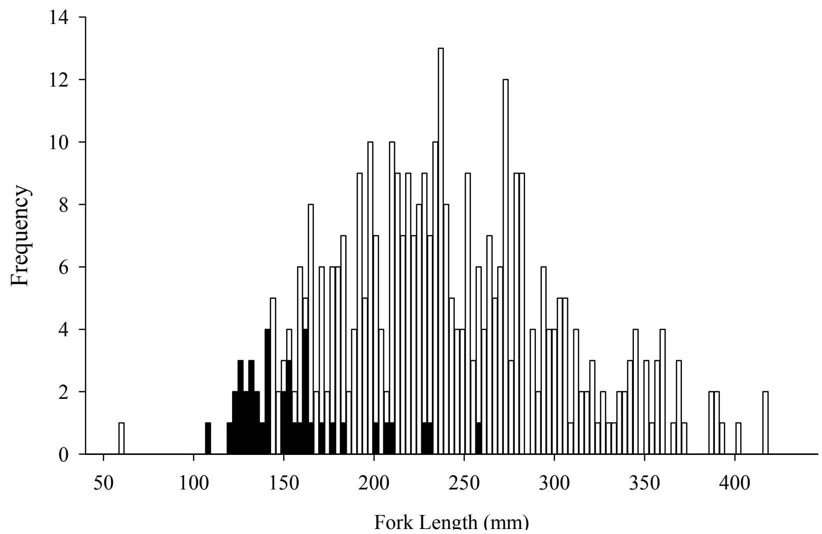

Figure 14. Size frequency histogram comparing fork lengths of cutthroat found in the estuarine marsh channels (black fill) compared to those found in the estuarine river channel.

96 Marsh PIT tag antenna

Cutthroat trout were frequent users of the 96 marsh throughout the time period the detector was in operation. We PIT-tagged 154 cutthroat trout at the screw trap from March through June 2010. That same year we PIT tagged 307 cutthroat trout at seine sites in the estuary from January through August 25. PIT tagged cutthroat trout used the 96 wetlands throughout the spring and summer (Table 6, Figure 15). We detected a total of 154 cutthroat trout at the 96 marsh antenna site during the time period from April 22 to August 25, 2010. Some fish were only recorded one time while others were detected multiple times (up to 87 recordings) throughout several weeks, suggesting these fish are estuarine resident cutthroat. Seventy-two of the 307 (23.4%) cutthroat trout tagged in the estuary from January to August of 2010 were detected in the 96 marsh. Of the 154 cutthroat tagged at the screw trap in 2010, 41 fish (26.6%) were detected on the 96 marsh antenna. Although catch rates with beach seine are low in the 96 Marsh, we did not collect any tagged cutthroat above the antenna that were undetected by the antenna.

Table 6. Tagging site of 154 PIT tagged cutthroat detected at the 96 Marsh PIT antennas April 22, 2010 to August 25, 2010.

Tagging site	Number	Percent
Screw trap 2010	41	27
Screw trap 2009	1	<1
Screw trap 2008	1	<1
Estuary seining 2010	72	23
Estuary seining 2009	10	3
Upper watershed 2009	28	6
Upper watershed 2008	1	<1

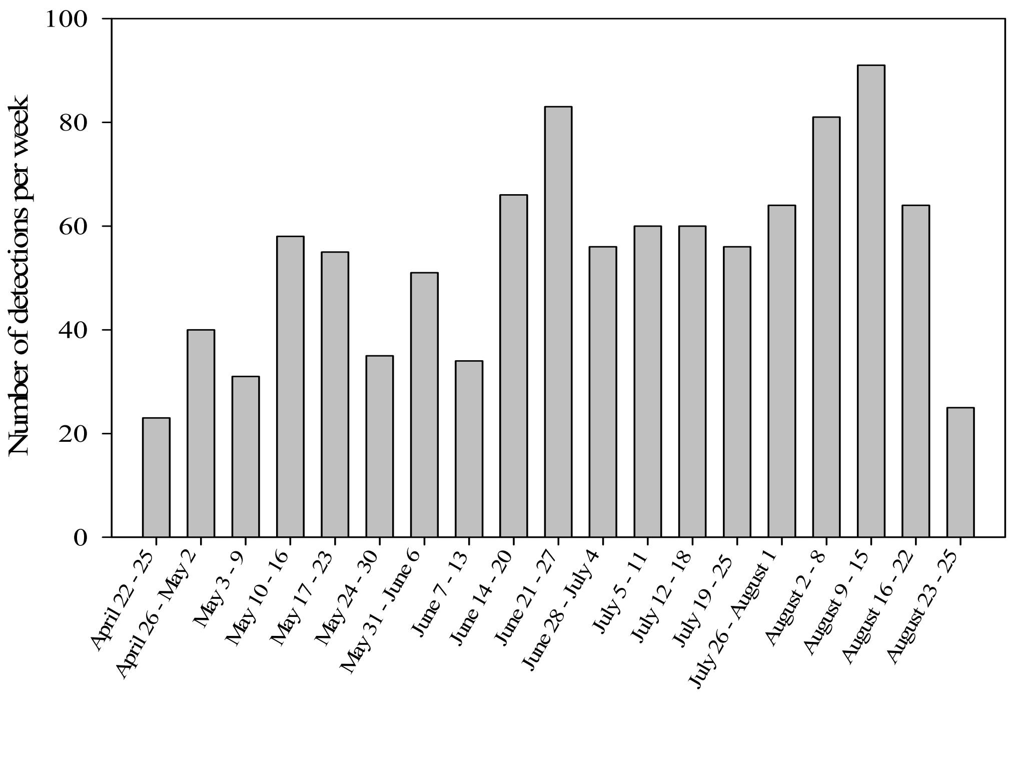

Figure 15. Number of detections per week of cutthroat trout at the PIT antennas in the 96 marsh from April 22 – August 25, 2010. Each fish was counted a maximum of once per day.

Growth

Cutthroat that resided all year in streams grew more slowly that those that reared for a portion of the year in the estuary (Table 7, Figure 16). We tagged and recaptured 23 fish in streams over a one to two year period in August and September. With one exception, these fish were recaptured at the site of tagging a year before and were likely stream resident fish during the intervening year. They ranged in size from 60 – 230mm and grew an average of 0.12 mm per day (Figure 16). Thirty-one fish that were tagged and recaptured in the estuary across a similar length of time were likely fish that reared in the estuary in the summer, and returned to streams to overwinter. These fish ranged in size from 100-230 mm and had an average annual growth of 0.36 mm per day regardless of size class (Figure 17).

Table 7. Average and range of annual growth of cutthroat tagged and recaptured in streams and estuary.

Rearing environment	N	Size at tagging (mm)	Number of days between tagging and recapture	Average growth (mm/day)	Average percent increase in growth per day
Freshwater	23	69 - 228	317 - 728	0.12 (.01 - .21)	0.10 (.01 - .27)
Estuary	31	97 - 228	301 - 686	0.36 (.23 - .56)	0.24 (.11 - .39)

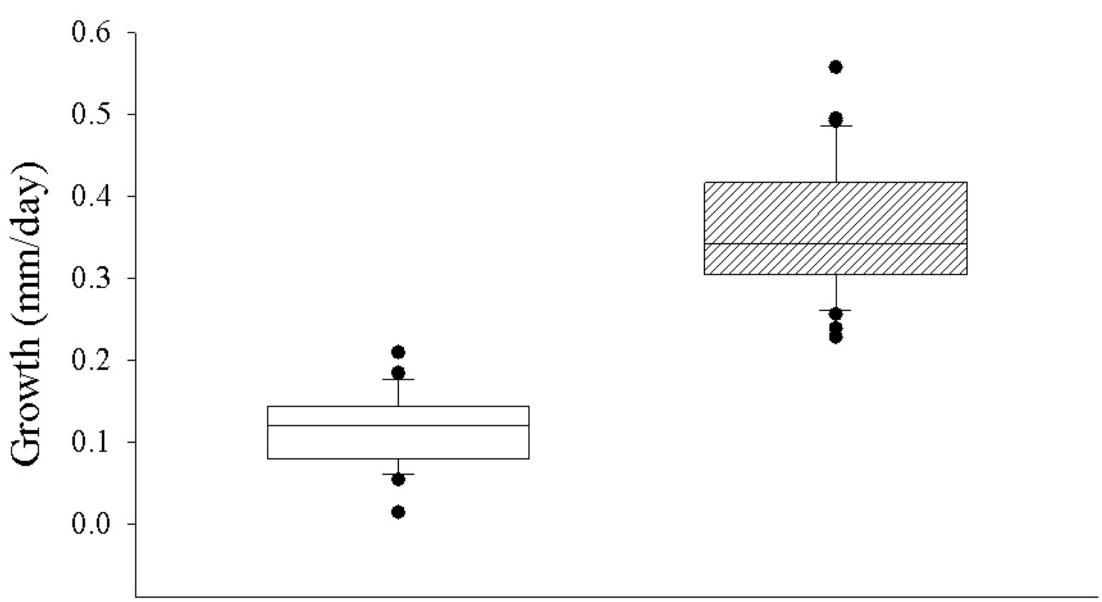

Figure 16. Growth of 23 cutthroat tagged and recaptured in freshwater (open box) and 31 cutthroat tagged and recaptured in the estuary (striped box). The median is displayed by solid line.

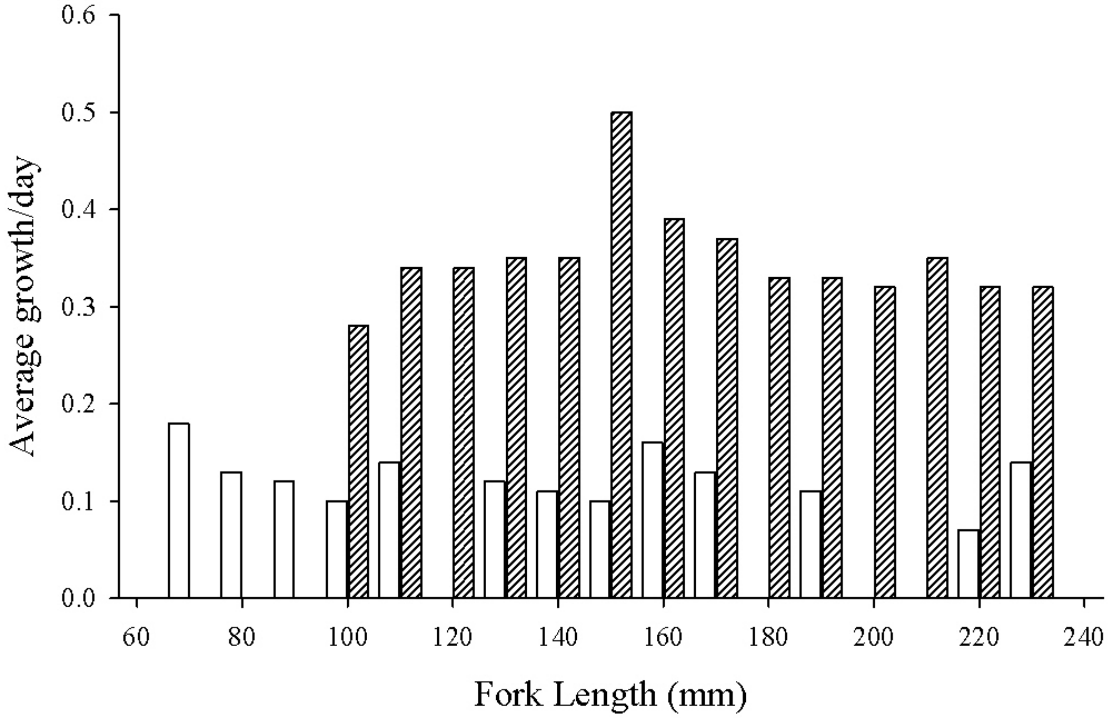

Figure 17. Average annual growth in length by size class from cutthroat tagged and recaptured in freshwater (open bars, n=23) and in estuary (striped bars, n=31).

Growth in the estuary environment is significantly higher than in streams. Average annual growth showed the effect of some estuary rearing, but within estuary growth is more indicative of the potential. Growth of cutthroat tagged and recaptured within a calendar year in the estuary averaged 0.40 mm per day. Growth in length dropped slightly at fish sizes above 310mm, which reflects added weight rather than length (Figure 18). The length to weight relationship was y=4E-06 $x^{3.16}$ ($r^2 = 0.985$) in the estuary and y=2E-05 $x^{2.91}$ ($r^2 = 0.989$) (Figure 18). The relationship was not significantly different. The slight differences probably reflect the small fish captured in the watershed and the larger fish captured in the estuary.

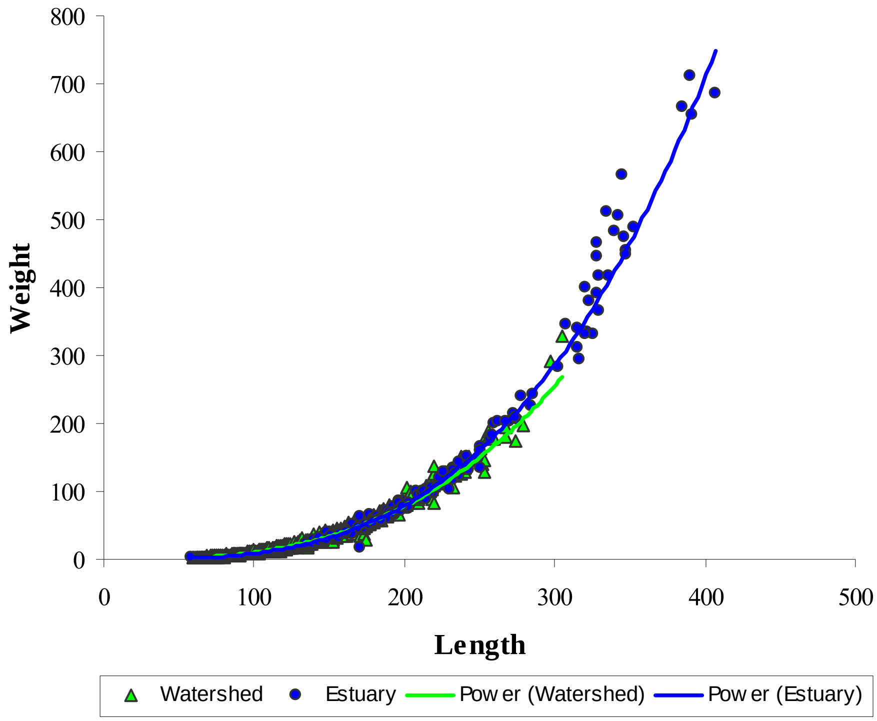

Figure 18. Length-weight relationship of cutthroat in the estuary (June – August; n=196) and watershed (August-September; n=1811).

Estuary-ocean migration and survival

In 2004 twelve acoustic receivers were deployed in the lower Salmon River and the estuary (Figure 5). Twenty-two cutthroat trout ranging from 173-388 mm were captured and tagged with an acoustic transmitter at the screw trap (Table 8). Three tags were never detected on any receiver once the fish were released from the holding tank. Five of the acoustic tagged fish were exclusively observed at rkm 7.8 (i.e. Hatchery Hole) and had no detected movement further downstream. This could indicate either the tags were not securely inserted in the fish, the fish died, or the fish moved upstream. One fish traveled quickly to the mouth and back to the river. Twelve cutthroat traveled past the receiver at rkm 1.3 (i.e. Crowley Creek), 4-25 days after tagging. The median time of travel for these fish from the screw trap to Crowley Creek was 12.2 days (Table 9). Two of these ocean bound cutthroat returned after 7-8 weeks (Table 10). They were last detected at the Deer Creek acoustic receiver at rkm 6.7. The detections of individual fish are summarized in Tables 10 and 11.

A total of thirteen acoustic receivers were placed in the Lower Salmon River, estuary and ocean in 2009. We placed an acoustic tag in eleven cutthroat trout (175-246 mm). Five of the 11 fish were detected near the screw trap area and were not observed further downstream or upstream. One fish moved upstream and was detected exclusively on the upstream receiver above the weir. One fish moved downstream and was last detected at rkm 1.3 in mid-June. Four fish were detected at receivers at the mouth, and two of these were detected on the ocean receivers. The four fish spent 8-44 days before entering the ocean, with a median travel time of 29.2 days (Table 9). None of the four fish were detected returning to the estuary, although one was detected on an ocean receive in mid-August. The five offshore receivers and two mouth receivers were removed in late September 2009. The other four receivers remained deployed in the estuary and river throughout the winter. We did not detect any of the estuary or ocean migrant fish later in the summer and presume they did not survive (Table 8).

In 2010, all thirteen acoustic tagged fish migrated downstream and entered the estuary. One returned within 3 weeks to the river. Two of the thirteen fish migrated quickly to the ocean (Table 9) and ten remained in the estuary. Of the ten, we know that one lost its tag while in the estuary because the fish was later detected by the PIT antenna in the 96 Marsh at rkm 3.8. The estuary resident fish moved throughout the mid- and lower estuary. The two fish that we believe migrated to the ocean were not observed on either of the two ocean receivers. One fish showed movement from the trap in late March and traveled directly toward the Crowley Creek receiver at rkm 1.3 in early April. The tag was detected until January of 2011; however, it is unclear whether the fish was alive or the tag was shed and moving along the substrate due to tidal influence. Two fish were last detected at the weir receiver (rkm 8.1) after displaying movement throughout the estuary. Survival of the estuary resident fish was at least 33% (Table 10). The presumed ocean migrant fish were not detected after leaving the estuary.

Twenty-seven percent (2004) and 55% (2009) of acoustically tagged cutthroat were not detected entering the estuary, presumably because these fish shed their tags, died, or did not continue downstream after tagging. All fish in 2010 were detected on an estuary receiver. Of those fish that did enter the estuary, 92% in 2004, 80% in 2009 and 18% in 2010 were detected entering the ocean.

The survival of cutthroat varied by rearing habitat and by year. Estuary survival was calculated based on the number of cutthroat still detected in the estuary in September or at the uppermost receiver. Ocean survival was the number of fish that migrated past the receiver at the mouth and were detected later in the summer in the estuary. The rate of return of acoustic tagged cutthroat trout from the ocean back to Salmon River estuary ranged from zero to 17% (Table 8). In 2004, 2 out of the 12 (16%) acoustically tagged fish that were last detected at Crowley Creek emigrated to the ocean in late May and returned to the estuary in mid July. In 2009 zero of the four acoustically tagged fish that migrated to the ocean were detected returning to the estuary, although one was detected by an offshore receiver on August 12, 2009. No fish were detected returning from the ocean in 2010. The two fish returning from the ocean in 2004 were the two largest cutthroat trout tagged that year. They were absent from the estuary (and presumably at sea) an average of 53 days (388m, 50 days; 352mm, 56 days, Table 9). In 2010, 3 of the 9 estuary residents were detected in the late summer or back upriver for a survival rate of 33%.

Table 8. Acoustic-tagged cutthroat by summer rearing habitat and survival to late summer. The total does not include dead or lost tags.

Year	N	River	Estuary	Estuary Survival	Ocean	Ocean Survival
2004	22[a]	6	1	1	12	2
2009	11	6	1	0	4	0
2010	13[b]	1	9	3	2	0
Total	42	13	11	4	18	2

[a] 3 presumed died shortly after release
[b] 1 presumed lost tag in estuary

Table 9. Migration Rates and number of acoustic tagged fish that were last detected at the ocean entrance. In 2004 the lowest receiver was at rkm 1.3.

Year	N	Elapse Time (days)	Median Elapse Time (days)
2004	12	4-25	12.2
2009	4	8-44	29.2
2010	2	4-15	9.5

Table 10. Length, travel time, and return time of acoustically tagged cutthroat that left estuary and were detected returning from the ocean in 2004.

Length	Release date	To Sea Date	Days traveled	Return Date	Days undetected
388mm	5/3/2004	5/31/2004	28	7/20/2004	50
352mm	5/21/2004	5/23/2004	2	7/18/2004	56

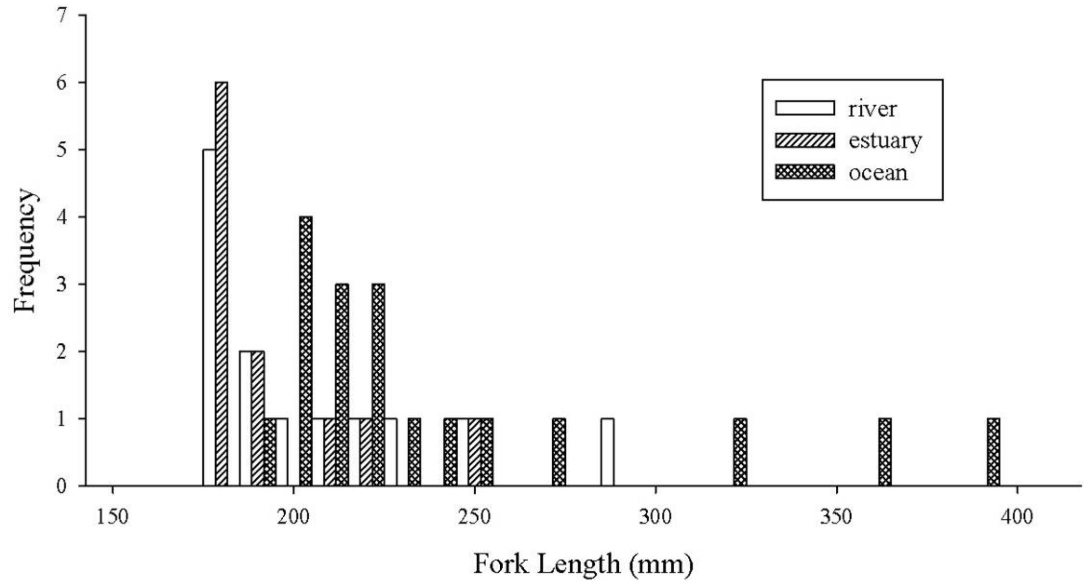

Figure 19. Size of acoustic tagged cutthroat in river, estuary, and ocean rearing environments.

DISCUSSION

Extensive studies of cutthroat life history, habitat use, and growth in Salmon River estuary were conducted by Krentz (2007). Here we complement Krentz's (2007) study, while providing a novel perspective on selected aspects of cutthroat life history, growth, and survival. We were able to supplement existing knowledge because of additional sampling in the watershed and use of PIT tag and acoustic tag technologies in the lower river, estuary, and ocean.

The summer stream resident population of cutthroat had consistent and high occupancy rates and abundance during a 3-year period. Abundance or density was not related to stream size or location in the watershed. The one site not occupied in 2010 was a site that was close to the estuary and the presence of saltwater may have reduced or nullified the effectiveness of the electrofisher. This site should have been dropped and considered non-target. Abundance was not significantly different between years, with a 3-year average of 37,169 fish greater than 60mm fork length, and average densities of 0.1 to 0.15 fish per m^2. The majority (70-80%) of cutthroat sampled were above 90mm, which corresponds to the portion of the length frequency distribution that may indicate age-1 (Giger 1972, Solazzi et al. 2000). Considerable overlap in size-at-age occurs for fish greater than 100mm (Zydlewski et al 2009). The density of cutthroat in Salmon River was higher than that reported in selected streams in the Nestucca and Alsea basins (Solazzi et al. 2000) and in Big and Bear creeks in the lower Columbia River (Hering et al. 2009).

The graph of length distribution of cutthroat captured in the screw trap the following spring had a shape similar to that seen in the watershed, although the median length shifted from 107mm in the summer to 137mm in the spring. This likely reflects a higher proportion of age 1, 2, and 3 fish migrating plus growth since the previous summer (Giger 1972). However, it is clear that the screw trap is biased towards capturing smaller cutthroat because the median length of cutthroat captured in beach seines in the estuary was 225mm with a range from 100 to 400mm. The larger cutthroat migrated before the trap was in place, avoided the trap, or overwintered in the estuary. Likely, the larger fish are able to avoid the screw trap on their downward migration because the increase in cutthroat CPUE in the estuary did not occur until March and April, with peak abundance in April and May. Giger (1972) also observed that ocean migrant fish peaked in the estuary in late-April to early May. In the Columbia River, Hering et al. (2009) and Zydlewski et al. (2009) reported that peak migration into the Columbia River estuary from tributaries was in May and June.

We estimate that about 12-13% of the summer resident population migrated to the screw trap at Rkm 7.9 in 2009 and 2010, and presumably into the estuary. However, our data from the PIT antenna indicated that at least 22% of the cutthroat tagged at the screw trap in spring 2011 (unpublished data) moved back upstream in late spring and early summer. Similarly, Hering et al. (2009) and Zydlewski et al. (2008) noted that an average of 43% of the cutthroat tagged (PIT, radio, or acoustic) at screw traps in seven tributaries in the lower Columbia River did not enter the estuary. Size ranges of the fish captured by these screw traps were similar to that in Salmon River.

The actual number of migrant cutthroat is difficult to estimate because the summer population is augmented by cutthroat that migrated from the ocean and estuary into streams in the fall to spawn or overwinter. We also know that the number of fish sampled by the screw trap is clearly biased towards smaller fish. The overlap between the size frequency of cutthroat sampled by beach seine in the estuary (March – June) and the screw trap is slightly less than half. Fish > 180 mm are under-represented. Based on survival estimates of PIT and acoustic tagged fish (expanded to the population), we suspect the adult population returning to the watershed every fall might be on the order of a thousand fish.

Migratory fish rear in the estuary for the summer, or rear in the ocean for a few months before returning in late July through the fall. The patterns of seaward migration of Salmon River cutthroat implanted with acoustic tags at the screw trap varied annually in 2004, 2009, and 2010. Eight to 55 percent stayed in the lower river or returned upstream. Five to 75% migrated to the estuary for the summer, and 11 to 63% migrated to the ocean. Our results differed from an earlier study in Salmon River. Krentz (2007) tagged 20 fish in April and May 2003 in the estuary. Ninety percent of the tagged fish survived through the summer and fall. Of the 18 survivors, 10 stayed in the estuary, 7 went to the ocean, and 1 may have made very brief forays to the ocean. None moved upriver until later in the summer. However, Krentz tagged fish ranging in size from 187 to 398 mm, with a median of 270 mm, in the estuary whereas we tagged fish with a median size of 200 mm at the trap in the lower river. By collecting and tagging fish in the estuary, Krentz (2007) tagged larger fish that already showed a tendency towards migration (to estuary or ocean), and may have survived early challenges of adapting to brackish water. Hering et al. (2009) and Zydlewski et al. (2008) observed that migratory cutthroat tagged at screw traps in tributaries to the lower Columbia River had very directed downriver migrations to the ocean, not unlike our 2004 tag year. In a study of post-spawn adult cutthroat (kelts) in the Columbia River, Hudson et al. (2009) reported a diverse array of movement patterns and habitat use, unlike the fish observed by Zydlewski et al. (2008). It suggests that in the Columbia River estuary the smaller (<~220 mm) cutthroat either stay in the tributaries or migrate to the ocean, whereas as the older age cutthroat use the estuary to a greater extent. In Salmon River, however, we did not see a specific migratory or habitat pattern related to size or age.

Fish that reared in the estuary during the summer used marsh channel habitat more often than previous reported in Krentz (2007) and observed in our beach seine catches. Even though we rarely sampled cutthroat in the 96 marsh channel with a beach seine, the PIT antenna indicated use by 25% of the population and regular use by 5-10% of the tagged fish. The cutthroat may be actively foraging in the marsh channels during high tide, suggesting that marsh networks may be more than a source of prey items exported to the main channel.

The benefits of estuarine rearing may be realized by increased growth of fish that use the estuary for part of the year. Annual growth rates increased threefold for cutthroat that spent at least the summer in the estuary or ocean. According to Krentz (2007), ocean growth was not significantly different from that in the estuary. Survival benefits of estuary and ocean rearing are more ambiguous, although it appears that larger cutthroat survived at a higher rate in both environments. The fish implanted with acoustic tags at the screw trap survived in the estuary at an average 20% rate whereas the Krentz (2007) reported a 90% survival rate in the estuary. It is difficult to compare survival of the PIT tagged fish because the PIT antenna does not cover the width of the river. At best we can calculate minimum survival rate to return. For example we observed 14% survival of fish tagged at the screw trap in 2010 and detected in the fall. Survival may be closer to 20% because a fourth of the tagged fish probably never entered the estuary (2011 unpublished data).

Ocean survival was lower in the current study (2 of 18 ocean migrants) than in Krentz (2007) (2 of 7 ocean migrants). Although Krentz showed a higher estuary survival of fish, the ocean survival was only 29%. Survival rates of migrants from Salmon River were higher than ocean migrants in the Columbia River (Hering et al. 2009). Only one of the 27 acoustic tagged fish that exited the Columbia River estuary returned to the natal stream, and returns of PIT-tagged fish from estuary entry to return were less than 5%. High mortality in the Columbia River estuary and plume was attributed to bird predation (Hudson et al. 2008, Zydlewski et al. 2008, Hering et al. 2009).

Cutthroat in Salmon River use a suite of rearing environments from tributary to river, estuary and ocean. The extensive use of the estuary in Salmon River may reflect the connectivity and quality of channel and marsh habitats, and lower predation pressure than that observed in the Columbia River estuary. Although we have found it difficult to ascribe individual fish to estuary or ocean rearing strategies, it appears that cutthroat use one or more rearing strategies before returning to freshwater in the fall. Repeated observations of individual fish over a two-year period in the estuary suggest that the growth potential for older fish compensates for susceptibility to higher mortality.

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APPENDIX A

Appendix A-1. Location and distance of sites referred to in estuary and lower river. Distance is measured in kilometers starting from the mouth of Salmon River.

Locations	River Kilometers
Above Hatchery Weir	8.1 rkm
Screw Trap	7.9 rkm
Hatchery Hole (Guard Rail)	7.8 rkm
Deer Creek	6.7 rkm
Sitka	5.9 rkm
Red Barn	5.4 rkm
Salmon Creek	4.8 rkm
Below 101	4.2 rkm
Booth Hole	3.7 rkm
96 Marsh	3.8 km
Dinosaur	3.3 rkm
LCM	3.0 rkm
Ditch	2.7 rkm
87 Marsh	2.5 rkm
Lighthouse	1.6 rkm
Crowley Creek	1.3 rkm
Mouth/ocean	0.0 rkm

APPENDIX B

Appendix B-1. Cutthroat trout tagged at the rotary screw trap in 2004. Tag number, length of fish at tagging, release date from holding pen, location and last date the fish was detected on receiver, and the total number of days fish was recorded on a receiver

Tag No.	Length (mm)	Released Date	Last Date Detected	Location	Total Days Observed
171	176	4/13/2004	8/23/2004	Below 101	137
172[a]	222	4/30/2004	5/8/2004	Crowley Creek	8
173 [a]	195	4/26/2004	5/15/2004	Crowley Creek	19
174 [a]	209	4/27/2004	5/22/2004	Crowley Creek	25
175	177	4/28/2004	6/22/2004	Hatchery Hole	55
176	178	4/28/2004	7/13/2004	Hatchery Hole	76
177	190	4/30/2004	6/19/2004	Hatchery Hole	50
179 [a]	239	4/30/2004	5/14/2004	Crowley Creek	14
180 [ab]	388	5/3/2004	7/21/2004	Deer Creek	79
181	228	5/8/2004	0	0	0
182 [a]	241	5/19/2004	5/23/2004	Crowley Creek	4
183 [a]	188	5/19/2004	5/23/2004	Crowley Creek	4
184	176	5/19/2004	0	0	0
185 [a]	199	5/21/2004	5/31/2004	Crowley Creek	10
186 [a]	214	5/21/2004	6/2/2004	Crowley Creek	12
188 [ab]	352	5/21/2004	7/25/2004	Deer Creek	65
196 [a]	192	5/23/2004	6/14/2004	Crowley Creek	22
197	175	5/23/2004	0	0	0
190	173	5/25/2004	6/27/2004	Hatchery Hole	33
191	220	5/25/2004	6/2/2004	Hatchery Hole	8
192	222	5/25/2004	7/1/2004	Hatchery Hole	37
193 [a]	198	6/4/2004	6/8/2004	Crowley Creek	4

[a] Entered the ocean
[b] Returned from the ocean

Appendix B-2. Cutthroat trout tagged at the rotary screw trap in 2009. Tag number, length of fish at tagging, release date from holding pen, location and last date the fish was detected on receiver, and the total number of days fish was recorded on a receiver

Tag	Length (mm)	Released Date	Last Date Detected	Location	Total Days Observed
57190	175	4/15/2009	4/16/2009	Guard Rail	1
57191[a]	218	4/16/2009	8/12/2009	Offshore	118
57192	246	4/21/2009	5/27/2009	Guard Rail	36
57193[a]	208	4/23/2009	6/1/2009	Offshore	39
57194	185	4/25/2009	4/30/2009	Above Weir	5
57195	178	5/1/2009	6/14/2009	Crowley Creek	44
57196[a]	204	5/7/2009	5/20/2009	Mouth	13
57197	179	5/7/2009	5/7/2009	Guard Rail	0
57198	204	5/22/2009	5/24/2009	Guard Rail	2
57199[a]	220	5/24/2009	6/1/2009	Offshore	8
57201	192	6/16/2009	8/25/2009	Guard Rail	70

[a] Entered the ocean

Appendix B-3. Cutthroat trout tagged at the rotary screw trap in 2010. Tag number, length of fish at tagging, release date from holding pen, location and last date the fish was detected on receiver, and the total number of days fish was recorded on a receiver

Tag No.	Length (mm)	Released Date	Last Date Detected	Location	Total Days Observed
57202	180	3/27/2010	1/31/2011	Crowley Creek	310
57203	177	4/11/2010	6/6/2010	Boothhole	56
57204	176	4/26/2010	5/15/2010	Crowley Creek	19
57205	245	5/1/2010	5/8/2010	Crowley Creek	7
57206	213	5/6/2010	5/17/2010	Crowley Creek	11
57207	175	3/30/2010	5/17/2010	Crowley Creek	48
57208	282	3/29/2010	5/3/2010	Below Trap	35
57209	209	5/8/2010	9/2/2010	LCM	117
57210	186	5/14/2010	8/12/2010	Lighthouse	85
57211[b]	255	5/15/2010	5/17/2010	96 Marsh	2
57212[a]	265	5/17/2010	5/21/2010	Mouth	4
57213[a]	320	5/17/2010	6/2/2010	Mouth	16
57215	185	6/11/2010	10/2/2010	Below Trap	113

[a] Entered the ocean
[b] Detected only at PIT antenna in 96 Marsh, apparently lost acoustic tag