Movements of Coastal Cutthroat Trout (*Oncorhynchus clarki clarki*) in the Lower Columbia River: Tributary, Mainstem and Estuary Use

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EXECUTIVE SUMMARY

In December 1997, the National Marine Fisheries Service (NMFS) received from 15 environmental groups a petition to list coastal cutthroat trout along the coasts of California, Oregon, and Washington under the Endangered Species Act (ESA) of 1973, as amended (ONRC et al. 1997). The petitioners concluded from available information that coastal cutthroat trout abundance was reduced from historic levels across the subspecies range, especially in the Willamette River and lower Columbia River populations in both Oregon and Washington. The proposed rule to list the southwestern Washington/lower Columbia River DPS of coastal cutthroat trout as threatened under ESA was jointly submitted by NMFS and the US Fish and Wildlife Service (USFWS) in April 1999 (64 FR 16397). This decision was warranted due to concern about the widespread declines in abundance and the small population sizes of anadromous coastal cutthroat trout. Furthermore, there was a lack of quantitative information (i.e., distribution, abundance, age structure, run timing) and a multitude of risk factors that could contribute to the extinction of this species in the foreseeable future.

In 2001, the US Army Corps of Engineers (Corps) issued the Columbia River Channel Improvements Project (Project) Biological Assessment (BA) to evaluate potential effects on federally listed threatened and endangered salmonids that may be associated with proposed channel improvements (USACE 2001). Coastal cutthroat trout were considered in this BA because they had been proposed for listing under ESA. Ecosystem research actions in the BA directed research to be conducted during and after project implementation to evaluate coastal cutthroat trout use of the project area. The USFWS transmitted a Conference Opinion (Opinion) in 2002, based on review of the Corps proposed Project (USFWS 2002). This Opinion addressed the effects of the Project on the proposed southwestern Washington/lower Columbia River DPS of coastal cutthroat trout. Proposed ecosystem research actions in the Opinion included research to provide additional information regarding coastal cutthroat trout use of river and estuary areas affected by the Project.

As per research proposed by both the BA and the Opinion, beginning in spring 2002, investigations began to increase the basic understanding of coastal cutthroat trout life history in lower Columbia River populations. The primary objectives of these investigations were to 1) identify the timing of smolt emigration, adult return, and the prevalence of juvenile excursions into mainstem and estuarine habitat from three lower Columbia River tributaries, 2) identify areas of main stem habitat use by emigrating juveniles (smolts), 3) describe the physiological and morphological characters of smolting by assessing standard smolt indices, and, 4) describe movement and identify areas of habitat use by adult coastal cutthroat trout. Results have allowed an initial understanding of timing and movement patterns of juvenile and adult coastal cutthroat trout from a few lower Columbia River tributaries. Juvenile emigrants from certain tributaries of the lower Columbia River may use the shipping channel during spring out migration. After spawning, adults exhibit a variety of movement patterns including no movement, movement into the main stem, movement into other tributaries, and movement toward the lower estuary and marine environment. Juvenile and adult returns have been minimal, but captures of hatchery coastal cutthroat trout not stocked into these tributaries and movement of tagged fish into other tributaries indicate some degree of straying occurs with this species.

Further understanding of coastal cutthroat trout life history and population dynamics is needed to effectively manage for conservation of this sensitive species. Toward this end, recommendations on future management actions and research resulting from this work include:

1) When planning management activities in the lower Columbia River mainstem and estuary, consider that from April through June migrating juvenile coastal cutthroat trout are present; 2) When planning management activities in the lower Columbia River mainstem and estuary, consider that from September through January migrating pre-spawn adult coastal cutthroat trout are present; 3) When planning management activities in the lower Columbia River mainstem and estuary, consider that from December through April migrating post-spawn adult coastal cutthroat trout (kelts) are present; 4) Given that multiple life history stages of coastal cutthroat trout are present in the lower Columbia River mainstem and estuary for the majority of the year, directly assess impacts to specific life history stages of the fish from management activities; 5) Evaluate coastal cutthroat trout population response to habitat restoration projects in the lower Columbia River mainstem and estuary; 6) Investigate impacts to coastal cutthroat trout relative to historic changes in the Columbia River hydrograph and how the current hydrograph affects behavior and productivity; 7) Investigate the anadromous component contribution to viability of lower Columbia River coastal cutthroat trout metapopulation; and, 8) Assess current distribution and abundance of coastal cutthroat trout in the lower Columbia River basin to establish a baseline and better monitor population trends to evaluate response to anthropogenic impacts or restoration benefits.

References

Oregon Natural Resources Council (ONRC), Coast Range Association, Native Fish Society, Northwest Ecosystem Alliance, Save the West, Siskiyou Regional Education Project, Siskiyou Audubon, Trout Unlimited of California, Western Ancient Forest Campaign, Salmon Defense Association, Salmon Forever, California Sportfishing Alliance, Oregon Wildlife Federation, Clark-Skamania Fly Fishermen, and the Washington Rivers Council. 1997. Petition to list sea-run cutthroat trout *(Oncorhynchus clarki clarki)* as threatened or endangered throughout its range in the states of California, Oregon, and Washington, under the Endangered Species Act (ESA) and to designate critical habitat. Unpublished manuscript, 38 pp.

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Coastal Cutthroat Trout Migration Patterns in Lower Columbia River Tributaries

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Introduction

The life history of coastal cutthroat trout (*O. clarki clarki*) is one of the most complex for Pacific Northwest salmonids. Sympatric individuals within a given watershed can be resident in headwater tributaries or migratory (Hall et al. 1997). Fish that leave their natal streams may remain in freshwater (fluvial or adfluvial) or enter seawater (anadromous). Beyond this, there is little known of the migratory tendencies of these fish.

The lack of comprehensive stock assessment data on this species and its precipitous decline in the Lower Columbia River over the last decades (Leider 1997) makes it vital to characterize populations in this region. What little we do know of Columbia River coastal cutthroat trout includes age of migration for those exhibiting anadromy (age-2 or age-3) and emigration timing for anadromous juveniles, spring (Johnston 1982; Trotter 1989). However, lack of clear morphological distinctions between juveniles that are resident or anadromous (Tomasson 1978; Fuss 1982) prevents identification of these life history strategies. Furthermore, the proportion of cutthroat leaving in the spring versus the proportion remaining in freshwater for later migration or residency is unknown for any tributaries of the Columbia River. Determining these parameters is vital in characterizing population dynamics and to manage this species.

The evaluation of habitat use of coastal cutthroat trout through all life history stages is necessary to gauge any potential impacts of anthropogenic activity in the mainstem and estuary of the lower Columbia River. Anadromous populations of coastal cutthroat have plummeted in recent years and therefore such activities should consider the relative impacts on this species. While the US Fish and Wildlife Service (USFWS) recently found listing of coastal cutthroat trout to be not warranted at this time, concern was expressed for the lack of information available to make informed decisions (67 FR 44934).

Changes in hydrology are understandably linked to the declines of upper Columbia River salmonid stocks through passage impacts (Deriso et al. 1996; Deriso 2001) but regulated flow has also resulted in a shift in the amplitude and timing of high flow events (Chaney 1978). This shift in hydrological character influences mainstem flows, plume structure, salinity profiles, tidal range, and productivity. Other projects on the mainstem and estuary, such as maintenance and deepening of the navigation channel, also perturb these physical factors that define available habitat. Coastal cutthroat trout are thought to make extensive use of the mainstem and estuary (as both juveniles and adults) and are believed to be more susceptible to changes in productivity than any other Pacific salmonid (Giger 1972; Pearcy 1997).

The objectives of this study were to identify the timing of smolt emigration, the prevalence of juvenile movement out of tributaries and the timing of adult return. To this end, coastal cutthroat trout from three tributaries in the Lower Columbia River were investigated. The results of this study provide information toward temporal use of the Columbia River mainstem and estuary in an effort to gauge potential impacts of activities associated with channel deepening.

Methods

Study Area

Coastal cutthroat trout were monitored from three tributaries, Abernathy Creek (river kilometer (RK) 87), Chinook River (RK 6), and Gee Creek (RK 140) in the lower Columbia River. These streams were chosen because coastal cutthroat trout were known to exist, there are sites on these waterways that are amenable to the construction of passive integrated transponder (PIT) tag interrogation systems, and they represent 140 km of the geographical range for coastal cutthroat trout in the lower Columbia River, spanning approximately 55% of the mainstem below Bonneville Dam.

Sampling

Electrofishing

In each fall 2001 through 2004, a 10.5 km stretch of Abernathy Creek was sampled using electrofishing to capture coastal cutthroat trout for the purpose of implanting PIT tags. Sampling in the Chinook River (3.5 km stretch) and Gee Creek (8 km stretch) began in fall 2002 and continued in the fall of 2003 and 2004. In all tributaries, electrofishing was used to capture coastal cutthroat. Captured trout were anesthetized with 25 ppm clove oil. Fish were measured for length, weighed, and a scale sample taken from the left side of the caudal peduncle. Coastal cutthroat trout larger than 100 mm fork length (FL) were surgically implanted with a 23 mm PIT tag (23 mm long, 3.84 mm diameter, 0.6 g; full duplex). Fish were allowed to recover in flow through stream water. All fish were released back into the reach of capture (within 500 m of capture location) after recovery. Capture location was documented for each individual. All electrofishing occurred above PIT tag arrays.

Smolt traps

Screw traps were operated in both Abernathy Creek and the Chinook River. Captured coastal cutthroat trout were anesthetized with 25 ppm clove oil, scanned for PIT tag, measured for length, weighed, and a scale sample taken from the right side of the caudal peduncle. If a tag was not detected, coastal cutthroat trout over 100 mm FL were surgically implanted with a 23 mm PIT tag and fish were allowed to recover in flow through stream water. When recaptured at the screwtrap, PIT-tagged fish were measured, weighed, PIT tag code recorded, and fish were released below the traps. On Abernathy Creek, Washington Department of Fish and Wildlife operated a screw trap from approximately 1 April to 30 June each year from 2001 through 2005. On the Chinook River, Sea Resources, Inc., operated two screw traps almost continuously. One was located immediately downstream of the antennas of the upper PIT array (Hatchery Screw Trap) and one was located immediately downstream of the lower PIT array (Mouth Screw Trap). No screw traps were operated on Gee Creek.

Migration Timing

PIT tag antenna arrays

Full duplex, 23 mm PIT tag technology was used to monitor emigration and immigration of coastal cutthroat trout from lower Columbia River tributaries. This long-range PIT tag technology was previously developed to monitor movements and stream use of juvenile Atlantic salmon (Zydlewski et al. 2001) and has been used to monitor steelhead in Abernathy Creek in the lower Columbia River (Zydlewski et al. 2003). The stationary detection system can monitor the entire width and depth of a stream for PIT tagged fish, even under high water conditions. This allows virtually continuous monitoring past a single point in a stream without obstructing the path of the fish. Antenna arrays were constructed using open coil inductor loops with multi-strand wire strung through PVC pipe. The readers, power supplies, and computers necessary to collect and record data were placed in weatherproof boxes near the sites.

Two antenna arrays were installed in Abernathy Creek approximately 3 and 4 RK above the confluence with the lower Columbia River. The arrays became functional on 1 October 2001. During this investigation, the systems operated almost continuously. Through the period of operation, detection efficiencies were 70-90% (Zydlewski et al. 2003).

The Chinook River had two antenna arrays at RK 0 and RK 6. The upper array was functional from September 2002 and had a calculated detection efficiency of 100% for each of two antennas. The lower array was installed at tide gates near the mouth of the Chinook River. Due to antenna placement (end-to-end in tide gate slots) and salinity (ranging from 0 ppt to 17 ppt) read range was low because of electrical loading. The site was manipulated between 2002 and 2004 to increase the read range. Read efficiencies were then between 10 and 99%. In 2004, another site was identified on the Chinook River for a third antenna array located at a culvert at RK 3.5. Operation of the antenna array at this site began in February 2004.

A single antenna was utilized to monitor fish movement in Gee Creek. This array was installed in August 2002 at RK 1 and had an efficiency of 75%.

Data collected from all sites included PIT code, time and date of detection. For Abernathy Creek and the Chinook River, all detections were recorded at the site and uploaded to the Pacific States Marine Fisheries Commission (PSMFC) database PTAGIS. Detection histories for all individuals were downloaded from the PSMFC website and used to evaluate migration timing and determine migratory status. Data collected from Gee Creek were recorded at the site and transferred to a data base housed at US Fish and Wildlife Service-Columbia River Fisheries Program Office.

Smolt traps

Screw traps were operated on Abernathy Creek and the Chinook River as described above. Data collected from these sites included date and time of capture and this information was uploaded to the PTAGIS database. Capture histories for all individuals were downloaded from the PSMFC website and used to evaluate migration timing and determine migratory status.

Prevalence of Juvenile Movements Out of Tributaries

Migratory proportion

Coastal cutthroat trout recaptured in a screw trap or detected on a PIT array were classified as migrants. Due to the close proximity between the lowermost electrofishing site and the upper PIT array on each stream, only those fish detected after 30 days post-tagging were considered migrants. This 30 day window allowed recovery from altered behavior patterns (i.e., excessive movement patterns) that were observed after the initial tagging event. Coastal cutthroat trout recaptured within the stream of initial tagging during electrofishing efforts were classified as residents. If a fish was classified as resident in one year and then migrated in the following year it was only used in analyses as a migrant.

Fall electrofishing efforts in years after the initial tagging event (2001 in Abernathy Creek and 2002 in the Chinook River and Gee Creek) allowed physical recapture of previously PIT-tagged cutthroat still residing in the tributaries. All captured individuals were scanned for a PIT tag. Those that were tagged were anesthetized, PIT tag code recorded, measured, weighed, and a scale sample was taken from the right side of the caudal peduncle. All fish were released back into the reach of capture (within 500 m of capture location) after recovery.

Longitudinal migrant origin within tributary

To evaluate likelihood of an individual to emigrate based on relative longitudinal distance from the mouth of the tributary, number of migrants and proportion of migrants were determined with respect to capture reach. Linear regression analyses were conducted to determine if such a relationship was statistically significant.

Age of juvenile migrants

To determine age at migration, scales were collected from all tagged cutthroat trout. Scale samples from fish in all tributaries from all years were placed on scale cards and pressed with acetate. Age determination was conducted by two people. If there was not agreement, a third person aged those samples. If there was then agreement between two of the three readers, that value was used. If all three readings did not agree the reading was discarded. Age could not be determined for a portion of the samples (36%) because many scales were unreadable or regenerative. It should be further noted that many of the scales of the larger fish tagged could not be used because of the high incidence of regeneration in cutthroat trout scales (Cooper 1970). Coastal cutthroat trout age-3 and older accounted for only 3% of all fish aged.

Adult Return

Adult returns were evaluated using PIT tag antenna arrays and electrofishing recaptures. Only migrants that had the potential to return within the study timeframe were considered in analyses to define the timing of adult return. Therefore, coastal cutthroat trout tagged in fall 2004 and beyond were not considered.

Data Analysis

All statistical differences are reported at the $p<0.05$ level. To compare fish size among years, Kruskall-Wallis analysis of variance on ranks was applied where normality assumptions failed. Significance was followed by Dunn's post-hoc analysis. Where data sets were normal, one-way ANOVA was conducted followed by Bonferroni post-hoc analysis.

Results

Sampling

Abernathy Creek

Between fall 2001 and spring 2005, 2,446 cutthroat trout were implanted with PIT tags. Of these 1,846 were tagged during fall electrofishing and 600 smolt trapped fish were tagged during spring out migration (Table 1-1). Fish captured and tagged during electrofishing ranged from 100 mm to 390 mm FL and 8.6 g and 680 g (Table 1-2). Fish captured and tagged during smolt trap efforts ranged from 115 mm to 258 mm FL and 15.0 g to 120.2 g (Table 1-3).

Table 1-1. Number of cutthroat trout tagged in Abernathy Creek by capture method and year.

	2001	2002	2003	2004	2005	total
Electrofishing	470	498	533	345		1846
Smolt trap		200	107	148	145	600
total	470	698	640	493	145	2446

Table 1-2. Fork length (mm FL) and weight (g) of electrofish captured cutthroat trout from Abernathy creek.

	2001		2002		2003		2004	
	FL	W	FL	W	FL	W	FL	W
Median	137	24.3	138	24.2	138	24.9	128	19.9
min	100	8.9	100	9.6	101	8.7	100	8.6
max	390	680	352	515	316	320	345	435

Table 1-3. Fork length (mm) and weight (g) of Abernathy coastal cutthroat trout captured and tagged during spring smolt trap operation.

	2002		2003		2004		2005	
	FL	W	FL	W	FL	W	FL	W
Median	181	41.8	173	43.9	182	51.9	177	48.0
min	128	17.1	135	22.2	134	20.3	115	15.0
max	258	120.2	221	85.1	233	115.8	235	119.6

Chinook River

A total of 2,345 cutthroat trout were PIT tagged through spring 2005. Of these, 1,137 were tagged during fall electrofishing efforts and 1,208 smolt trapped fish were tagged (Table 1-

4). Fish captured during electrofishing ranged from 100 mm to 293 mm fork length and 7 g to 247.5 g (Table 1-5). Fish captured and tagged during smolt trap efforts ranged from 100 mm to 425 mm FL (Table 1-6). Weight is not reported for smolt trap captures because it was not consistently collected.

Table 1-4. Number of cutthroat trout tagged in Chinook River by capture method and year.

	2002	2003	2004	2005	total
Electrofishing	443	310	384		1137
Smolt trap					
MST	53	25	14	45	137
HST	238	250	363	220	1071
total	734	585	761	265	2345

Table 1-5. Fork length (mm) and weight (g) of electrofish captured cutthroat trout from Chinook River.

	2002		2003		2004	
	FL	W	FL	W	FL	W
Median	131	20.5	130	19.0	129	21.1
min	102	7	100	9	100	10
max	293	232	250	160	289	248

Table 1-6. Fork length (mm) of cutthroat trout captured and tagged at the Chinook river smolt traps.

	2002	2003	2004	2005
MST				
Median	218	195	213.5	215
min	118	143	168	141
max	399	307	363	425
HST				
Median	141	128	151	128.5
min	101	100	100	100
max	341	272	377	368

Gee Creek

Between fall 2002 and fall 2004, 132 cutthroat trout were implanted with PIT tags (Table 1-7). Fish captured and tagged during electrofishing range from 102 mm to 317 mm fork length and 9.8 g and 276.5 g (Table 1-8), although weight was recorded for only 18 of the 39 individuals tagged in 2002.

Table 1-7. Number of coastal cutthroat trout tagged in Gee Creek by capture year.

	2002	2003	2004	total
Tagged CCT	39	55	38	132

Table 1-8. Fork length (mm) and weight (g) of electrofish captured cutthroat trout from Gee Creek.

	2002		2003		2004	
	FL	W	FL	W	FL	W
Median	226	47.2	204	78.2	194	73.5
min	102	9.8	136	22.6	106	11.4
max	317	241.2	309	276.5	280	240.1

Migration Timing

Abernathy Creek

Detections of tagged cutthroat trout follow a seasonal pattern of movement that appears consistent among years (Figure 1-1). Detections from both the upper and lower antenna arrays are combined to represent total number of migrants detected. The majority of movement occurred in April and May, with 123 of 169 detections during this time, and the median day of migrants detected occurring between May 9 and May 19 (Table 1-9). However, migrants from Abernathy Creek were also detected in January, March, June, October, November and December.

Table 1-9. Median day of coastal cutthroat trout emigration from both Abernathy Creek and Chinook River based on PIT detections at lower most array.

	2002	2003	2004	2005
Abernathy Creek	17 May	19 May	9 May	19 May
Chinook River	NA	6 May	27 April	28 April

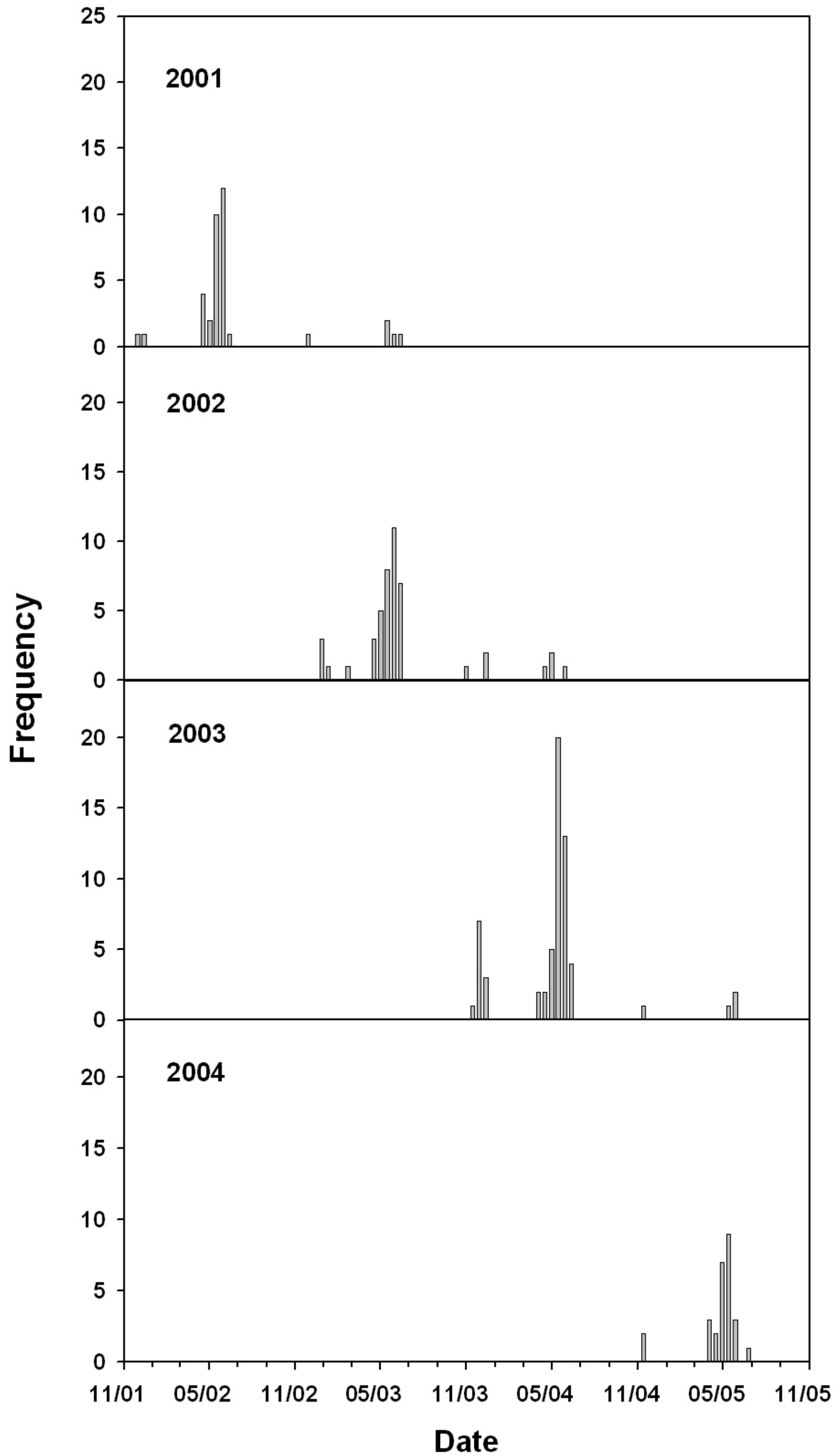

Figure 1-1. PIT tag antenna detection timing of emigrating juvenile coastal cutthroat trout tagged in Abernathy Creek, 2001-2004.

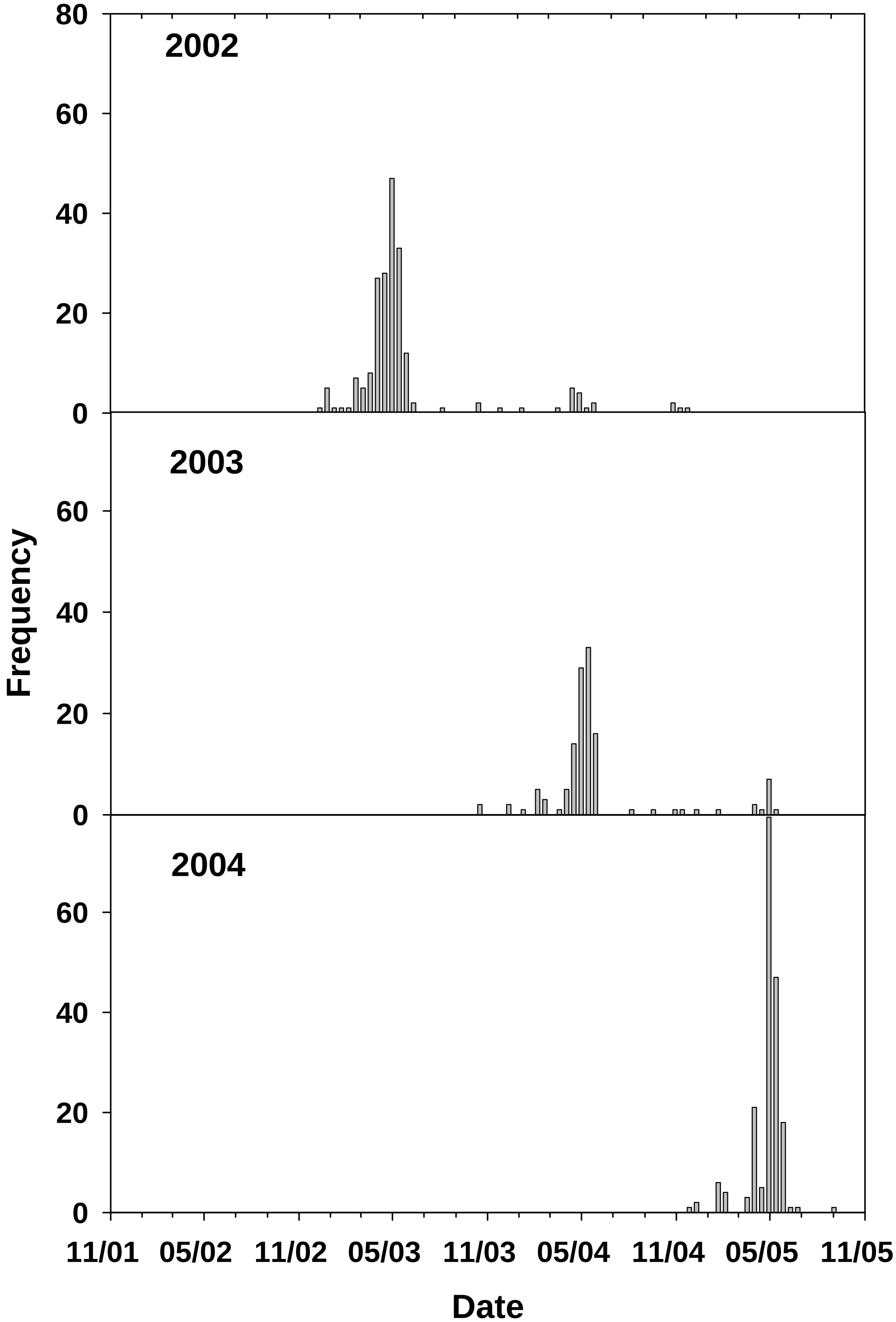

Figure 1-2. PIT tag antenna detection timing of emigrating juvenile coastal cutthroat trout tagged in Chinook River, 2002-2004.

Chinook River

Detections of tagged cutthroat trout followed a seasonal pattern of movement consistent among years (Figure 1-2). Peak movement occurs between March and May. There are slight differences between the upper and lower antenna arrays. A majority of movement occurs in April and May past the lower array with 227 of 363 detections during this time. Movement was slightly more protracted at the upper array. There, peak movement occurred between March and May with 80% of individuals first detected at this time. Median day of migration occurs between April 27 and May 6 (Table 1-9). However, migrants from the Chinook River were also detected in January, June, August, September, October, and November.

Gee Creek

Few detections of Gee Creek tagged fish occurred, though fish from each tagging year were recorded. The single detection from a 2002 tagged fish occurred 19 February. Detections from 2003 tagged fish range from 3 February to 16 April and those from 2004 fish range from 6 April through 1 May (Figure 1-3).

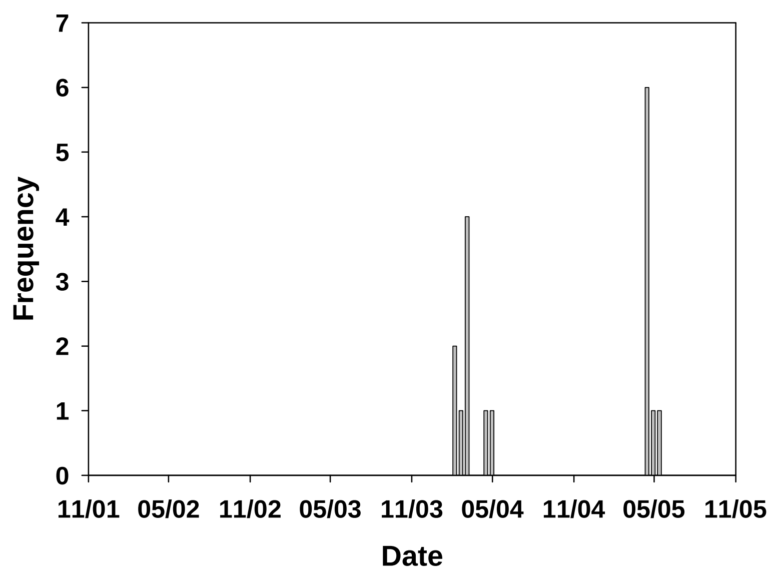

Figure 1-3. PIT tag antenna detection timing of emigrating juvenile coastal cutthroat trout tagged in Gee Creek, 2002-2004.

Prevalence of Juvenile Movements Out of Tributaries

Abernathy Creek

The number of migrants detected during each tag year ranged from a low of 27 individuals for the 2004 tag year to a high of 61 for the 2003 tag year. Proportion of detected migrants from total tagged in each tag year ranged from a low of 7.7% from 2001 to a high of 11.4% for 2003 (Table 1-11).

Table 1-11. Total number of individuals tagged during electrofishing detected migrating and the corresponding proportion (with 95% confidence intervals) by tag year in Abernathy Creek.

Tag year	2001	2002	2003	2004
Total	36	45	61	27
Proportion	7.7%	9.0%	11.4%	7.8%
(95% CI)	(5.5-10.3%)	(6.7-11.7%)	(8.9-14.3%)	(5.3-11.0%)

All tagged fish detected at the antenna arrays can be traced back to the site of capture, tag and release (Figure 1-4). For all years electrofishing captures were tagged, fish detected out migrating represented most reaches (2001 – 89%; 2002 – 92%; 2003 – 92%; 2004 – 83%). Exceptions occurred where few fish (<20) were tagged. Linear regression analyses are inconclusive on the relationship between proximity to the mouth a fish is tagged and likelihood that the fish is detected outmigrating.

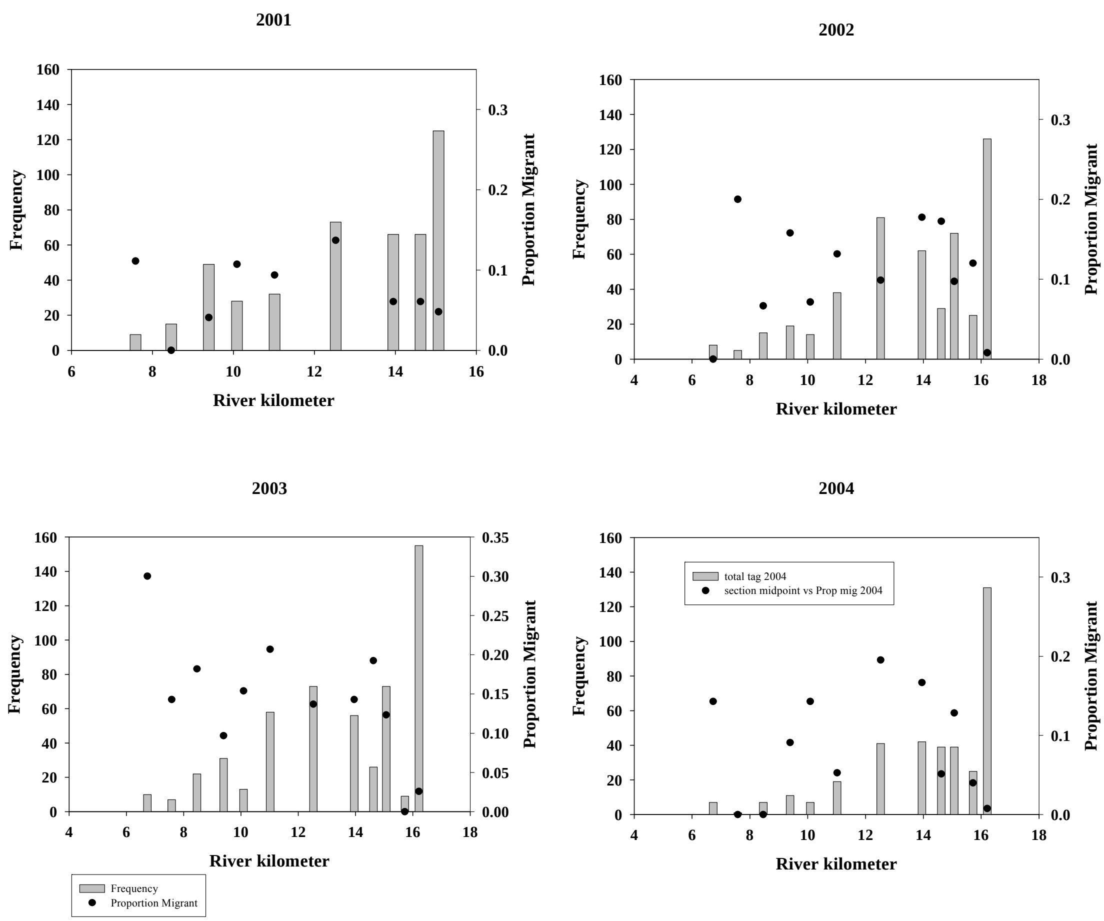

Figure 1-4. Frequency of tagged coastal cutthroat trout and proportion of migrant individuals by reach in Abernathy Creek, 2001-2004.

Electrofishing recapture events occurred in fall 2002, 2003, 2004 and 2005 (Table 1-12). Tagged adults and juveniles were recaptured and are presented together. Proportion of tagged fish that were subsequently recaptured range from a low of 9.2% for 2003 tagged fish to a high of 12.6% for those tagged in 2004 (Figure 1-5). Tagged individuals were recaptured from most electrofishing reaches. However, the number of recaptures was not sufficient to test relationships between tagging location of resident proportion and river kilometer.

Table 1-12. Abernathy Creek coastal cutthroat trout electrofishing recapture events separated by year fish were tagged and recapture events. Total events and total individuals are different due to multiple recaptures of the same individual.

Year recaptured	Year tagged			
	2001	2002	2003	2004
2002	36			
2003	11	51		
2004	2	10	32	
2005	2	2	23	44
Total events	51	64	55	44
Total individuals	45	58	49	44
Proportion recaptured	9.6%	11.6%	9.2%	12.6%

In all cases, tagged individuals migrated within two years of tagging. Of fish tagged in fall 2001, 4 of the 36 (11%) migrated two springs post tagging. This occurred again with 2002 tagged fish where 4 of the 45 (9%) delayed an additional year and with 2003 tagged fish where 3 of 61 (5%) delayed an additional year. The four individuals that delayed from 2002 were age one. Age could be determined on 25 of the 45 individuals that migrated the first spring post tagging. Eighteen of these were age 1 and seven were age 2. The three individuals that delayed from 2003 were age one. Age could be determined on 42 of the 61 individuals that migrated the first spring post tagging. Twenty-five of these were age 1 and seventeen were age 2. Age could be determined only on two fish from 2001 tagging. In all cases, the group of fish that delayed migration appeared shorter and lighter than the group that left the first spring post tagging (Table 1-10). This trend holds when comparing groups tagged at the same age. However, these relationships are not statistically significant due to a lack of power in the analysis.

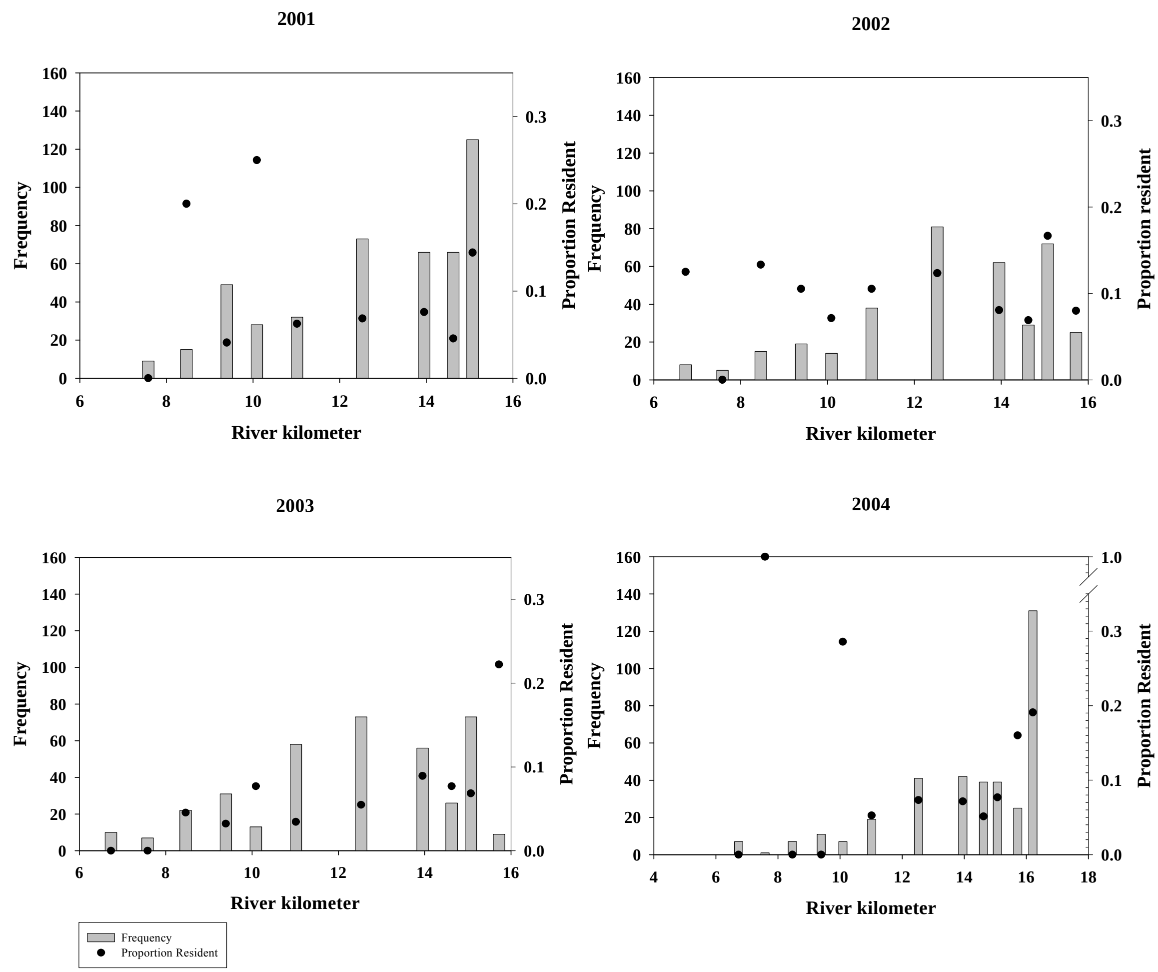

Figure 1-5. Frequency of tagged coastal cutthroat trout and proportion resident by reach in Abernathy Creek, 2002-2004.

Table 1-10. Fork length (mm) and weight (g) data of migrant cutthroat trout captured and tagged through electrofishing efforts in Abernathy Creek. Fish that migrated the first spring subsequent to tagging are compared to those that delayed an additional year.

Tag year	2001				2002				2003			
Migration year	2002		2003		2003		2004		2004		2005	
	FL	W	FL	W	FL	W	FL	W	FL	W	FL	W
Median	138	25.1	111	13.2	134	23.0	117	15.0	142	26.7	116	13.0
min	110	13.4	104	10.8	105	11.0	107	11.8	105	11.2	114	11.9
max	204	77.5	119	16.6	176	52.5	119	16.4	203	71.3	118	15.9

Chinook River

The number of migrants from each tag year range from a low of 130 individuals from the 2003 tag year to a high of 200 from the 2002 tag year. Proportion of migrants of total tagged in each tag year range from a low of 41.9% from 2003 to a high of 48.7% for 2004 (Table 1-13). All tagged fish later recaptured or detected can be traced back to the site of capture, tag and release (Figure 1-6). In all years, fish detected at the antenna arrays represented most all tagging reaches (2002 – 100%; 2003 – 96%; 2004 – 97%). The exceptions were one reach in 2003 and one reach in 2004. In both of the reaches, less than five individuals were tagged. Linear regression analyses are inconclusive on the relationship between proximity to the mouth a fish is tagged and likelihood that the fish is detected outmigrating.

Electrofishing recapture events occurred in fall 2003, 2004 and 2005. Tagged adults and juveniles were recaptured and are presented together. In each year, tagged fish from each of the previous tagged cohorts have been recaptured (Table 1-14). Proportion of tagged fish that were subsequently recaptured range from 2.1% for 2004 tagged fish to 6.1% for fish tagged in 2003. Efforts were unsuccessful in recapturing fish in approximately half the reaches.

Most migrating fish did so the spring following tagging whereas some delayed until the following spring (Figure 1-2). Of fish tagged during fall 2002, 9 of 50 (18%) detected individuals delayed migration to spring 2004. These two groups were compared to determine if size difference at tagging might account for delayed migration. This analysis was standardized by comparing only those individuals that were successfully determined to be age one through scale analysis. Although fish that delayed migration were both shorter (mean 125 mm vs. 119 mm) and lighter (mean 18.5 g vs. 15.4 g), the relationship is not statistically significant due to a lack of power in the analysis.

Table 1-13. Total number of individuals tagged during electrofishing detected migrating and the corresponding proportion (with 95% confidence intervals) by tag year in the Chinook River.

Tag year	2002	2003	2004
Total	200	130	187
Proportion	45.1%	41.9%	48.7%
(95% CI)	(40.6-49.8%)	(36.5-47.5%)	(43.7-53.7%)

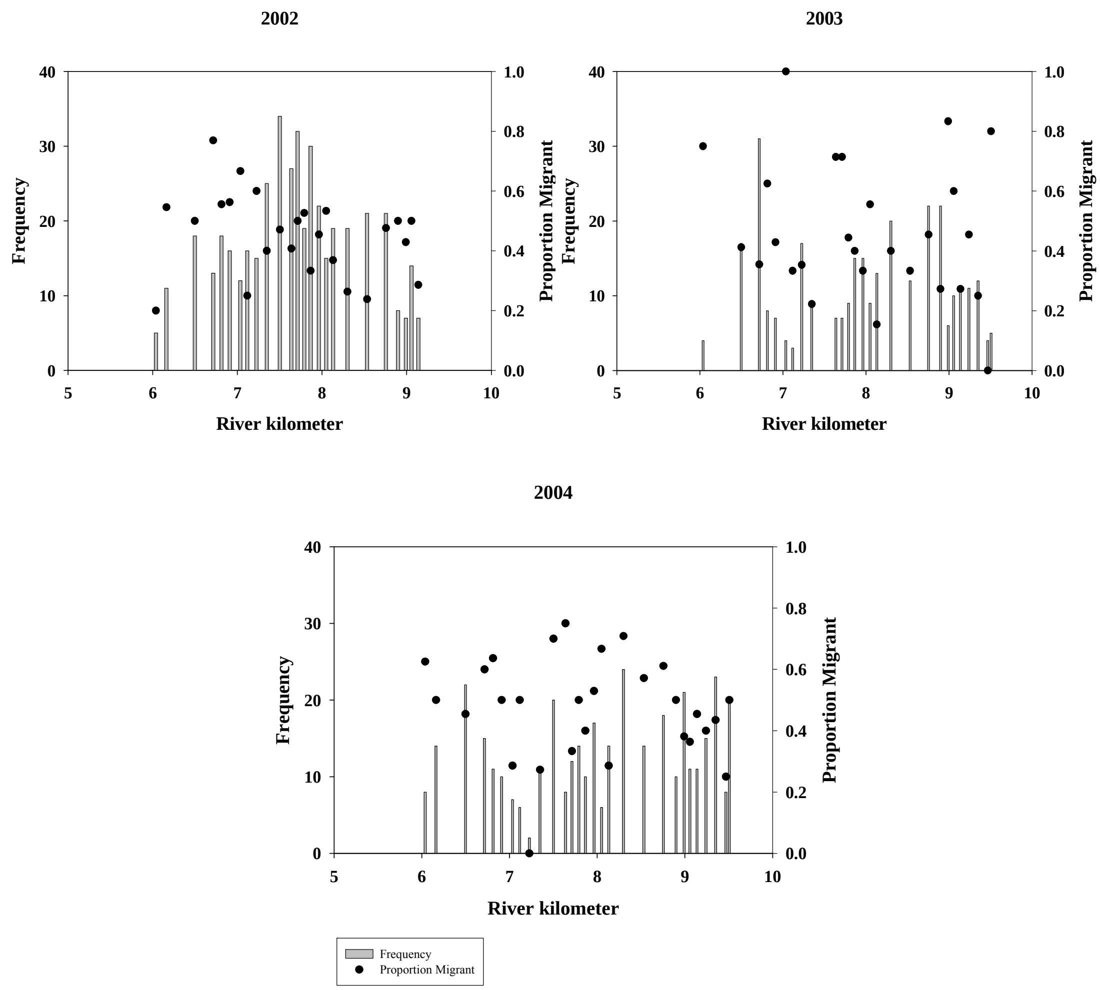

Figure 1-6. Frequency of tagged coastal cutthroat trout and proportion of migrant individuals by reach in Chinook River, 2002-2004.

Table 1-14. Chinook river coastal cutthroat trout recapture events. Includes fish tagged and recaptured during electrofishing operations. Separated by year fish were tagged and recapture events during proceeding years.

Year recaptured	Year tagged 2002	2003	2004
2003	20		
2004	2	17	
2005	0	3	8
Total events	22	20	8
Total individuals	20	19	8
Proportion recaptured	4.5%	6.1%	2.1%

Gee Creek

Proportion of tagged individuals that were detected at the antenna array ranged from 2.6% in 2002 to 18.4% in 2004 (Table 1-15).

Table 1-15. Total number of individuals tagged during electrofishing detected migrating and the corresponding proportion (with 95% confidence intervals) by tag year in Gee Creek.

Tag year	2002	2003	2004
Total	1	9	7
Proportion (95% CI)	2.6% (0.1-11.4%)	16.4% (8.3-27.5%)	18.4% (8.5-32.4%)

Electrofishing recaptures occurred in fall 2003, 2004 and 2005 (Table 1-16). Each tagging year was represented in the recaptures. Proportion of tagged fish that were subsequently recaptured range from 7.3% for 2003 tagged fish to 12.8% for fish tagged in 2002.

Table 1-16. Coastal cutthroat trout electrofishing recapture events in Gee Creek separated by year fish were tagged and recapture events. Total events and total individuals are different due to multiple recaptures of the same individual.

Year		Year tagged	
recaptured	2002	2003	2004
2003	4		
2004	2	3	
2005	0	1	3
Total events	6	4	3
Total individuals	5	4	3
Proportion recaptured	12.8%	7.3%	7.9%

Adult Return

Abernathy Creek

Fifteen individual fish exhibited migratory behavior and subsequent return to Abernathy Creek (2.5% return; 95% CI = 1.5-4.0%). Nine of these individuals were tagged in the spring from smolt trap operation and the remaining six were tagged during fall electrofishing (Table 1-17). The nine returning individuals tagged in spring are from a total of 455 migrant fish tagged during smolt trapping (2.0% return; 95% CI = 0.9-3.6%). The six returning individuals tagged during fall electrofishing are from a total of 142 fish detected at PIT arrays leaving Abernathy creek (4.2% return; 95% CI = 1.7-8.4%). Of these fifteen returning adults, eight of them exhibited a second migration. Only one of these eight returned to Abernathy Creek (12.5% return; 95% CI = 0.8-43.3%), and it was not detected leaving a third time. All but one of these migratory fish left during the spring outmigration and returned the following fall or winter (Figure 1-7). One coastal cutthroat trout left in December and returned in May. The mean number of migratory days was 158.47 (σ = 46.02).

Table 1-17. Coastal cutthroat trout returns to Abernathy Creek by tagging year.

Method	Year	Number Return
Smolt trap	2002	2
	2003	3
	2004	4
Electrofishing	2001	3
	2002	1
	2003	2

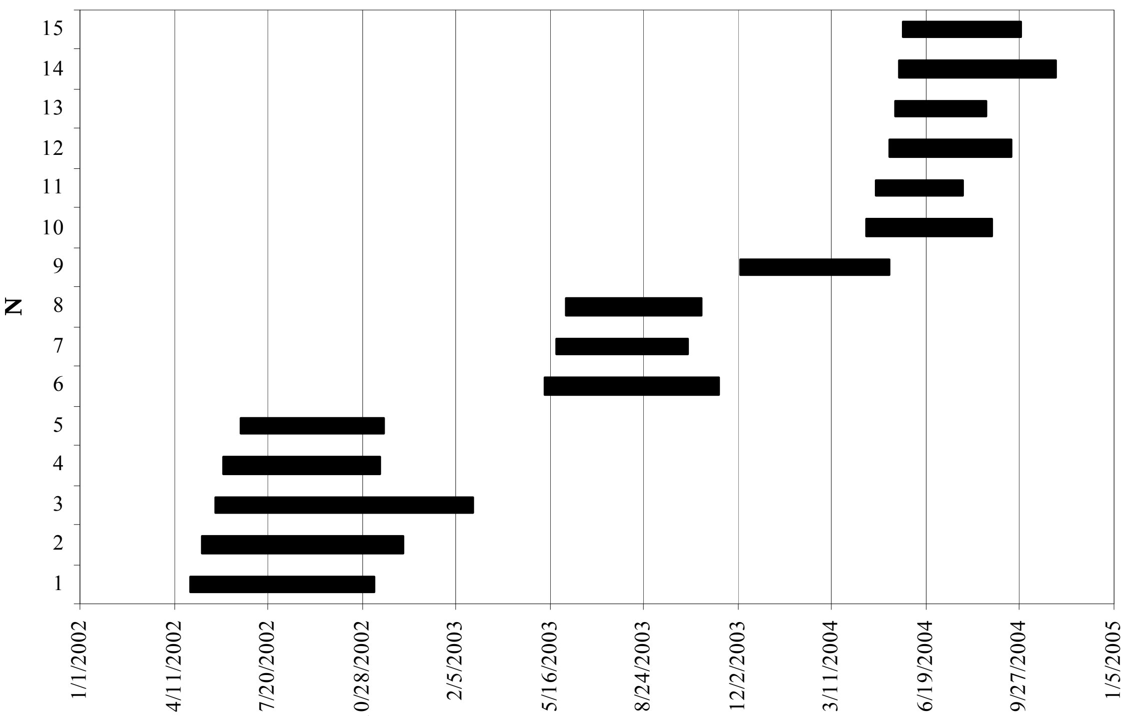

Figure 1-7. Timeframes depicted for migratory coastal cutthroat trout from Abernathy Creek during which these fish were not in the tributary to the lower Columbia River. Only fish for which the emigration and return dates are known were included. Two of these timeframes represent the same fish on its first and second migrations.

Chinook River

In the Chinook River, forty-three tagged individuals that have left the system have subsequently returned (7.4% return; 95% CI = 5.4-9.7%). Of these, 13 fish were tagged during fall electrofishing operations and 30 were tagged during smolt trap operations (Table 1-18). The 30 returning individuals tagged from the smolt traps are from a total of 254 migrant fish tagged (11.8% return; 95% CI = 8.2-16.2%). The 13 returning individuals tagged in fall are from a total of 330 fish tagged during fall electrofishing and subsequently detected at PIT arrays leaving the Chinook River (3.9% return; 95% CI = 2.2-6.4%). Of these 43 returning adults, sixteen of them exhibited a second migration. Ten of these sixteen returned to the Chinook River (62.5% return;

95% CI = 39.2-82.3%). Four of these ten exhibited a third migration. Only one of these returned to the Chinook River (25% return; 95% CI = 2.6-67.0%), and it was not detected leaving a fourth time. All but three of these migratory fish left during the spring outmigration and returned the following fall or winter (Figure 1-8). One left in November and returned the following October. One left in November and returned in January. The third coastal cutthroat trout left during the spring outmigration, but did not return until 19 months later in November of the following year. The mean number of migratory days was 211.46 ($\sigma = 77.81$).

Table 1-18. Coastal cutthroat trout returns to the Chinook River by tagging year.

Method	Year	Number return
Smolt trap	2002	6
	2003	6
	2004	18
Electrofishing	2002	8
	2003	5

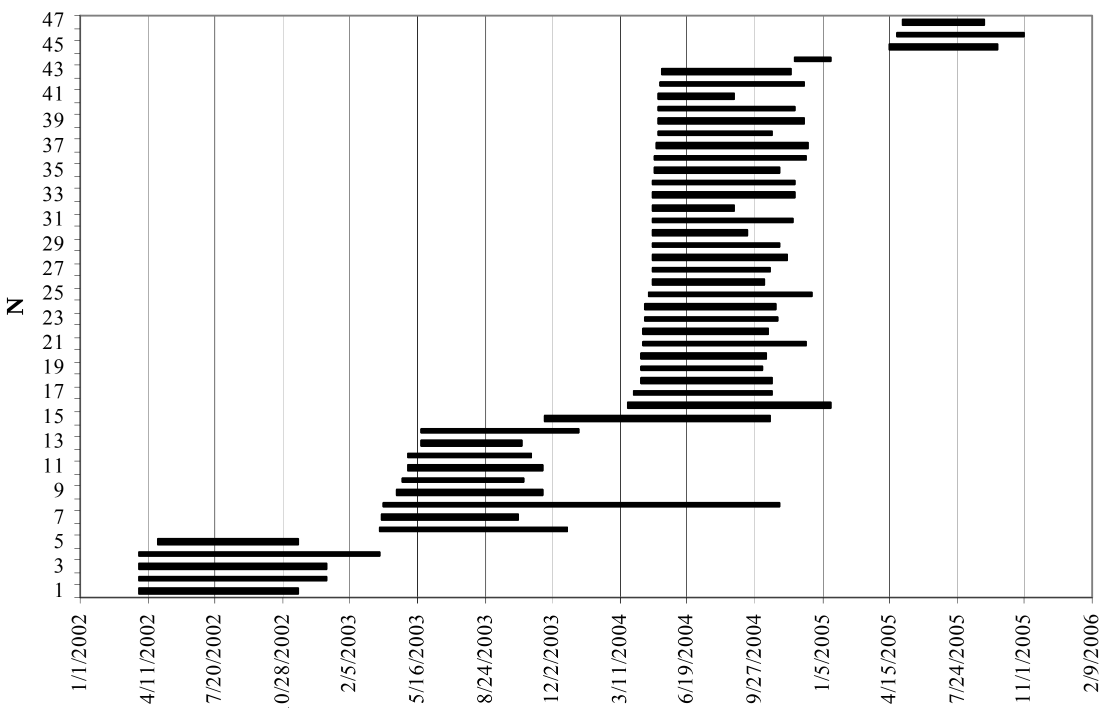

Figure 1-8. Timeframes depicted for migratory coastal cutthroat trout from the Chinook River during which these fish were not in the tributary to the lower Columbia River. Only fish for which the emigration and return dates are known were included. Eight of these timeframes represent the same fish on its first and second migrations. Three of these timeframes represent the same fish on its fish, second and third migrations.

Gee Creek

No fish were detected returning to Gee Creek.

Discussion

Coastal cutthroat trout varied in relative abundance from fall sampling efforts in each of the three tributaries with respect to the amount of habitat sampled. The low number of trout collected from Gee Creek is despite the 8 kilometer reach sampled each fall, possibly reflecting the impacts of agriculture and urban land use encompassing it. While similar numbers of fish were tagged during fall electrofishing in Abernathy Creek and the Chinook River, both of which resulted in annually tagged cutthroat trout a magnitude greater than Gee Creek, there was a substantial difference in amount of habitat sampled. This result may reflect higher productivity, supported by the larger size of migrant coastal cutthroat trout from this stream, and fewer steelhead with which to compete in the Chinook River.

Migrants annually enter the Columbia River from both Abernathy Creek and the Chinook River. In addition, though coastal cutthroat trout exhibit peak movement during spring, they are detected moving downstream in these tributaries most months of the year and presumably enter the mainstem lower Columbia River and estuary. This consistent pattern in these two tributaries may be indicative of a larger migratory pattern exhibited by many lower Columbia River coastal cutthroat trout populations.

The Chinook River has by far the highest number and proportion of emigrating fish of the three tributaries investigated. Fish in Gee Creek were detected moving but because of low numbers of tagged fish, emigration estimates may be misleading. Whether this difference between the three systems is due to habitat quality, fish density or migration distance to the Columbia River estuary is unknown. Within the same system, proportion of migratory fish was similar among years.

Migrant fish originated from most reaches sampled, suggesting that there is not a distinct separation between migratory and resident fish. The reduction in the proportion of migrants higher in the system suggests a relationship between fish origin in the system and the likelihood of becoming migrant or could represent a different level of mortality for migrants higher upstream. Further investigation of the relationship between migrant and resident coastal cutthroat trout should be conducted considering genetic structure and early life rearing habitat influences.

Adult return to spawning tributaries occurs at different times in different years likely corresponding to fall and winter freshets. However, the peak is consistently concentrated during the months of October to December when approximately 79% of adults returned to the Chinook River and approximately 53% of adults returned to Abernathy Creek. The low number of returning adults, particularly in Abernathy Creek, makes return time estimates weak. However, from those fish that did return, it appears that adult cutthroat exhibit a protracted migration. Fish were detected returning to Abernathy Creek as early as 27 July and the Chinook River on 26 August. The latest return was 22 February to Abernathy and 20 March to the Chinook River. Additional years of data from these tributaries and supporting data from other lower Columbia River tributaries would strengthen the estimate of adult return times.

The known emigration and return dates for migrant fish provides windows of time that migratory coastal cutthroat trout are not in the tributary. It is not known exactly what happens to these fish, but some insight is provided by Zydlewski et al. (2008) and Hudson et al. (2008). These papers (Hudson et al. 2008; Zydlewski et al. 2008) provide support that migratory juvenile and adult coastal cutthroat trout are using the lower Columbia River and estuary during this time either as a migratory corridor and/or rearing habitat.

Coastal cutthroat trout from the Chinook River exhibited higher adult return rates and a higher likelihood of migratory fish to migrate multiple times than those from Abernathy Creek. This higher success by migrant fish may be a function of two factors. First, the Chinook River produces larger size migrants which can provide a competitive advantage in feeding and predator avoidance. Second, the Chinook River confluence is in the estuary at the mouth of the Columbia River. Therefore, migratory rearing habitat requires a much reduced corridor in which migrants are subject to a number of anthropogenic and natural threats such as channel maintenance, ship traffic, commercial and sport fishing, marine mammals, predatory birds, and a number of others.

This data indicates that multiple life history stages of coastal cutthroat trout from these two streams can be found in the lower Columbia River mainstem and estuary during most months of the year. A majority of migratory coastal cutthroat trout leave their natal tributary in the spring and those that return do so the following fall or winter. Fish that make multiple migrations follow a similar pattern. Consideration of these timeframes when planning channel deepening and maintenance activities can minimize impacts to coastal cutthroat trout.

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Seaward Migration of Coastal Cutthroat Trout (*Oncorhynchus clarki clarki*) from Four Tributaries of the Columbia River

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Introduction

Coastal cutthroat trout (*Oncorhynchus clarki clarki*) are found on the west coast of North America from Alaska to northern California (Behnke 1992; Gerstung 1997; Schmidt 1997). These fish exhibit tremendous diversity in life history strategies both within a watershed and throughout their range (Armstrong 1971; Giger 1972; Jones 1978; Johnston 1982; Trotter 1989; Northcote 1997). Some individuals complete their life history within their natal stream yet sympatric individuals may undertake active downstream migrations (Northcote 1997; June 1981; Johnston 1982). There are no clear morphological distinctions between juvenile cutthroat trout that are resident or migratory (Tomasson 1978; Fuss 1982). Migratory cutthroat trout generally emigrate from natal waters at age II or III in the spring (Giger 1972; Sumner 1972; Trotter 1989). Age II migrants predominate in the lower Columbia River watershed of Oregon and Washington (Johnston 1982; Trotter 1989). Seaward migration at the juvenile stage affords periods of high growth in the ocean environment (Gross 1988). This migration also requires the development and maintenance of appropriate osmotic tolerances necessary for survival.

Migratory cutthroat trout have been characterized as weakly anadromous (Northcote 1997) and reportedly select lower salinities in the estuary (Loch and Miller 1988). While cutthroat trout have been caught offshore, conventional wisdom prescribes that migrating cutthroat trout do not venture far from the estuary if at all (Tipping 1981; Pearcy 1997). In many systems, these trout are thought to make more extensive use of the mainstem river and estuary habitats (as both juveniles and adults) rather than offshore environments. Though migrating juveniles are characterized as “smolts” (Trotter 1997), it is unclear whether juveniles undergo a parr-smolt transformation process similar to those observed in other salmonids (Hoar 1976, McCormick and Saunders 1987). Shifts in migratory behavior and physiology (such as elevated gill Na^+,K^+-ATPase activity) associated with smolting are not well documented in coastal cutthroat trout.

Many migratory populations of coastal cutthroat trout have declined in recent years, including those of the Columbia River (Nehlsen et al. 1991; Hooton 1997; Leider 1997). Coastal cutthroat trout have been impacted by anthropogenic practices such as logging (Holtby 1987; Johnson et al. 1999) over-fishing (Giger 1972; Ricker 1981; Gresswell and Harding 1997) and artificial propagation (Campton and Utter 1987; Flagg et al. 1995). In addition, coastal cutthroat trout are thought to use estuaries more extensively than other Pacific salmonids, particularly during certain stages in their life history. This may make them more vulnerable to changes in estuarine conditions than other Pacific salmonids (Giger 1972; Pearcy 1997).

The objective of this study was to determine the movement patterns of coastal cutthroat trout entering into the Columbia River from four tributaries known to have migratory populations and to characterize the degree to which these fish used the mainstem and estuary of the Columbia River. Additionally, gill biopsies of study fish were used to measure Na^{+},K^{+}-ATPase activity as an indirect indicator of smolt development.

Methods

Study Area

Coastal cutthroat trout from four tributaries to the Columbia River, Germany Creek (river kilometer (RK) 91), Abernathy Creek (RK 88), Mill Creek (RK 87) and the Chinook River (RK 6), were studied in 2002 and 2003 using radio and acoustic telemetry (Figure 2-1). The Chinook River is a tidal system that is regulated by a tide gate at its confluence with the Columbia River. This system experiences salinity fluctuations from 0 ppt to full strength seawater and empties into an estuarine mixing zone. Germany, Mill and Abernathy Creeks are third order systems that experience tidal fluctuations at their confluences with the Columbia River, but do not experience salinity fluctuations.

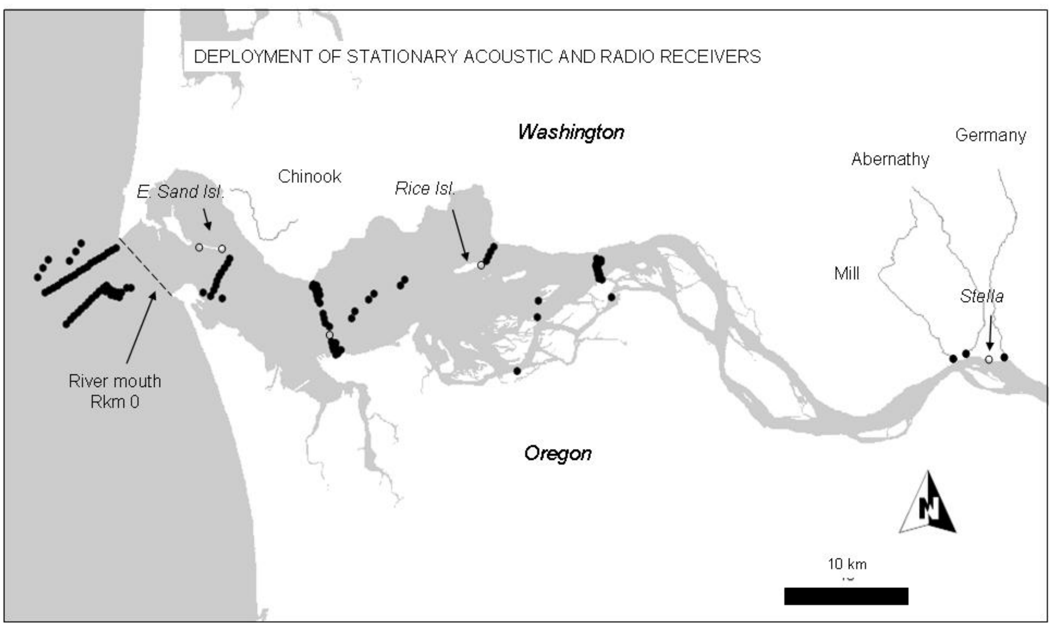

Figure 2-1. Deployment of stationary acoustic (solid circle) and radio receivers (open circle) in the Columbia River in 2003. The four tributaries studied (Germany Creek, Mill Creek, Abernathy Creek and Chinook River) are indicated.

Capture of Cutthroat Trout

In 2002 and 2003, juvenile coastal cutthroat trout were captured at the mouths of Germany, Abernathy and Mill creeks in 1.5 m screw traps (operated by the Washington Department of Fish and Wildlife; WDFW) and in a screw trap (2.4 m) at the mouth of the Chinook River (operated by Sea Resources, Inc., Chinook WA). In 2002, cutthroat trout implanted with radio tags were captured from May 5 through May 30, while those implanted with acoustic tags were captured from May 12 through May 21. In 2003, cutthroat trout receiving radio tags were captured from May 9 to June 25 while those receiving acoustic tags were captured from May 17 through June 11. Water temperature ranges observed during tagging were recorded. Length and weight of all captured cutthroat trout was recorded and condition factor determined.

Tagging

Fish were held in the screw traps a maximum of 24 h prior to tagging. Cutthroat trout were anesthetized with a buffered solution of MS-222 (100 $mg \cdot l^{-1}$, $NaCO_3$ buffered 0.2 mmol $NaHCO_3$, pH=7.0) in 4 L of water from the area of capture then measured for length and weight. Also, a non-lethal gill biopsy was taken for subsequent analysis of Na^+,K^+-ATPase activity. Two to four filaments from the first gill arch on the left side were removed with iris scissors above the septum (which avoids major vascularization) and handled as described below. Fish were then implanted with acoustic tags (26 mm x 9 mm diameter; 3.1 g; 69 kHz, 20-60 sec pulse rate; estimated minimum tag life of 68 days) or radio tags (1.65 g; 148-150 MHz; 3 sec pulse rate; estimated minimum life of 25 days).

Fish larger than 37 g were selected for implantation of acoustic tags (this excluded less than 10% of collected fish). The skin on the ventral surface was swabbed with Betadine (10% povidone-iodine) and an incision made in the peritoneal wall with a sterilized scalpel tip. The tag was inserted through the incision which was then closed with three sutures (coated braided absorbable suture) and swabbed with Betadine. Typically the wound heals within 7-10 days (depending on temperature) and sutures dissolve within 10-14 days (Zydlewski unpublished data).

Fish greater than 30 g were selected for radio tagging (excluding only a few fish). Radio tags were inserted into the peritoneal cavity the same as acoustic tags except for accommodation of an external antenna which was threaded through the body cavity with a sterile 18 gauge, 20 cm long deflected septum needle. The needle was then pushed through the lateral wall of the cavity approximately 1 cm anterior to the anus on the right side. The area around the antenna exit was swabbed with Betadine and the initial incision closed with two sutures. Cutthroat trout receiving either tag were allowed to recover for 10-15 minutes prior to release downstream of the trapping sites (within 50 m) at the closest area away from rapid flow.

Radio Tracking

In 2002 and 2003, movements of tagged fish were monitored passively via five stationary radio telemetry locations. The locations of the receivers (as indicated on Figure 2-1 for 2003) varied slightly between years; however areas of coverage were consistent. Receivers were located at Stella (WA), Rice Island, East Sand Island, and Astoria Bridge. These units were equipped with yagi antenna oriented towards the main channel of the Columbia River and were downloaded multiple times through the study. Observations were considered to be duplicates if occurring at the same point within a 10 minute interval. The time of duplicate observations were averaged for analysis.

In both 2002 and 2003, active tracking was performed by both boat (minor component in 2002) and automobile. The areas of initial capture and release were generally checked at 24 h intervals to determine if individuals remained in the vicinity of the tag and release site. In 2003, greater emphasis was put on active tracking by boat. Subsequent to tagging, an individual observed leaving the tributary was generally tracked until it could not be relocated. Location of tagged fish was determined using two boat-mounted yagi antennas and a hand-held yagi antenna with the receivers. Tests with drones verified the ability to confidently localize tag positions to within 50 m. Twenty four hour-a-day tracking was accomplished in two shifts, changing approximately at 0600 and 1800.

Acoustic Tracking

In 2002 and 2003, movements of acoustic-tagged cutthroat trout were monitored passively via stationary acoustic receivers. The locations of the receivers are indicated on Figure 2-1 (for 2003). As with the radio telemetry receiver locations, deployment of the acoustic receiver array varied slightly between 2002 and 2003 though areas of coverage were consistent between years with 50-60 receivers deployed at any one time. Because these units were moored using a buoy and anchor system, positions changed within year as well as when units were retrieved and redeployed. Receivers were deployed near the surface as described in Clements et al. (2005). Notable differences between 2002 and 2003 were the deployment of three receivers near Sand and East Sand Islands to monitor movements of fish from the Chinook River in 2002 (not shown in Figure 2-1) and the addition of three receivers deployed in the mouths of Germany, Abernathy and Mill Creeks in 2003. As with radio telemetry data, observations were considered to be duplicate if occurring at the same point within a 10 minute interval. The time of duplicate observations were averaged for analysis.

There was no active tracking of acoustic tagged fish in 2002, but in 2003 efforts were made to track by boat using a directional towed receiver. This effort was largely unsuccessful due to boat equipment failure, producing a single track. The tracking protocol was the same as that described for active radio tracking.

Patterns of Movement

Calculation of time to reach the Columbia River mouth was based on first observation of a tagged individual at (or downstream) of RK 20 (this was the lowest point in the system where radio tags could be reliably detected due to salinity). Two speed calculations were made, one using initial time from release after tagging and a second using last observation of tagged individual at (or upstream) of RK 85, to allow for variation in recovery from tagging and resumption of migration. Significance within these data using Kruskal-Wallis (using either tributary or year as factors) was followed by Mann-Whitney U tests for multiple comparisons. The relationship between gill Na^+,K^+-ATPase and individual speed to reach the river mouth were evaluated using a linear regression.

We defined “directed movement” as a movement parallel to the Columbia River shipping channel (as demarked by the US Coast Guard buoy system) with downstream movements being defined as positive and upstream movements being defined as negative. To consider patterns of directed movement in the context of tidal and diel cycle, observations from active radio tracking in 2003 were analyzed. Only those individuals that had tracks that lasted more than 48 h and met the criteria described below were considered.

Migration speed is defined as a series of directed movements calculated from position data collected at intervals of less than one hour, but greater than 10 minutes. Exclusion of observations at intervals less that 10 min was necessary to prevent erroneously high speed calculations based on fluctuations in GPS position measurements. Speeds greater than 11 km/h were rejected as this represented the greatest directly observed speed during tracking efforts. Time used in calculations described below was an average of the two observed positions.

Tidal reference was determined using tidal predictions from the National Oceanic and Atmospheric Administration from Skamokawa, WA (RK 54, 46° 16 N 123° 27 W), which represented an approximate midpoint in the range of observations from RK 20 to RK 91. Tides can differ through this reach by approximately 2h based on data from Astoria, OR (-1 hour, RK 20; 46° 12 N 123° 46 W) and Stella, WA (+1 hour, RK 91, 46° 11' N 123° 7' W). Data were not interpolated for the fish location. Based on tidal predictions, a tidal cycle was defined to ten discreet categories from 0 to 1, with 0 defined as high tide, 0.5 defined as low tide, 1 representing the next high tide, and the remaining 8 tenths appropriately representing each portion of the cycle (regardless of whether the cycle represented a spring or neep tide).

Similarly, data for the diel cycle experienced by moving fish was based on prediction for Skamokawa, WA. To consider diel cycles under a changing day length, the photoperiod was defined to ten discreet categories between 0 and 1, with sunrise being 0, 0.5 sunset, 1 the following sunrise, and the remaining 8 tenths appropriately representing each portion of the cycle. Because the photoperiod was changing (14.2 hours light on May 1 to 15.4 hours on June 30) when tracking occurred, the absolute time assigned to each category changed through the season but continued to represent sunrise and sunset.

For both tidal and diel representations, calculated speeds of directed movement for a fish were assigned to one of these ten discreet categories in both the tidal and diel cycle. (For example, a fish assigned 0.1 for the diel cycle and 0.3 for the tidal cycle would have been observed just after sunrise over half way through the outgoing tide). Individuals that did not have more than 10 observations in each of ten categories were excluded from analysis. For each individual, and each category, the 25th, 50th and 75th percentiles for migration speed were calculated. Differences in averages of the 50th percentile were analyzed via one-way ANOVA (using tidal or diel categories as a grouping variable). Significance with one-way ANOVA analysis was followed by a Tukey's post-hoc test.

Gill Na^+,K^+-ATPase Activity Determination

Gill Na^+,K^+-ATPase activity was determined using the microplate method described by McCormick (1993) as validated for cutthroat trout (Zydlewski unpublished data). Briefly, gill tissue was removed and immersed in 100 µL of ice cold SEI buffer (150 mM sucrose, 10 mM EDTA, 50 mM imidazole, pH = 7.3) and stored at -80 °C. Gill samples were thawed immediately prior to assay and homogenized in 200 µL of 0.1 % sodium deoxycholate in SEI buffer. The homogenate was centrifuged to remove insoluble material. Specific activity of Na^+,K^+-ATPase was determined in duplicate by measuring ATPase activity with and without 0.5 M ouabain in a solution containing 4 U/mL lactate dehydrogenase, 5 U/mL pyruvate kinase, 2.8 mM phosphoenolpyruvate, 0.7 mM adenosine triphosphate (ATP), 0.22 mM nicotinamide adenine dinucleotide (reduced)(NADH), 50 mM imidizole, 45 mM NaCl, 2.5 mM $MgCl_2$, 10 mM KCl, pH = 7.5. Kinetic analysis of ATP hydrolysis was measured at 25 °C by monitoring

[NADH] at 340 nm using a 96 well plate reader. Protein concentration of the gill homogenate was determined in triplicate using the bicinchoninic acid (BCA) method (Smith et al. 1985) using bovine serum albumen as standard. Activity of gill Na^+,K^+-ATPase is expressed as µmol ADP•mg protein^{-1}•h^{-1}.

Two-way ANOVA was used to compare length, weight, condition factor and gill Na^+,K^+-ATPase activity between years and tributaries (Germany, Abernathy and Mill creeks). Significance of factors or of interactions was followed by analysis within each factor. One-way ANOVAs were used for comparison within each year where significance was found. An inclusive one-way ANOVA was also run for all groups to include unbalanced groups. In all analyses, significance with a one-way ANOVA was followed by a Tukey's post-hoc test. Intervals about a mean are reported as ± one standard error (SE) or standard deviation (SD) as indicated. The relationship between Na^+,K^+-ATPase activity and time it took for successful individuals to reach the mouth of the Columbia River was analyzed using linear regression.

Results

Radio Tracking

In 2002, 96 cutthroat trout were tagged with radio transmitters and released in Germany, Abernathy and Mill creeks (Table 2-1). From these fish, 91 tracks were collected and 5 fish were not observed after release. A total of 31,223 observations were made with 433 active and 30,790 passive observations. In 2003, 22 cutthroat trout were tagged with radio transmitters and released in Germany, Abernathy and Mill creeks (Table 2-1). From these fish, 17 tracks were collected and 5 fish were not observed after release. A total of 9,072 observations were recorded; 3,234 active and 5,838 passive. Lengths, weights and condition factors of tagged fish did not differ between tributaries or between years (Table 2-1).

Table 2-1. Mean fork lengths (cm), weights (g) and condition factors (100 • g •cm^{-3}) of coastal cutthroat trout implanted with acoustic and radio tags in 2002 and 2003. Values are presented ± 1 SD. There are no statistical differences between groups. Ranges of water temperatures at collections for each tag type within each year are given.

Year	Tag type	River (n)	Length (cm)	Weight (g)	CF (100 •g •cm^{-3})
2002	Acoustic	GERM (1)	20.4	72.2	0.85
	(9-11 °C)	ABER (12)	19.2±1.4	62.0±15.7	0.86±0.04
		MILL (10)	18.7±1.3	55.5±12.5	0.83±0.04
		CHIN (26)	20.0±2.7	72.8±33.3	0.86±0.06
	Radio	GERM (21)	18.8±1.5	60.6±15.8	0.89±0.06
	(7-12 °C)	ABER (32)	18.8±2.1	61.4±22.3	0.89±0.06
		MILL (43)	18.4±1.4	53.7±13.2	0.85±0.06
2003	Acoustic	GERM (15)	17.9±0.9	48.4±7.1	0.84±0.05
	(7-15 °C)	ABER (9)	18.4±1.0	56.8±12.3	0.91±0.08
		MILL (15)	19.4±1.6	66.6±16.9	0.90±0.09
	Radio	GERM (8)	18.5±1.6	56.1±13.5	0.87±0.06
	(13-18 °C)	ABER (4)	17.3±1.2	43.4±10.1	0.83±0.05
		MILL (10)	18.5±1.2	56.8±13.0	0.85±0.07
		ALL (206)	18.8+1.8	59.4+19.6	0.87+0.06

In both years, fish exhibited downstream movement 55/96 (57%) in 2002 and 17/22 (77%) in 2003 moving toward the estuary (Figure 2-2). No fish was observed moving more that 3 km upstream after entry into the main stem of the Columbia River. Of those fish displaying downstream movement, 49/55 (89%) in 2002 and 13/17 (76%) in 2003 were subsequently observed at RK 20 or lower in the system.

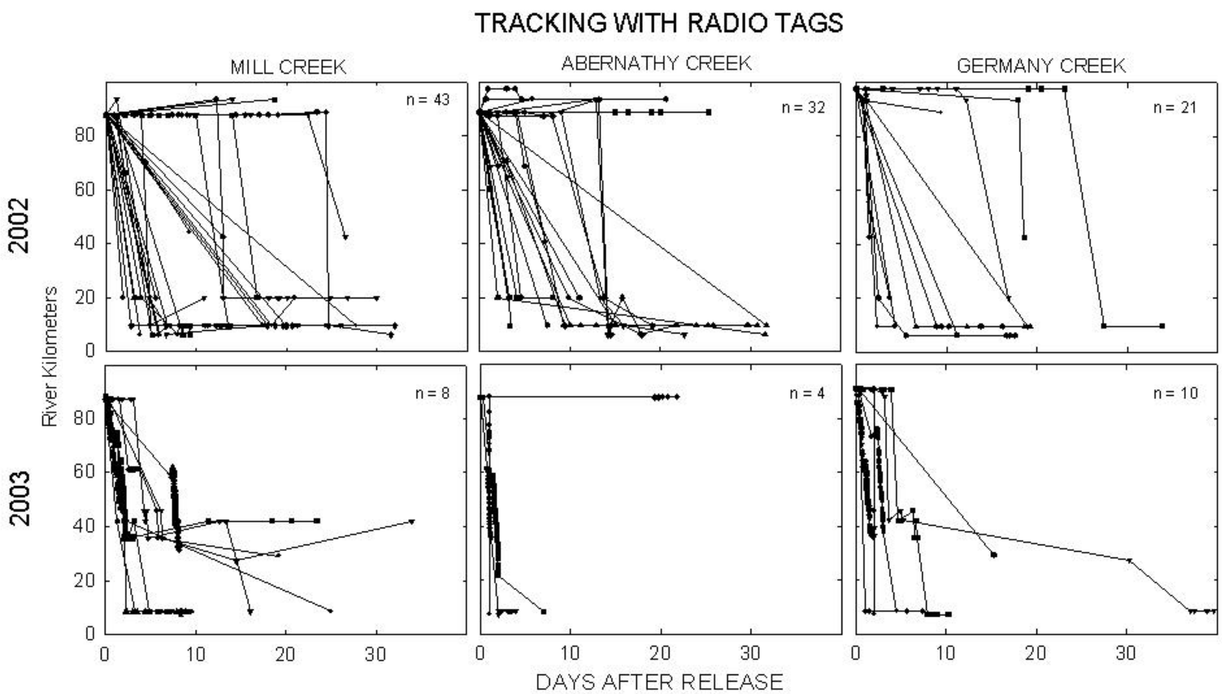

Figure 2-2. Downstream movement data for coastal cutthroat trout implanted with radio tags in the mouths of up-river tributaries (Germany, Abernathy and Mill creeks) of the Columbia River. The number of trout tagged for each tributary and year is indicated in the upper right corners of the graphs. River kilometer is provided for location on the Columbia River from the mouth of the Columbia River.

Acoustic Tracking

In 2002, 49 cutthroat trout were tagged with acoustic transmitters, 23 from Germany, Abernathy and Mill creeks and 26 from the Chinook River (Table 2-1). From these fish, 7,189 passive observations were collected and 32 tracks were collected. Seventeen fish were not observed after release. In 2003, 39 cutthroat trout were tagged with acoustic transmitters in Germany, Abernathy and Mill creeks (Table 2-1). From these fish, 13,022 observations were made, 280 during active tracking and 12,742 passive observations. Seven fish were not observed after release. Lengths, weights and condition factors of tagged fish did not differ between tributaries or between years (Table 2-1).

As with the radio telemetry, the acoustic tracks in 2002 (17/23; 74%) and 2003 (12/39; 31%) demonstrated downstream movement from Germany, Abernathy and Mill creeks towards the mouth of the Columbia River (Figure 2-3). Of the fish observed to move downstream, 10/17 (59%) in 2002 and 7/12 (58%) in 2003 were observed at or in the ocean. In the Chinook River (2002), 14/26 (54%) cutthroat trout rapidly moved downstream and 13/14 (93%) left the Columbia River (Figure 2-4).

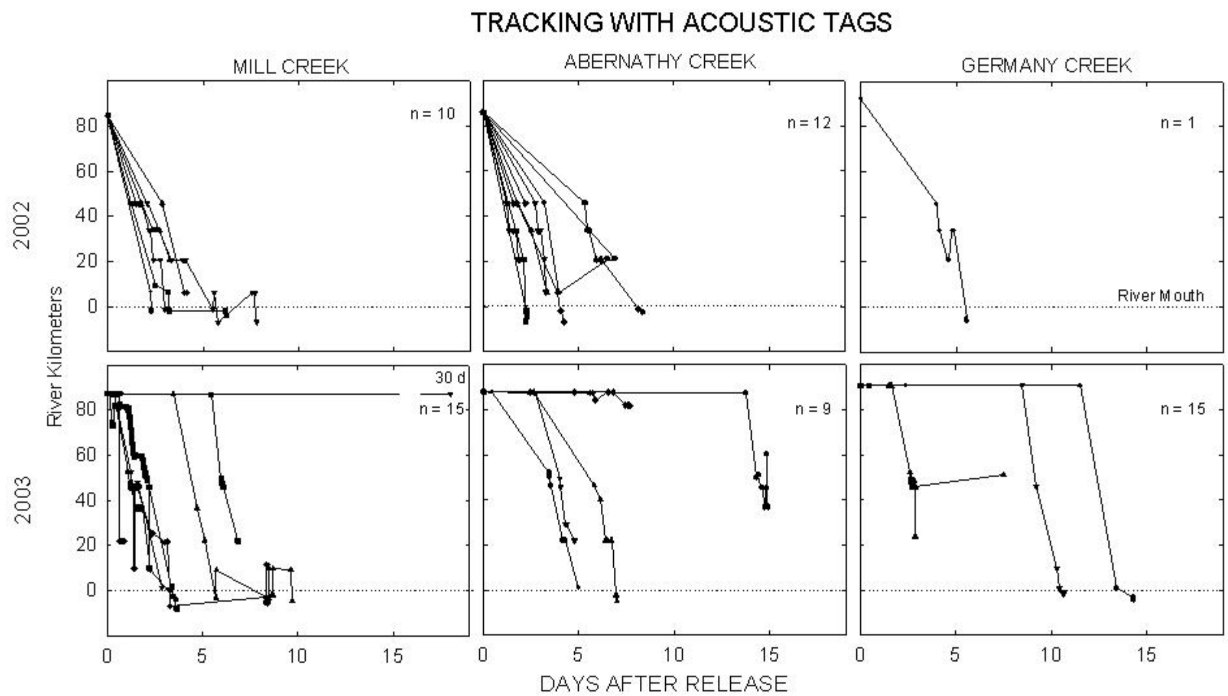

Figure 2-3. Downstream movement data for coastal cutthroat trout implanted with acoustic tags in the mouths of up-river tributaries (Germany, Abernathy and Mill Creeks) of the Columbia River. The number of trout tagged for each tributary and year is indicated in the upper right corners of the graphs. River kilometer is provided for location on the Columbia River from the mouth of the Columbia River. The mouth of the Columbia River (RK 0) is indicated with a dotted horizontal line.

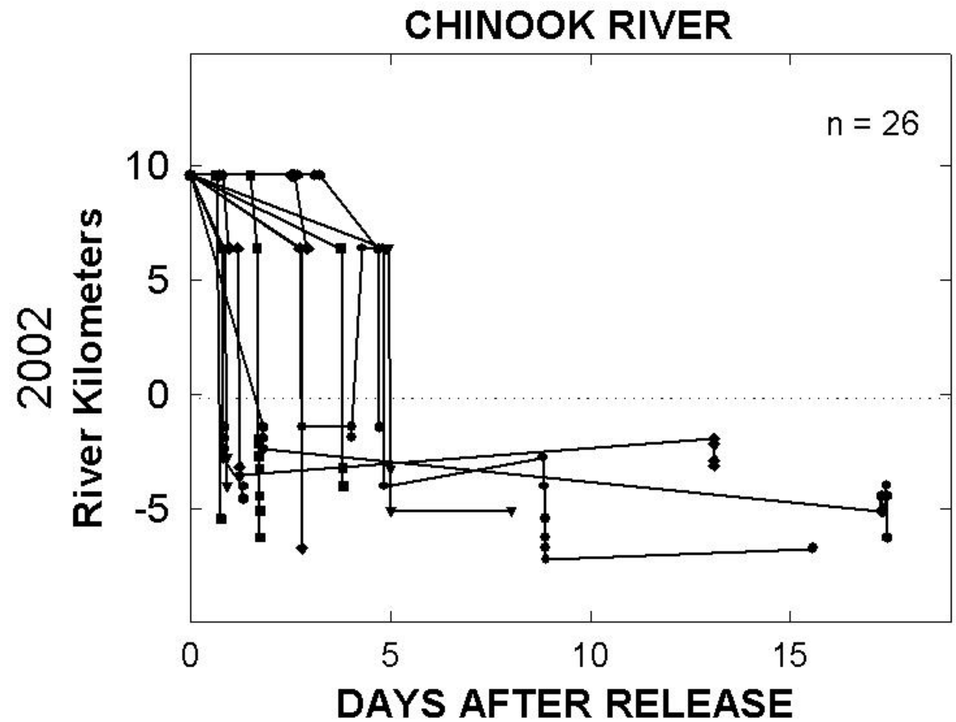

Figure 2-4. Downstream movement data for coastal cutthroat trout implanted with acoustic tags in the mouth of the Chinook River. The mouth of the Columbia River (RK 0) is indicated with a dotted horizontal line. The number of trout tagged for each tributary and year is indicated in the upper right corner of the graph.

Patterns of Movement

For cutthroat trout leaving Germany, Abernathy and Mill creeks in 2002, individuals took a median of 6.6 days to reach the mouth of the Columbia River from the time of tagging and a median of 5.5 days once movement had been initiated. This movement was primarily in the main channel of the lower Columbia River (Figure 2-5). In 2003, downstream movement was more rapid, moving to the mouth at median times of 4.3 and 3.2 days (p=0.07 and p=0.01), respectively (Table 2-2). Several individuals did not initiate movement for as long as 23 days, followed by directed downstream movement.

Cutthroat trout were observed traveling at rates greater than 10 km/h. Conversely, tracks of fish were punctuated with long lulls in activity or upstream movement, often associated with changes in the tidal cycle. Migration speeds less than 0.01 km/h (including upstream migration speeds) accounted for over half of all movement observations. Cutthroat often traveled near shore; however several individuals were observed not only crossing the shipping channel, but also traveling in the channel for multiple hours.

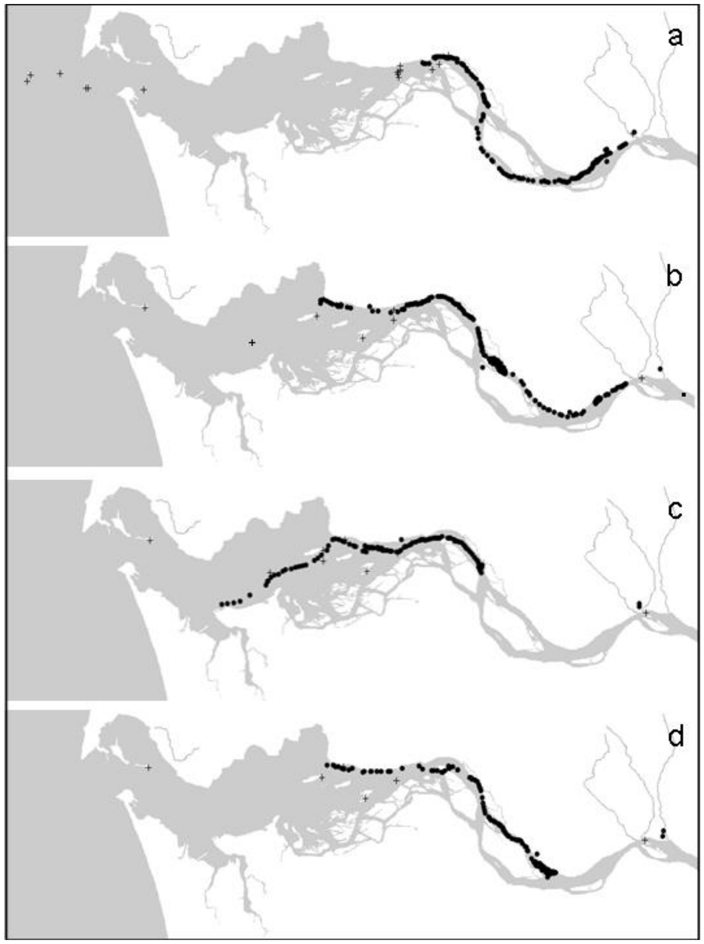

Figure 2-5. Detailed tracks of cutthroat trout implanted with acoustic (a) and radio (b,c,d) tags in 2003. These representative tracks show both active and passive data ("•" and "+" respectively).

Analysis of downstream movement patterns indicate migration speed is associated with tidal cycle and may be influenced by diel cycle. Twelve fish had sufficient observations to fit the analysis criteria. There was a significant relationship between tidal cycle and migration speed ($p=0.006$). Coastal cutthroat trout exhibited greater downstream migration speed (up to 11 km/h) during the ebb tide than during the flood tide with fish travelling fastest during the latter half of the outgoing tide. All twelve fish exhibited reduced downstream migration speed (no more than .0001 km/h) or negative migration speed (directed movement upstream at speeds as high as 9 km/h) during the flood tide. There was no significant relationship between diel cycle and downstream migration speed ($p= 0.06$). However, fish tended to have greater downstream migration speed just after sunrise and after sunset independent of tidal cycle.

Gill Na^+,K^+-ATPase Activity Determination

Gill Na^+,K^+-ATPase activity from cutthroat trout did not differ between years or tributaries (Table 2-2). Average Na^+,K^+-ATPase activity in 2002 was 3.6 ± 0.13 µmol ADP•mg protein^{-1}•h^{-1} and 3.2 ± 0.19 µmol ADP•mg protein^{-1}•h^{-1} in 2003. There was a weak positive relationship between gill Na^+,K^+-ATPase activity and time it took successful individuals to reach the mouth of the Columbia River (R^2=0.01, p=0.002, n=64). That relationship is marginally strengthened (R^2=0.09, p = 0.0005, n=44) when coastal cutthroat trout that delayed the initiation of movement by 10 or more days are excluded.

Table 2-2. Mean gill Na^+,K^+-ATPase $\pm$ 1 SE (expressed as µmol ADP•mg protein^{-1} • h^{-1}) and median speed of tagged cutthroat trout from of time of tagging and time of departure from tagging area, respectively, to first detection at RK 20 or lower.

			Days to reach Columbia River mouth			
		Gill Na^+, K^+-ATPase	From tagging		From departure	
Year	Source	(:ADP • mg prot^{-1} • h^{-1})	Median	Range	Median	Range
2002	GERM	3.4 $\pm$ 0.18 (17)	6.1	2.3 – 18.9 (8)	5.6	1.7 – 17.8 (8)
	ABER	3.7 $\pm$ 0.25 (32)	9.4	2.2 – 31.8 (20)	6.1	1.0 – 31.8 (20)
	MILL	3.5 $\pm$ 0.21 (52)	5.8	2.2 – 27.7 (23)	5.5	1.0 – 27.7 (23)
	CHIN	3.7 $\pm$ 0.38 (23)	na	na	na	na
	ALL	3.6 $\pm$ 0.13 (124)	6.6	2.2 – 31.8 (51)	5.5	1.0 – 31.8 (51)
2003	GERM	2.8 $\pm$ 0.24 (22)	6.2	1.1 – 37.1 (8)	2.4	1.0 – 33.9 (8)
	ABER	3.5 $\pm$ 0.53 (14)	4.5	2.0 – 7.0 (6)	3.9	2.0 – 6.7 (6)
	MILL	3.5 $\pm$ 0.30 (23)	3.5	2.3 – 25.0 (10)	3.2	2.0 – 25.0 (10)
	ALL	3.2 $\pm$ 0.19 (59)	4.3	1.1 – 37.1 (24)	3.2	1.0 – 33.9 (24)

Discussion

Cutthroat trout tagged with both radio and acoustic tags in this study displayed directed downstream movement towards the ocean consistent with smolting behavior (Figures 2-4). Fish traveling from Mill, Abernathy and Germany Creeks to the mouth of the Columbia River exhibited travel speeds of 6.6 and 4.3 days (from time of tagging and resumption of migration respectively; Table 2-2). Many individuals traveled the distance in 1-2 days. Speeds were consistent with the movements of cutthroat trout tagged with PIT tags in these creeks and detected in the lower Columbia River (Zydlewski unpublished data) using a PIT trawl (Ledgerwood et al. 2004). These speeds are also similar to those observed in other anadromous salmonid smolts in the Columbia River and other rivers (Schreck et al. 2002).

The calculated speeds of movement from the time of departure of the tagging area to the mouth of the Columbia River differed between 2002 and 2003 (Table 2-2). In 2003, travel speed of migrants was nearly 2 fold lower than that observed in 2002. A possible explanation for this difference is the timing of tagging differed between years. In 2002 migrants were tagged from May 5 to May 30 while in 2003 migrants were tagged from May 9 through to June 25. Based on flow data from the Columbia River (USGS), fish in 2003 were tagged during a period of moderately higher flows than those in 2002. In addition to annual variations in river flow conditions, migrants experienced higher river temperatures in 2003, perhaps influencing migratory behaviors.

While the cumulative set of observations indicate a pattern of directed movement downstream, this should not be confused with continuous downstream migration as over half of movement observations documented lulls in activity or upstream movement. There are a number of fish for which there is either no data subsequent to tagging or only observations at or near the point of release. These fish could have lost their tag, not been detected by the receivers, not displayed migratory behavior or been mortalities. Tagging is unlikely to be a direct cause of mortality. Immediate and delayed tagging mortality was rare (<1%) in controlled tagging studies (Zydlewski unpublished data). Likewise, tag loss is rare during the life of the tag. However, it can be assumed that surgical tagging is likely to affect short term performance (e.g. swimming speed; Adams 1998) and may contribute to vulnerability to predation. While acoustic tags cannot be located out of water, six radio tags were recovered on the islands of the lower Columbia River (Rice and East Sand Islands; Figure 2-1) which harbor nesting colonies of Caspian terns (*Sterna caspia*) and double crested cormorants (*Phalacrocorax auritus*). The birds inhabiting these colonies are known to impact salmonid smolt numbers in the Columbia River (Collis et al. 2001).

A minority of tagged fish may have not been migrating seaward when tagged and their capture could simply have been a result of local movements. For a small number of fish, the last observation was in the creek where they were tagged. In several cases, the fact that the fish was alive subsequent to remaining near the tag site was confirmed with electrofishing (one fish in 2003) and recapture of tagged fish in the rotary screw trap (4 recaptures in 2002). In at least five cases, tagged fish entering the Columbia River traveled into the mouths of the neighboring creeks; two of the five were eventually observed at the mouth of the Columbia River. The possibility remains, however, that tagged fish were active migrants that ceased migratory behavior, possibly as a result of tagging.

Data from acoustic telemetry suggests that fish tagged in Mill, Abernathy and Germany creeks that reached the mouth of the Columbia River tended to exit the river mouth and move into the plume (Figure 2-3 and Figure 2-5a). At least three individuals were observed remaining in the area of the river mouth for 3-5 days before their last observation, apparently moving with the tide. This pattern appears to be consistent with the behaviors of juveniles exiting the Chinook River (RK 6; Figure 2-4).

Once exiting the mouth of the Columbia River, the evidence suggests that the migrants leave the area of the river plume in the vicinity of the ocean array receivers. One tagged fish (from Abernathy Creek) was observed to have left the immediate area of the Columbia River mouth and traveled 65 km south in two weeks, near the Nehalem River mouth on the Oregon coast (where an unrelated acoustic tracking study was underway). This movement is consistent with observations that coastal cutthroat trout do not venture far offshore. Tipping (1981) surmised that coastal cutthroat trout from the Cowlitz River may not go far from the estuary of the Columbia River. Similarly the highest numbers of coastal cutthroat trout are caught from 10-45 km from the coast of Oregon and Washington (Johnston 1982). A relatively short sojourn to sea before retuning in the fall has been hypothesized to result in relatively high survival of returns (some 40% higher than other salmonids; Giger 1972).

The observed directed seaward movement described here differs from some observations where juvenile cutthroat trout evidently make greater use of the estuaries (Trotter 1997; Tomasson 1978; Lisa Krentz, Oregon Department of Fish and Wildlife, unpublished data). Variation in observed life history strategies among rivers should not be surprising. Migratory patterns for coastal cutthroat trout have been described as diverse, with both sea-run and river run (potadromous) migratory behaviors being observed (Trotter 1997). However, the relative uniformity of seaward movements subsequent to entry into the mainstem of the Columbia River (and the apparent absence of potadromy) was unanticipated. It may be the case that rapid and directed downstream movement seaward may be the most advantageous migratory strategy in this and other large river systems. Typical waters supporting anadromous coastal cutthroat trout are generally small streams with low flow (Johnston 1982) possibly limiting competition from larger salmonids for spawning habitat (Pearcy et al. 1990). Exploitation of the lower reaches of these small systems may therefore afford greater rearing opportunities.

The possibility that this somewhat uniform migratory pattern is a recent condition cannot be cast aside. Life history diversity of cutthroat trout may have declined in the Columbia River due to changes in the hydrograph. The impacts of hydropower on upriver salmonid stocks are understandably linked to passage (Deriso et al. 1996; Deriso 2001). In the lower Columbia River, however, regulated flow has resulted in a shift in the amplitude and timing of high flow events (Chaney 1978). This shift in hydrological character influences mainstem flows, plume structure, salinity profiles, tidal range and productivity (Bottom et al. 2001). The shift in invertebrate community has likely altered the growth opportunities of juvenile salmonids that linger in the estuary (including cutthroat trout). A short period of time in the mainstem Columbia River may be specific to the juvenile life history stage. Returning anadromous adults to the system have been observed to use the mainstem river more extensively (Hudson et al. 2008).

Capture and tracking efforts in this study were limited to juvenile cutthroat trout emigrating from lower Columbia River tributaries during spring. It is possible that the anadromous component of these populations makes a rapid and directed downstream migration during this part of the year, and any remnant potadromous component of these populations may emigrate during other times of the year, similar to other salmonids exhibiting this migratory behavior (Muhlfeld and Marotz 2005; Downs et al. 2006). The potential for this behavior to be expressed is supported by the emigration of juveniles from Abernathy Creek and Chinook River during late fall/early winter (Johnson et al. 2008). To an unknown extent, potadromous juvenile cutthroat may use the mainstem river more similar to migratory adults (Hudson et al. 2008).

Migrating juvenile cutthroat trout used the whole main channel of the lower Columbia River. This was evidenced by observations documenting travel near shore as well as observations of several juveniles not only crossing the shipping channel (e.g., Figure 2-5a and 5c) but also traveling in the channel for several hours. This observation was unanticipated as an avoidance of open waters has been suggested (Jones 1976). Entry into the channel was often associated with the presence of formations (natural or human) that intersected with the flow of the water (e.g., pile dikes).

Downstream movements of coastal cutthroat trout were greatest on an outgoing tide. Patterns of tidal transport have been reported for many species (deVeen, 1978, Locke 1997) including juveniles of spring Chinook, fall Chinook and steelhead trout in the Columbia River and estuary (Moore et al. 1998; Shreck et al. 2005). Migrating using tidal currents offers obvious advantages for energetics and navigation. Observations in this study also suggest a pattern such that downstream movement is greatest in the hours just after sunrise and just after sunset. This would be similar to what has been observed in other salmonids (Carlsen et al. 2004; Emmett et al. 2004)

Smolting salmonids develop seawater tolerance coincident with migration as part of a complex developmental shift, the parr-smolt transformation. There is some correlation between gill Na^+,K^+-ATPase activity and the parr-smolt transformation in salmonids (Hoar 1976; McCormick and Saunders 1987; Hoar 1988). However, we have insufficient data to do more than speculate as to the developmental state of the fish studied. Average gill Na^+,K^+-ATPase activity values (3.6 and 3.2 µmol ADP•mg protein^{-1}•h^{-1} for 2002 and 2003 respectively) are nearly 2-fold higher than activities measured in coastal cutthroat trout captured in November 2002 (Zydlewski unpublished data), but are lower than those measures in many smolt species (McCormick and Saunders 1987). It is reasonable to conclude from similar enzyme activities among streams and time that those fish tagged were of roughly similar developmental stage. While gill Na^+,K^+-ATPase should be viewed as an indirect indicator of smolting, this should not be viewed as a surrogate for more detailed physiological work including seawater challenges. There is some suggestion that gill Na^+,K^+-ATPase activities are related to downstream migration speed. As both metrics (behavior and Na^+,K^+-ATPase activity) are variable, the relationship is understandably weak.

Juvenile coastal cutthroat trout studied in these four tributaries to the Columbia River exhibited behavioral patterns that are consistent with those observed in other salmonid species. In spring, juveniles leaving tributaries of the mainstem Columbia River move in a rapid and directed fashion seaward. Because of these similarities, anthropogenic activities and management actions in the mainstem Columbia River, such as direct mortality from channel deepening and maintenance (NMFS 2002), that influence other salmonid smolts are likely to affect anadromous coastal cutthroat trout smolts in a parallel fashion.

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Movement of Adult Coastal Cutthroat Trout (*Oncorhynchus clarki clarki*) in the Lower Columbia River Mainstem and Estuary

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Introduction

Coastal cutthroat trout exhibit a variety of life history strategies across their range, including residency, adfluvial migration, fluvial migration and anadromy (Northcote 1997; Johnson et al. 1999). Expression of these strategies may also vary among populations throughout the range of the species (Armstrong 1971; Giger 1972; Jones 1978; Johnston 1982; Trotter 1989; Northcote 1997). Populations in the lower Columbia River basin may be comprised of multiple life history components and individuals may exhibit multiple life history strategies over time (Johnson et al. 1999).

It is the anadromous component of coastal cutthroat trout that is of particular conservation concern in the lower Columbia River basin. Little data exists to estimate coastal cutthroat trout abundance in lower Columbia River populations. However, what information that does exist points to declines in the anadromous component of these populations (Hooton 1997, Leider 1997, 67 FR 44934).

Changes in lower mainstem and estuary conditions may be a contributing factor to the decline of the anadromous component of coastal cutthroat trout in the lower Columbia River (64 FR 16407). Similar to other Pacific salmonids in the Columbia River basin, the lower Columbia River estuary not only provides an important migratory corridor for smolts, it also provides the return corridor of migration for adults. The extent to which coastal cutthroat trout may use this habitat is not clearly understood, and duration of lower mainstem and estuarine residency may vary within and among drainages (Pearcy 1997).

The anadromous component of populations may be limited to excursions into near shore marine environments or may not venture out of the lower Columbia River estuary at all (Trotter 1997). Return migrations from the marine environment to the estuary or freshwater habitat vary in timing across the range (Behnke 1992; Trotter 1997). Previous information indicates that return migrations of coastal cutthroat trout in the lower Columbia River may begin as early as June and continue through October (67 FR 44934).

The objective of this study was generally to describe adult coastal cutthroat trout behavior in the lower Columbia River mainstem and estuary. More specifically, the purpose of this project was to describe adult coastal cutthroat trout movement patterns, duration of time spent in the lower mainstem and estuary of the Columbia River as kelts, proximity to the shipping channel, and potential causes of mortality. The impetus of this project was the channel deepening project in the lower Columbia River and estuary and how it may affect this species. A better understanding of adult coastal cutthroat trout behavior, spatially and temporally, in the lower Columbia River mainstem and estuary will help guide management decisions that may affect this species.

Methods

Movement Patterns

Adult coastal cutthroat trout movement in the lower Columbia River mainstem and estuary was investigated in 2004 and 2005 using a radio telemetry protocol that was adapted between the first and second year. Radio telemetry has been used successfully in the past to investigate movement of not only coastal cutthroat trout, but other subspecies of cutthroat trout as well (Jones and Seifert 1997; Young 1998; Hilderbrand and Kershner 2000; Schmetterling 2001; Shrank and Rahal 2004). Location of capture, methods of capture and approach to tracking were adapted in the second year to better address the project objectives.

2004 Movement Patterns

Coastal cutthroat trout kelts were captured via hook and line from Mill Creek, WA, a tributary of the lower Columbia River (RK 87.2) during February 2004 (Figure 3-1). Captured fish greater than 250 mm fork length (FL) and 140 g were anesthetized with 25 ppm clove oil and surgically implanted with a radio tag (365 day battery life) following methods in Zydlewski et al. (2008). Tagged fish were allowed to recover at least 15 minutes, and released at the point of capture.

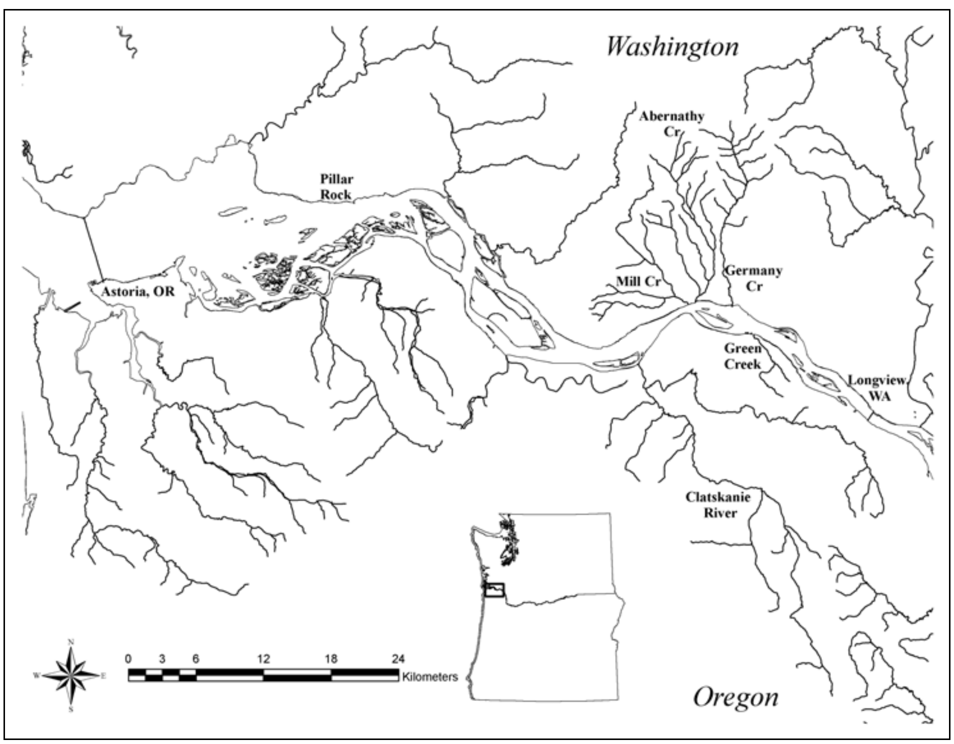

Figure 3-1. Locations of tributaries sampled for adult coastal cutthroat trout in the lower Columbia River, 2004 and 2005.

Movement of coastal cutthroat trout was determined by passive and active telemetry. Passive telemetry utilized a stationary antenna and radio telemetry receiver located at County Line Park, Cowlitz County, WA (RK 83), 3.8 RK downstream of the mouth of Mill Creek on the Columbia River. This station was operated continuously through the duration of the project. Active telemetry occurred 2-3 days per week from the date coastal cutthroat trout were tagged until November 2004. From November 2004 until February 2005, active telemetry occurred 1-2 days per week. Active telemetry was conducted on established routes for 64 days via boat and 51 days via car. Tracking routes evolved with fish movement and exploration of safe passageways for boat tracking and suitable access roads for car tracking. The final routes were generally established between Longview, WA, and Astoria, OR, for these two methods of tracking (Figure 3-2). Upriver tracking upstream of Longview, WA, occurred on occasions when fish that could not be located were suspected of moving that direction.

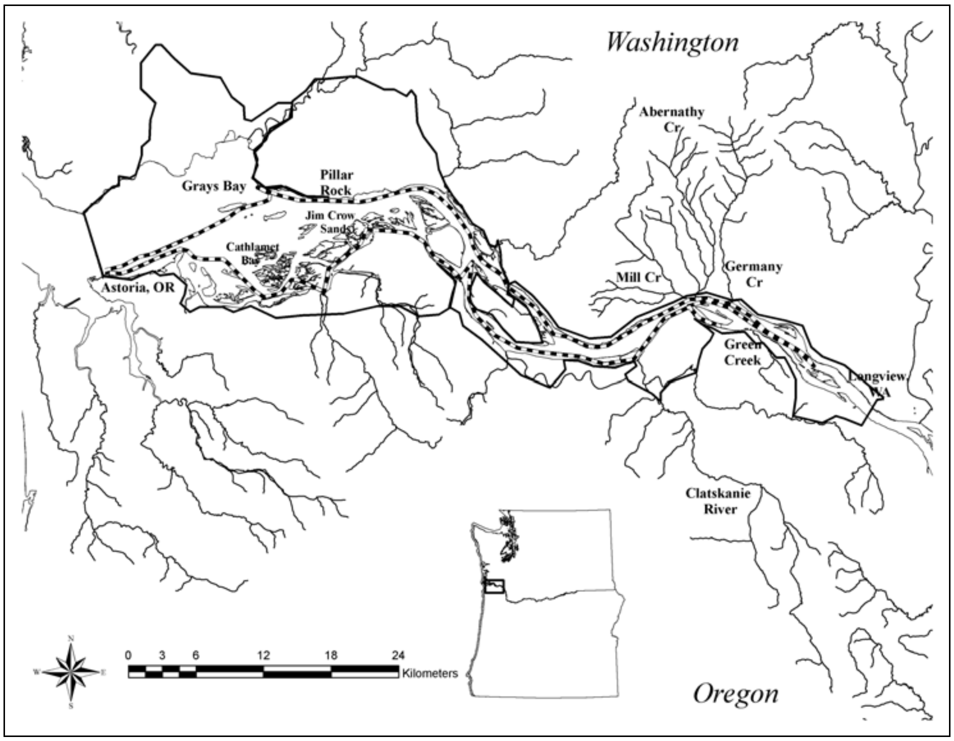

Figure 3-2. Routes followed for active telemetry. The dashed inner loop represents the path followed during boat tracking. The solid outer loop represents the path followed during car tracking.

Telemetry coverage of the Columbia River mainstem and estuary between Longview, WA, and Astoria, OR, was fairly complete with a few exceptions. Two large areas that were inaccessible via boat or car were Grays Bay and the islands area between Jim Crow Sands and Cathlamet Bay (Figure 3-2). In addition, radio telemetry was impeded between Astoria, OR, and Rice Island (RK 35) during high tide due to increased salinity levels.

One active telemetry flight was conducted September 24, 2004. This flight occurred to ensure individuals were not in areas inaccessible to routine tracking. Coverage included the Columbia River mainstem, estuary, and tributaries between Vancouver, WA, and Astoria, OR.

2005 Movement Patterns

Coastal cutthroat trout kelts were captured via hook and line from Mill Creek, WA, a tributary of the lower Columbia River (RK 87) during February 2005 (Figure 3-1). Additional individuals were captured from Mill and Germany creeks, WA, using screw traps (located near the mouth) and from Abernathy Creek, WA, using the electric weir at Abernathy Fish Technology Center (USFWS) during March, April, and May 2005. Attempts were made to capture coastal cutthroat trout via hook and line on Abernathy Creek, WA, in February 2005, and on the Clatskanie River, OR, in March 2005. Fish captured greater than 250 mm FL were surgically implanted with a radio tag (365 day battery tag), allowed to recover, and released at the point of capture.

Movement of coastal cutthroat trout was determined by passive and active telemetry. In addition to the established passive telemetry station at County Line Park, two additional stations were established in 2005. These stations utilized a stationary antenna and radio telemetry receiver and were located on the south side of Puget Island, WA, and near Pillar Rock on Pillar Rock Road, WA. These three stations were operated continuously through the duration of the project.

Active telemetry was adapted in 2005 to concentrate on the period that most movement occurred based on data from the previous year. Initially, active telemetry occurred every other day from the time the first coastal cutthroat trout were tagged. When the first individuals began moving out of the tributaries into the Columbia River mainstem, active telemetry occurred every day to maintain contact with fish that were moving. All active telemetry initially occurred by car. When an individual could not be located by car, efforts were made to locate that individual by boat and maintain daily contact by either active telemetry method. Daily tracking occurred in this manner until all fish had appeared to cease movements, had presumably migrated downstream of Astoria, OR, or were known or suspected mortalities. Telemetry coverage was similar to 2004 with the exception that the two additional passive telemetry stations provided additional continuous coverage.

One active telemetry flight was conducted April 27, 2005. This flight occurred to ensure individuals were not in areas inaccessible to routine tracking. Coverage included the Columbia River mainstem, estuary, and tributaries between Vancouver, WA, and Astoria, OR.

Duration in Lower Columbia River Mainstem and Estuary

Duration in lower Columbia River mainstem and estuary was determined in number of days between the first detection outside of the tributary and the last detection before returning to the tributary or not being detected again. Suspected or confirmed mortalities were included in the analysis up to the date they were first detected at their last documented location.

Proximity to the Shipping Channel

Proximity to the shipping channel is described in reference to whether a fish had to cross the shipping channel to get from one documented location to the next. Absolute distance of fish location to shipping channel is not defined because most of the data collection was not designed to collect information this detailed.

Mortality

Suspected and confirmed mortalities are described for each year. Suspected mortalities are defined as fish that ceased movement for over one month and/or were detected in water temperatures exceeding 25°C. Confirmed mortalities are defined as fish in which predation was observed or they ceased movement and tags were recovered.

Data Analysis

Coastal cutthroat trout detected via active telemetry were identified and GPS location was determined (UTM NAD 1983 CONUS). Other data collected included time, habitat type, and bearing. In addition, tidal direction of the fish at the time of detection was collected in the second year of the study. All telemetry contacts with tagged coastal cutthroat trout were input into ArcMap. Analysis of movement and interpretation of behavior patterns was facilitated through the use of this software and extensions.

Results

2004 Movement Patterns

A total of 23 adult coastal cutthroat trout were radio tagged from Mill Creek, WA, in 2004 (Table 3-1). The average fork length of radio-tagged kelts was 309 mm (range 254 to 402, median 310 mm). Two fish had adipose clips indicating hatchery origins, and the other fish were considered wild. The 23 fish tagged in Mill Creek generally fell into four behavior categories: 1) Coastal cutthroat trout detected outside of Mill Creek and returning to Mill Creek; 2) Coastal cutthroat trout detected outside of Mill Creek and not detected again; 3) Coastal cutthroat trout detected outside of Mill Creek continuously in one location; 4) Coastal cutthroat trout not detected outside of Mill Creek.

Coastal cutthroat trout detected outside of Mill Creek and returning

Five adult coastal cutthroat trout were detected outside of Mill Creek that returned to Mill Creek one or more times. Two of these individuals (#1 and #19) were detected in a neighboring tributary. Four of these individuals (#11, #17, #19 and #23) most likely migrated downstream in the Columbia River at least as far as Astoria, OR.

Two adult coastal cutthroat trout tagged in Mill Creek migrated to Abernathy Creek for various durations. One individual (#1) was detected in Abernathy Creek for only a day (4/5/2004) before returning to Mill Creek. This individual was not detected outside Mill Creek on any other occasion and the transmitter was recovered in working condition 10/15/2004. There was no fish carcass found with the transmitter. The second individual migrated to Abernathy Creek the day after it was tagged and remained in that stream for approximately two weeks (2/8-23/2004) before returning to Mill Creek for approximately a month (2/25/2004 – 3/29/2004).

Four coastal cutthroat trout left the Mill Creek drainage and migrated downstream in the Columbia River at least as far as Astoria, OR. One of these (#19) was not detected again after the last contact moving downstream. Three of these individuals (#11, #17, and #23) returned to Mill Creek after this migration and subsequently left Mill Creek again. The dates these coastal cutthroat trout were last detected in Mill Creek were 3/17/2004 (#23), 4/9/2004 (#17), and

4/21/2004 (#11). In addition, one of these individuals (#11) had previously left Mill Creek and returned six days later in late February. These fish returned to Mill Creek from their migration downstream in the Columbia River on 7/23/2004 (#11), 8/11/2004 (#23), and 12/14/2004 (#17). One of these individuals (#23) subsequently left Mill Creek again on 9/1/2004 and was not detected again. The other two individuals went on apparent spawning runs in the Mill Creek drainage around 11/2/2004 (#11) and 1/20/2005 (#17). These movements were considered spawning runs because both fish moved upstream approximately one kilometer for only a few days before returning to approximately the same location in the drainage before departing Mill Creek (#11 – 1/5/2005; #17 – 2/23/2005). These individuals left Mill Creek again on 1/5/2005 (#11) and 2/23/2005 (#17) and were subsequently last detected moving downstream in the Columbia River. Additional detail on the movement of one of these fish (#17) prior to last contact in 2005 is provided below.

Table 3-1. Adult coastal cutthroat trout radio tagged in the lower Columbia River, 2004-2005. NR - Not Recorded.

Tag Code	Fork Length (mm)	Wt (g)	Tagging Date	Tag Code	Fork Length (mm)	Wt (g)	Tagging Date
1	332	308.9	2/14/2004	24	340	NR	2/7/2004
2	258	NR	2/7/2004	25	345	309.1	2/12/2005
4	265	149.5	2/14/2004	26	325	280.4	2/12/2005
5	310	269.5	2/14/2004	27	355	357.3	2/12/2005
6	291	NR	2/7/2004	28	352	354.1	2/12/2005
7	351	NR	2/8/2004	29	335	295.8	2/12/2005
8	331	NR	2/8/2004	30	330	241.8	2/12/2005
9	330	NR	2/8/2004	31	360	318.6	2/12/2005
10	288	NR	2/8/2004	32	325	258.7	2/12/2005
11	358	NR	2/8/2004	33	415	550.0	2/12/2005
12	254	143.2	2/14/2004	34	375	382.5	2/12/2005
13	283	209.6	2/14/2004	35	306	233.4	2/26/2005
14	276	185.9	2/15/2004	36	340	305.0	2/26/2005
15	300	211.3	2/14/2004	37	272	176.1	2/27/2005
16	318	NR	2/7/2004	38	460	>600	3/9/2005
17	292	NR	2/8/2004	39	446	>600	3/18/2005
18	282	209.9	2/14/2004	40	260	155.7	3/21/2005
19	310	NR	2/7/2004	41	374	430.9	4/1/2005
20	402	NR	2/7/2004	42	308	246.2	4/14/2005
21	331	NR	2/7/2004	43	287	208.5	5/3/2005
22	286	NR	2/7/2004	44	335	338.9	5/3/2005
23	328	NR	2/7/2004	45	323	308.8	5/5/2005

Coastal cutthroat trout detected outside of Mill Creek and not detected again

Four fish (#5, #14, #18, and #20) left Mill Creek, were detected in the Columbia River for various durations and not detected again. These individuals were last detected in Mill Creek 3/3/2004 (#14), 3/26/2004 (#5), 4/7/2004 (#18) and 4/9/2004 (#20). They were last detected in the Columbia River on 3/5/2004 (#14), 4/16/2004 (#5), 4/23/2004 (#18), and 4/26/2004 (#20). The fate of these individuals is uncertain. It is probable that these fish moved downstream of Astoria, OR, based on downstream patterns of movement prior to losing contact and the lack of detection during telemetry flights.

Coastal cutthroat trout detected outside of Mill Creek continually in one location

Eight coastal cutthroat trout (#4, #6, #7, #9, #10, #16, #21, and #22) left Mill Creek and were detected moving in the Columbia River before their movement ceased. Given the length of time (greater than five months in all cases) each fish maintained its position and certain habitat variables (i.e., water temperature in excess of 25^{o}C) associated with some of these areas, it is suspected that these fish were mortalities. It is unknown whether the fish selected these locations prior to death or were preyed upon elsewhere and the tag was dropped in these locations. The last detected movements of these individuals corresponded with three distinct habitat types: sloughs, side channels, or the lower Columbia River estuary (Table 3-2, Figure 3-3). In addition, one of these individuals (#22) was detected in Abernathy Creek for nearly a month (3/8/2004 – 4/7/2004) before its last detected movement.

Table 3-2. Coastal cutthroat trout detected outside of Mill Creek in the lower Columbia River continually in one location, 2004.

Tag Code	Last Detected in Mill Creek	Last Detected Movement	Location	Habitat Type
4	4/5/2004	4/7/2004	Bradbury Slough	Side Channel
6	2/9/2004	3/5/2004	Driscoll Slough	Slough
7	3/10/2004	4/5/2004	Fitzpatrick Island	Estuary
9	4/5/2004	5/24/2004	Mott Island	Estuary
10	3/1/2004	3/19/2004	Elochoman Slough	Slough
16	2/11/2004	3/24/2004	Wallace Slough	Side Channel
21	5/21/2004	5/24/2004	Willow Grove	Side Channel
22	3/3/2004	4/7/2004	Cathlamet Channel	Side Channel

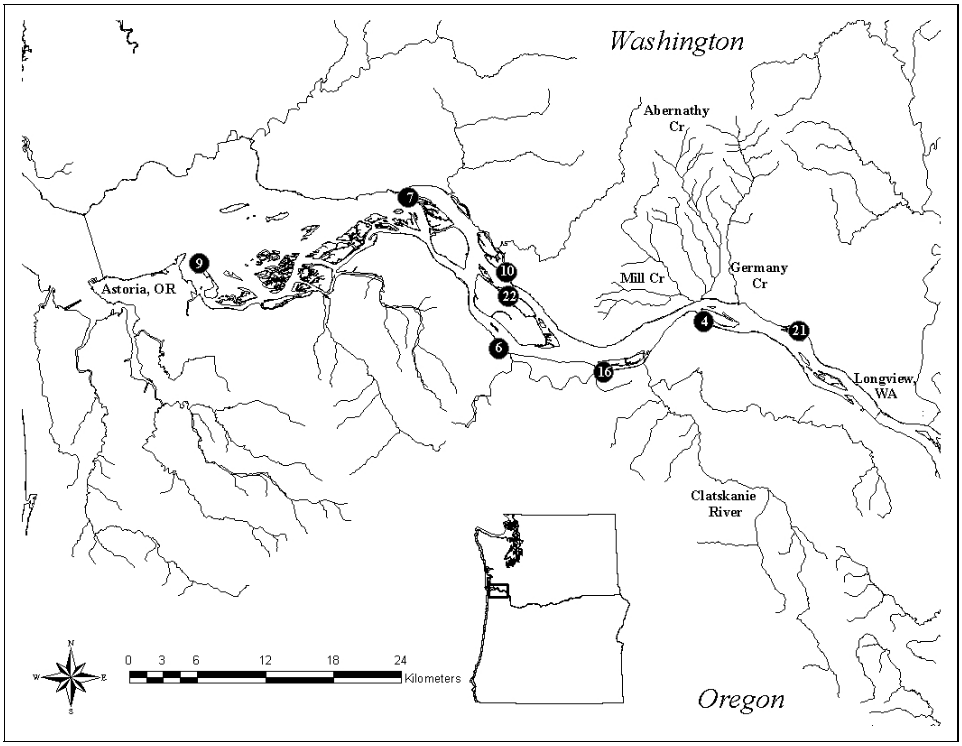

Figure 3-3. Locations in the lower Columbia River of coastal cutthroat trout detected outside of Mill Creek continually in one location, 2004.

Coastal cutthroat trout not detected outside of Mill Creek

Five coastal cutthroat trout were not detected outside the Mill Creek drainage during the first year of the study. Of these five fish, two were not detected ever moving within Mill Creek (#2 and #24). The three remaining individuals were last detected moving between 2/20/2004 and 4/7/2004 (#8, #13, and #15). The transmitters from these five coastal cutthroat trout were recovered in working condition 10/15/2004. One was on the bank and the other four were submerged in the stream channel. No fish carcasses were found with these transmitters.

A final individual in this group was detected moving occasionally throughout 2004, but never left the system (#12). This individual moved out of the Mill Creek drainage nearly a year after being tagged and was found across the main channel from the mouth of Mill Creek on 2/19/2005. It remained in this location until at least the end of February. Subsequent contact was not made with this individual and it is thought the radio tag battery died.

2005 Movement Patterns

A total of 21 adult coastal cutthroat trout were radio tagged from Mill Creek, Abernathy Creek, and Germany Creek, WA, in 2005 (Table 3-1). The average fork length of radio-tagged kelts was 344 mm (range 260 to 460, median 335 mm). Four fish had adipose clips indicating hatchery origins, and the other fish were considered wild.

The 21 fish tagged in these tributaries generally fall in the same four categories characterized in 2004, with consideration that these fish originated from multiple tributaries: 1) Coastal cutthroat trout detected outside of the tributary and returning; 2) Coastal cutthroat trout detected outside of the tributary and not detected again; 3) Coastal cutthroat trout detected outside of the tributary continually in one location; 4) Coastal cutthroat trout not detected outside of the tributary.

The adapted tracking approach for 2005 also provided the opportunity to better describe other behaviors observed in coastal cutthroat trout: 5) Coastal cutthroat trout use of multiple tributaries; 6) Coastal cutthroat trout movement with the tide; 7) Coastal cutthroat trout mortality.

Coastal cutthroat trout detected outside of the tributary and returning

One coastal cutthroat trout (#25) detected outside of the tributary (Mill Creek) returned in 2005. This individual migrated into the Columbia River for one day approximately a week after it was tagged. It returned to Mill Creek for five days before migrating upstream in the lower Columbia River approximately 10 km. This fish was continually detected at this location downstream of Longview, WA, through the duration of the study and is suspected to be a mortality.

Coastal cutthroat trout detected outside of the tributary and not detected again

Six coastal cutthroat trout (#28, #30, #34, #39, #41, and #45) left the tributary, were detected in the Columbia River for various durations and not detected again. These fish were last detected in the tributary 2/16/2005 (#34), 2/24/2005 (#30), 3/26/2005 (#39), 3/31/2005 (#28), 4/2/2005 (#41), and 5/5/2005 (#45). They were last detected in the Columbia River on 3/2/2005 (#30), 4/3/2005 (#34 and #41), 4/5/2005 (#28), 4/8/2005 (#39), and 5/21/2005 (#45). The fate of these individuals is uncertain. It is probable that these fish moved downstream of Astoria, OR, based on downstream patterns of movement prior to losing contact and lack of detection during telemetry flights.

Coastal cutthroat trout detected outside of the tributary continually in one location

Seven coastal cutthroat trout (#26, #27, #29, #31, #33, #36, and #44) left the tributary and were detected moving in the Columbia River before their movement ceased. It was possible to confirm that five of these individuals were mortalities by retrieving or locating the radio tag. The other two fish are highly suspected to be mortalities. In addition, one individual tagged in 2004 (#17), left Mill Creek and moved downstream in the Columbia to an area containing shoreline pilings just downstream of Skamokawa, WA. This fish remained at this location until its tag died at the beginning of May 2005. Movement among the pilings in the location was confirmed prior to losing contact, therefore mortality is not suspected.

Coastal cutthroat trout not detected outside of the tributary

Seven coastal cutthroat trout (#32, #35, #37, #38, #40, #42, and #43) were not detected outside of the tributary in 2005. Four of these fish (#32, #38, #40, and #42) were confirmed mortalities when their tags were retrieved 1 to 58 days after tagging. One of these individuals (#43) was not detected again after 6/30/2005 and its fate is unknown. The final two individuals (#35 and #37) are still alive in Mill Creek, but have never left the drainage.

Coastal cutthroat trout use of multiple tributaries

Similar to the three coastal cutthroat trout (#1, #19, and #22) in 2004 that were detected using Abernathy Creek, two individuals (#26 and #34) used multiple tributaries in 2005. One individual left Mill Creek on 2/17/2005 and was detected in the Clatskanie River in downtown Clatskanie, OR, (approximately 5 km upstream of the river mouth) on 2/20/2005. This fish continued to migrate upstream approximately another kilometer and resided in this general location until 3/26/2005, when it migrated back down to the Columbia River. The second individual left Mill Creek on 2/23/2005 and was detected in Green Creek, OR, on 2/26/2005 approximately 100 m upstream of the mouth. This fish resided in this general location until 3/20/2005, when it migrated back down to the Columbia River.

Coastal cutthroat trout movement with the tide

Daily tracking in 2005 allowed the documentation of several individuals moving with the tide. While this project was not designed to quantify this behavior, this movement appeared to be influenced by the tide both when fish were leaving the tributary and when fish were migrating in the mainstem. All departures from the tributary that could be identified to a specific window of time related to the tidal cycle qualitatively appear to show a correlation between the direction of the tide (e.g., ebb or flow) and the initial direction of migratory movement in the mainstem. This movement in the mainstem appeared to continue such that movement would occur when the tide was moving in the direction the fish was moving. Movement would cease or backtrack during the alternate tide of the cycle. The individuals that moved upstream in the mainstem, and were not confirmed or suspected mortalities, eventually turned downstream and showed the same type of movement behavior as they migrated toward the estuary.

Duration of Use in Lower Columbia River Mainstem and Estuary

Of 44 coastal cutthroat trout radio tagged over two years, thirty of them left the tributary and used the lower Columbia River mainstem and estuary to some extent (Table 3-3). These fish were found to use the mainstem and estuary after spawning from February through May. Only three of these fish were detected returning from the migration to the lower estuary and/or marine environment. These fish were detected in July, August and December. The total number of days all fish were observed using the mainstem and estuary ranged from 1 to 60, which equates to 0.3% to 16.4% of the year. More than half of the thirty coastal cutthroat trout (n=16) were suspected or confirmed mortalities. There were no statistically significant differences between the mortality group and the survivor group with respect to timing of entry into the mainstem or total number of days observed in the mainstem and estuary.

Table 3-3. Summary of radio tagged coastal cutthroat trout that used the lower Columbia River mainstem and estuary, the months that use spanned, total number of days observed in the mainstem and estuary, and the percent of the year encompassed.

Tag Code	Months Spanned	Total Number of Days Observed	Percent (%) of Year
4*	Mar-Apr	19	5.2
5	Apr	2	0.5
6*	Feb-Mar	16	4.4
7*	Mar-Apr	22	6.0
9*	Apr-May	49	13.4
10*	Mar	17	4.7
11	Feb, Apr, **Jul**	32	8.8
14	Mar	1	0.3
16*	Feb-Mar	40	11.0
17	Feb-May, **Dec**	52	14.2
18	Apr	15	4.1
19	Feb-Apr	27	7.4
20	Apr	15	4.1
21*	May	2	0.5
22*	Mar-Apr	36	9.9
23	Mar-Apr, **Aug**	21	5.8
25*	Feb-Mar	6	1.6
26*	Feb-Apr	18	4.9
27*	Mar	5	1.4
28	Mar-Apr	6	1.6
29*	Feb-Apr	60	16.4
30	Feb-Mar	7	1.9
31*	Mar	2	0.5
33*	Feb-Mar	12	3.3
34	Feb-Apr	11	3.0
36*	Mar-May	39	10.7
39	Mar-Apr	13	3.6
41	Apr	2	0.5
44*	May	3	0.8
45	May	16	4.4

* - suspected or confirmed mortality

Bold – indicates months that adults returned to tributary after migration to lower estuary and/or marine environment

Proximity to the Shipping Channel

Of 44 coastal cutthroat trout radio tagged over two years, thirty of them left the tributary and were observed at different locations in the lower Columbia River mainstem and estuary. Some of these moves from one location to the next required movement across the shipping channel (Table 3-4). Thirteen of the thirty fish made 1 to 5 moves across the shipping channel during the period of tracking. These movements comprised 36.9% of the observed moves exhibited by these individuals.

Table 3-4. Summary of radio tagged coastal cutthroat trout that used the lower Columbia River mainstem and estuary, the total number of moves observed, the total number of moves that required movement across the shipping channel, and the percentage of movement those moves comprised.

Tag Code	Total Number of Moves Observed	Total Number of Moves Across Shipping Channel	Percent (%) of Moves Across Shipping Channel
4*	1	1	100.0
5	2	0	0.0
6*	2	1	50.0
7*	5	3	60.0
9*	3	1	33.3
10*	3	0	0.0
11	7	0	0.0
14	2	0	0.0
16*	3	1	33.3
17	14	1	7.1
18	4	2	50.0
19	5	0	0.0
20	3	0	0.0
21*	1	0	0.0
22*	5	0	0.0
23	3	0	0.0
25*	5	0	0.0
26*	7	2	28.6
27*	3	0	0.0
28	2	0	0.0
29*	4	0	0.0
30	3	2	66.7
31*	1	1	100.0
33*	4	2	50.0
34	8	2	25.0
36*	10	5	50.0
39	5	0	0.0
41	2	0	0.0
44*	2	0	0.0
45	3	0	0.0

* - suspected or confirmed mortality

Mortality

2004

Five coastal cutthroat trout (#2, #8, #13, #15 and #24) never left Mill Creek and their tags were recovered confirming mortality. Eight coastal cutthroat trout (#4, #6, #7, #9, #10, #16, #21, and #22) left Mill Creek and were detected moving in the Columbia River 2-39 days prior to their final detected location. These tags were not recovered, but mortality of these individuals is highly suspected. Five fish left Mill Creek, were detected in the Columbia River for two to 10 days and not detected again. The final disposition of these fish is unknown.

2005

Four coastal cutthroat trout (#32, #38, #40, and #42) never left the tributary in which they were tagged. With the exception of one (#40), their tags were recovered confirming mortality. In the case of #40, mortality was confirmed through observation of predation of this individual by a merganser. Eight coastal cutthroat trout (#25, #26, #27, #29, #31, #33, #36, and #44) left the tributary in which they were tagged and were detected moving in the Columbia River 2-39 days prior to their final detected location. Two of these tags were recovered, confirming mortality. Mortality of the remaining individuals is suspected. In the case of #26, mortality was documented by contacts only ten minutes apart between the CNL and Puget Island stationary receivers and only 20 minutes apart at the Puget Island and Pillar Rock stationary receivers. The tag was later detected during an aerial telemetry flight on Sand Island near the mouth of the Columbia River, an island that contains large nesting populations of terns and cormorants. Seven fish left the tributary in which they were tagged, were detected in the Columbia River for zero to 15 days and not detected again. The final disposition of these fish is unknown with the exception of one individual whose tag was recovered in June 2006. This tag was recovered near Seal Rock State Recreation Site south of Newport, OR, on the Oregon coast. This location is approximately 225 miles south of the mouth of the Columbia River.

Cumulative Mortality Rate

In each year of the study, thirteen radio tagged coastal cutthroat trout were suspected or confirmed mortalities. These 26 mortalities in a total of 44 fish radio tagged result in a probable cumulative mortality rate of 59.1% for the duration of the study.

Discussion

Coastal cutthroat trout use a variety of habitats in the lower Columbia River mainstem and estuary. In general, these habitats could be characterized as the main river channel of the Columbia River, side channels, tidally influenced backwater sloughs, and multiple tributaries. While information is lacking on movement patterns of migratory coastal cutthroat trout, some of these same patterns have been seen in other parts of the species range and on different scales (L. Krentz ODFW *unpublished data*; Jones and Seifert 1997).

Upon leaving lower Columbia River tributaries, coastal cutthroat trout exhibited a variety of behaviors with respect to direction headed. Upstream and downstream movement appeared to be motivated by the prevalent tide upon entry into the mainstem. Most fish that initially moved upstream eventually turned around and headed downstream if they were not subject to predation. Movement also occurred regularly from one side of the river to the other, whether headed upstream or downstream, with some fish moving into multiple tributaries on both sides of the river. In some places in the lower Columbia River, this equates to 3-5 km from the Oregon shoreline to the Washington shoreline. In contrast, Jones and Seifert (1997) did not detect coastal cutthroat trout crossing large open waterways such as the Chatham and Peril straits near Sitka, Alaska.

Overall movement in the lower Columbia River mainstem and estuary resulted in cumulative movements over 90 km if fish moved from the tributaries to the mouth of the lower Columbia River. However, movement was generally not sustained. Factors affecting sustained movement apparently included tidal cycle, structures that provided temporary cover (i.e., pilings), and use of additional tributaries.

Avian and marine mammal predation may present a threat to coastal cutthroat trout in the lower Columbia River. One radio tag was detected on Sand Island, which is the home of nesting colonies of Caspian terns (*Sterna caspia*) and double crested cormorants (*Phalacrocorax auritus*). These colonies are known to significantly impact salmonid numbers in the Columbia River (Collis et al. 2001). Predation by a common merganser (*Mergus merganser*) was also documented. Marine mammal (i.e., sea lion) predation was considered in the cases of a few retrieved tags, but is suspected for the tag that was retrieved near Seal Rock on the Oregon coast. It is not clear whether this rate of predation (>50% in 2005) is natural or biased because these fish were radio tagged. There are not reliable estimates of avian predation on other adult salmonids utilizing the lower Columbia River mainstem and estuary, but it is estimated that the tern population consumes approximately 11.2% of out-migrating salmonid smolts that survive to the estuary (Collis et al. 2001). Given that adult coastal cutthroat trout are smaller than other adult anadromous salmonids, it is not hard to imagine that all life stages of this species could be impacted by avian and marine mammal predation.

Coastal cutthroat trout adults can be found in the lower Columbia River mainstem and estuary in most months of the year. This coupled with the fact that juvenile coastal cutthroat trout emigrate downstream predominantly in April through June and use a large portion of the lower river and estuary (Johnson et al. 2008; Zydlewski et al. 2008) demonstrates that multiple life stages and age classes of coastal cutthroat trout may be found in the lower Columbia River mainstem and estuary throughout the year. Consideration of these timeframes when planning channel deepening and maintenance activities can minimize impacts to coastal cutthroat trout.

Given the apparent close relationship this species has with this habitat, it may prove to be a good indicator species for salmonid response to habitat restoration in this part of the Columbia River basin. Other species of Pacific salmonids (i.e., Chinook salmon, coho salmon, steelhead) tend to use the lower Columbia River mainstem and estuary as a migratory corridor going to and from the ocean, where these species spend more time than coastal cutthroat trout. These species not only have a shorter estuarine residence time relative to historic occupation timeframe (Bottom et al. 2001), but are not as pervasive as coastal cutthroat trout throughout the year. Furthermore, an individual coastal cutthroat trout is more likely to be subjected to anthropogenic impacts and benefits of restoration given that the species is iteroparous and may spend several years traveling through or residing in the lower Columbia River mainstem and estuary. There have been declines in the anadromous component of lower Columbia River coastal cutthroat trout populations in recent years (67 FR 44934), and future activities, whether anthropogenic impacts or restoration benefits, can consider how this sensitive species may potentially be impacted by using this data.

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RECOMMENDATIONS

- When planning management activities in the lower Columbia River mainstem and estuary, consider that from April through June migrating juvenile coastal cutthroat trout are present.

- When planning management activities in the lower Columbia River mainstem and estuary, consider that from September through January migrating pre-spawn adult coastal cutthroat trout are present.

- When planning management activities in the lower Columbia River mainstem and estuary, consider that from December through April migrating post-spawn adult coastal cutthroat trout (kelts) are present.

- Given that multiple life history stages of coastal cutthroat trout are present in the lower Columbia River mainstem and estuary for the majority of the year, directly assess impacts to specific life history stages of the fish from management activities.

- Evaluate coastal cutthroat trout population response to habitat restoration projects in the lower Columbia River mainstem and estuary.

- Investigate impacts to coastal cutthroat trout relative to historic changes in the Columbia River hydrograph and how the current hydrograph affects behavior and productivity.

- Investigate the anadromous component contribution to viability of lower Columbia River coastal cutthroat trout metapopulation.

- Assess current distribution and abundance of coastal cutthroat trout in the lower Columbia River basin to establish a baseline and better monitor population trends to evaluate response to anthropogenic impacts or restoration benefits.

The goal of this study was to monitor and evaluate the basic life history and habitat use of various life history stages of coastal cutthroat trout in the Columbia River basin. In particular, this project focused on identifying both spatial and temporal mainstem and estuarine use by all life history stages of coastal cutthroat trout. To gauge any potential impacts to coastal cutthroat trout from anthropogenic activities, such as channel deepening, this study was designed to provide information on the habitat use of coastal cutthroat trout in the mainstem and estuary of the Lower Columbia River. In addition, the information gained from this project would set the foundation for long term population monitoring and evaluation of coastal cutthroat trout in the Lower Columbia River tributaries.

Coastal cutthroat trout exhibited extensive spatial and temporal use of the mainstem of the Lower Columbia River. Juvenile coastal cutthroat trout have been documented leaving lower Columbia River tributaries. While downstream migration of individuals may be relatively quick and direct, the presence of this life history stage in the lower Columbia River mainstem and estuary is constant through this timeframe. Returning coastal cutthroat trout have been documented in the lower Columbia River mainstem and estuary returning to lower Columbia River tributaries. The presence of this life history stage in the lower Columbia River mainstem and estuary also appears to be quite widespread. However, while it is known that returning coastal cutthroat trout can be found on both sides of the river and crossing the main channel, density and detailed habitat use has not been documented. Post-spawn adult coastal cutthroat trout (kelts) have been documented in the lower Columbia River mainstem and estuary and leaving lower Columbia River tributaries. The presence of this life history stage in the lower Columbia River mainstem and estuary also appears to be quite widespread. However, while it is known that this lifestage can be found on both sides of the river and crossing the main channel, density and detailed habitat use has not been documented. Although the specific impacts to coastal cutthroat trout are unknown, when planning management activities in the lower Columbia River mainstem and estuary it would be prudent to consider that from April through June migrating juvenile coastal cutthroat trout are present, from September through January migrating pre-spawn adult coastal cutthroat trout are present, and from December through April migrating kelts are present. Thus, management activities (i.e., such as those identified in the Columbia River Federal Navigation Channel Improvements Project (CRCIP) Biological Opinion, the Federal Columbia River Power System (FCRPS) Biological Opinion, or the Northwest Power and Conservation Council (NPCC) subbasin plans) that are implemented in this portion of the river during these timeframes may impact coastal cutthroat trout.

The exact nature of CRCIP impacts to coastal cutthroat trout is unclear. The literature contains relatively few studies of the effects on fish of activities such as dredging. However, it has been suggested that the knowledge of dredging practices, and the biology and physics of streams indicate there are likely a variety of mechanisms linking dredging to aquatic resources (Harvey and Lisle 1998). As such, fishery managers have been concerned about the effects of activities such as dredging on aquatic resources for many years (Allen and Hardy 1980; Gardiner 1988). It has been considered likely that the alteration of a river through new channel construction or deepening projects has the potential for severe direct and indirect impacts on the entire river and floodplain ecosystem (Allen and Hardy 1980). The majority of work that has been done to understand the impacts of dredging on pelagic fishes has focused on salmonids. For examples: 1) Tutty (1976) reported that maintenance dredging in the Lower Fraser River resulted in numerous juvenile salmon mortalities; 2) Levings (1985) reported changes to littoral areas resulting from dredging and suggested this may create habitat unusable by some juvenile salmonids; 3) Berg and Northcote (1985) reported juvenile coho salmon exhibiting changes in territorial, gill-flaring, and feeding behavior in response to dredging activities; and 4) Newcombe and Jensen (1996) reported that suspended sediment from dredging resulted in behavioral effects as well as sublethal responses, such as reduced feeding and altered swimming behavior in salmonids. While these examples exist, the specific impacts to fish from dredging activities are likely related to the particular river system and fish communities in question. Despite this, it has been suggested that particularly where threatened or endangered aquatic species inhabit dredged areas, fisheries managers would be prudent to suspect that dredging is harmful to aquatic resources (Harvey and Lisle 1998). As such, previous examples exist where managers have recommended that activities such as dredging be avoided when fish are present (such as juvenile salmon during their smolt migration in the spring) (Ward et al. 1994, USACE 2001).

Given that coastal cutthroat trout are present in the lower Columbia River mainstem and estuary for the majority of the year, directly assess impacts to the fish from various management activities. Multiple year classes and lifestages of coastal cutthroat trout use the lower Columbia River mainstem and estuary throughout the year. However, detailed spatial distribution and how that distribution may be affected by management actions is lacking. An interaction between coastal cutthroat trout and management activities may result in an impact to the species. The nature of this interaction has not been documented.

Evaluate coastal cutthroat trout population response to habitat restoration projects in the lower Columbia River mainstem and estuary. While most habitat restoration projects in the Columbia River basin are targeted at benefiting listed salmonids, it may be difficult to assess a population level response in these species (i.e., Pacific salmon and steelhead) that spend a relatively small portion of its life history in the lower Columbia River mainstem and estuary. This is particularly true for upper Columbia River basin stocks of salmon and steelhead. If a long-term monitoring program were established to track population status for coastal cutthroat trout, the pervasive nature of coastal cutthroat trout in these habitats would make it a reliable indicator species to assess biological response of listed Columbia River basin salmonids to habitat restoration projects.

Investigate impacts to coastal cutthroat trout relative to historic changes in the Columbia River hydrograph and how the current hydrograph affects behavior and productivity. Regulated flow has resulted in fundamental changes in historic seasonal flows. This shift in hydrological character influences mainstem flows, plume structure, salinity profiles, tidal range, and productivity. How these parameters currently affect coastal cutthroat trout behavior and productivity in the lower Columbia River mainstem and estuary will provide insight into how behavior has changed with the hydrograph over time and how to better manage for conservation of this species.

Investigate the anadromous component contribution to viability of lower Columbia River coastal cutthroat trout metapopulation. Coastal cutthroat trout populations of the lower Columbia River basin are comprised of sympatric anadromous and resident components. It has been shown in other species with similar population structure (i.e., *Oncorhynchus mykiss*) that the anadromous component is crucial to the viability of metapopulation structure. The anadromous component provides the ability for locally extirpated populations to be reestablished and, therefore, stabilizes metapopulation structure and contributes to long-term persistence of the species. An understanding of the relationship between the anadromous and resident components of coastal cutthroat trout in the lower Columbia River basin will allow better management for conservation of this species throughout its range.

Assess current distribution and abundance of coastal cutthroat trout in the lower Columbia River basin to establish a baseline and better monitor population trends that may be in response to anthropogenic impacts or restoration benefits. Little information exists on the distribution and abundance of coastal cutthroat trout in the lower Columbia River basin. This data is important to determine if recovery actions for listed species and additional restoration activities targeted at benefiting coastal cutthroat trout are having a positive affect at the population level.

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