State of California
The Resources Agency
DEPARTMENT OF FISH AND WILDLIFE

JUVENILE SALMONID USE AND RESTORATION ASSESSMENT OF THE TIDAL PORTIONS OF SELECTED TRIBUTARIES TO HUMBOLDT BAY, CALIFORNIA, 2011-2012

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Fisheries Administrative Report No. 2015-02
April 2015

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Administrative Fisheries Report 2015-02

[1] This report was prepared as part of the Federal Aid in Sport Fish Restoration Act Program (California Project F-137-R) and Fisheries Restoration Grant Program Project P1010516.
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NOTE TO THE READER

This report presents the results of continuing California Department of Fish and Wildlife sampling in the stream-estuary ecotone in Humboldt County's Freshwater Creek and its tributaries (i.e., Wood Creek and Ryan Creek), Salmon Creek, and a future off channel pond on Jacoby Creek in 2011 and 2012. The report also documents the life history traits and use of ecotone habitat by juvenile salmonids and assesses the performance of estuarine habitat restoration projects. This project has been monitoring juvenile salmonid life history patterns and estuarine habitat restoration projects in Humboldt Bay for approximately ten years and has documented extensive use of the ecotone by juvenile coho salmon (*Oncorhynchus kisutch*). By describing life history traits and habitat needs of juvenile coho salmon, Chinook salmon (*O. tshawytscha*), steelhead trout (*O. mykiss*), and sea-run cutthroat trout (*O.clarkii clarkia)* and by assessing the performance of newly constructed off channel ponds, this project provides important data to natural resource agencies and the restoration community to aid current and future restoration projects to succeed.

Stafford Lehr, Chief
Fisheries Branch
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August 24, 2015

ABSTRACT

California Department of Fish and Wildlife and Pacific States Marine Fisheries Commission staff sampled the stream-estuary ecotone of selected Humboldt Bay tributaries to document their use by juvenile salmonids and to assess estuarine habitat restoration projects. We sampled fish using seine nets and minnow traps baited with frozen salmon roe. Juvenile coho salmon (*Oncorhynchus kisutch*) was the most numerous salmonid captured but we also commonly captured Chinook salmon (*O. tshawytscha*), steelhead trout (*O. mykiss*), and cutthroat trout (*O.clarkii clarkii*). Sub yearling coho salmon were present from April to December with peak catches occurring in the summer. Their mean ecotone residence time was one to two months but individual fish reared there up to eight months. Age 1+ coho salmon were present during the winter and spring. One group of Age 1+ coho arrived in the ecotone in the fall and reared there throughout the winter and into the spring. A later group of Age 1+ coho emigrated through the ecotone relatively quickly primarily during May. Juvenile Chinook salmon were present only in Freshwater Creek Slough in the late spring and early summer. Juvenile steelhead trout and cutthroat trout were captured throughout the year and some reared for months in the ecotone. Mean growth rates of juvenile salmonids in the ecotone were typically 0.15 to 0.25 mm/day which was higher than growth rates observed by other projects in stream habitats upstream of the ecotone. Juvenile salmonids sought out freshwater rather than brackish water habitat while rearing in the ecotone. Juvenile salmonids, especially coho salmon, utilized newly constructed ponds as soon as they were completed and fall/winter stream flow converted the ponds to fresh water habitat. The stream-estuary ecotone provides productive rearing habitat for juvenile salmonids, especially over winter habitat for juvenile coho salmon.

Introduction

Estuaries are important habitat for juvenile salmonids and other fish species. Numerous studies have documented extended estuarine residence by juvenile Chinook salmon *Oncorhynchus tshawytscha*, (Reimers 1971; Healey 1982; Kjelson et al.1982; Healey 1991), coho salmon *O. kisutch* (Tschaplinski 1982; Miller and Sadro 2003; Koski 2009), steelhead trout *O. mykiss*, (Bond et al. 2008), and sea-run coastal cutthroat trout *O.clarkii clarkii*, (Trotter 1997; Northcote 1997). Faster growth in the estuary and larger size at ocean entrance for estuarine rearing salmonids has been shown to account for higher marine survival (Nicholas and Hankin 1989; Northcote 1997; Pearcy 1997; Trotter 1997).

Studies on coho salmon have shown that larger individuals, like those rearing in tidal habitat, experience greater over-winter survival in stream and estuary habitats (Ebersole et al. 2006; Roni et al. 2012). Studies have identified the importance of the greater transition zone, or ecotone (Odum 1971), between fresh and brackish water to juvenile coho salmon (Tschaplinski 1982; Miller and Sadro 2003; Koski 2009). Miller and Sadro (2003) defined this stream-estuary ecotone (SEE), and we adapted their definition. In our study, SEE was defined as the wetland area of low gradient stream extending from where the stream entered the tidal plain, the upper limit of tidal influence on stream habitat, and the channel bordered by tidal mudflats. This definition of the SEE includes all side channels, off channel ponds, tidal channels, and fringing marsh habitats that are accessible to fish for at least some portion of the tidal cycle.

In California, juvenile salmonid estuary studies have been conducted mostly in the Sacramento-San Joaquin Delta (Kjelson et al.1982; Sommer et al. 2001; Nobriga et al. 2005) or in coastal lagoons along the central coast (Bond et al. 2008; Hayes et al. 2008; Atkinson 2010). Some north-coast estuaries have also been studied such as the Klamath River (Wallace and Collins 1997), Mattole River (Zedonis 1992; Busby and Barnhart 1995) and Humboldt Bay tributaries (Wallace 2006; Wallace 2010; Wallace and Allen 2007, 2009, 2012). However, few studies have identified the importance of the SEE.

Recent studies conducted by California Department of Fish and Wildlife's (CDFW) Natural Stocks Assessment Project (NSA) in the tidal portions of Humboldt Bay tributaries have shown that juvenile salmonids heavily utilize SEE habitat and routinely rear there for months (Wallace and Allen 2007, 2009, 2012; CDFG 2009, 2010). CDFW estimated that about 40% of coho salmon smolts and 80 to 90% of large steelhead trout smolts originated from the SEE of Freshwater Creek in 2007 and 2008 (Ricker and Anderson 2011). CDFW studies also have shown that juvenile salmonids using this habitat grew faster and obtained a larger size than juvenile salmonids rearing in stream habitat (Wallace and Allen 2007, 2009, 2012; Ricker and Anderson 2011; CDFG 2006, 2007, 2008; Wallace 2006).

Multiple salmonid recovery plans encourage estuary and marsh habitat restoration projects around Humboldt Bay (NMFS 2014; HBWAC 2005; CDFG 2004). The majority of tidal wetlands around Humboldt Bay have been diked and converted to pasture land during the past 150 years (HBWAC 2005). Most of the Humboldt Bay sloughs are now contained between levees. Their adjacent marshes have been converted to pasture land and consequently the historic connectivity between slough channels and marsh habitat has been lost.

Currently, former marshlands around Humboldt Bay are being acquired by various public agencies for the purpose of habitat restoration. Willing private landowners are partnering with local land trusts and other non-profit groups to restore wetlands. The result is numerous SEE restoration projects are being planned and implemented in Humboldt Bay's tributaries and sloughs including constructing off channel ponds. CDFW monitored the effects of marsh restoration projects in Wood Creek and Salmon Creek on juvenile anadromous salmonid use and basic water quality conditions, specifically in the newly created off channel ponds.

The focus of this report is stream-estuary ecotone sampling conducted during 2011 and 2012 in Freshwater Creek and its tributaries, including Wood Creek and Ryan Creek, Salmon Creek, and a future off channel pond on Jacoby Creek. We also document the life history traits and use of ecotone habitat by juvenile salmonids in addition to assessing the performance of estuarine habitat restoration projects.

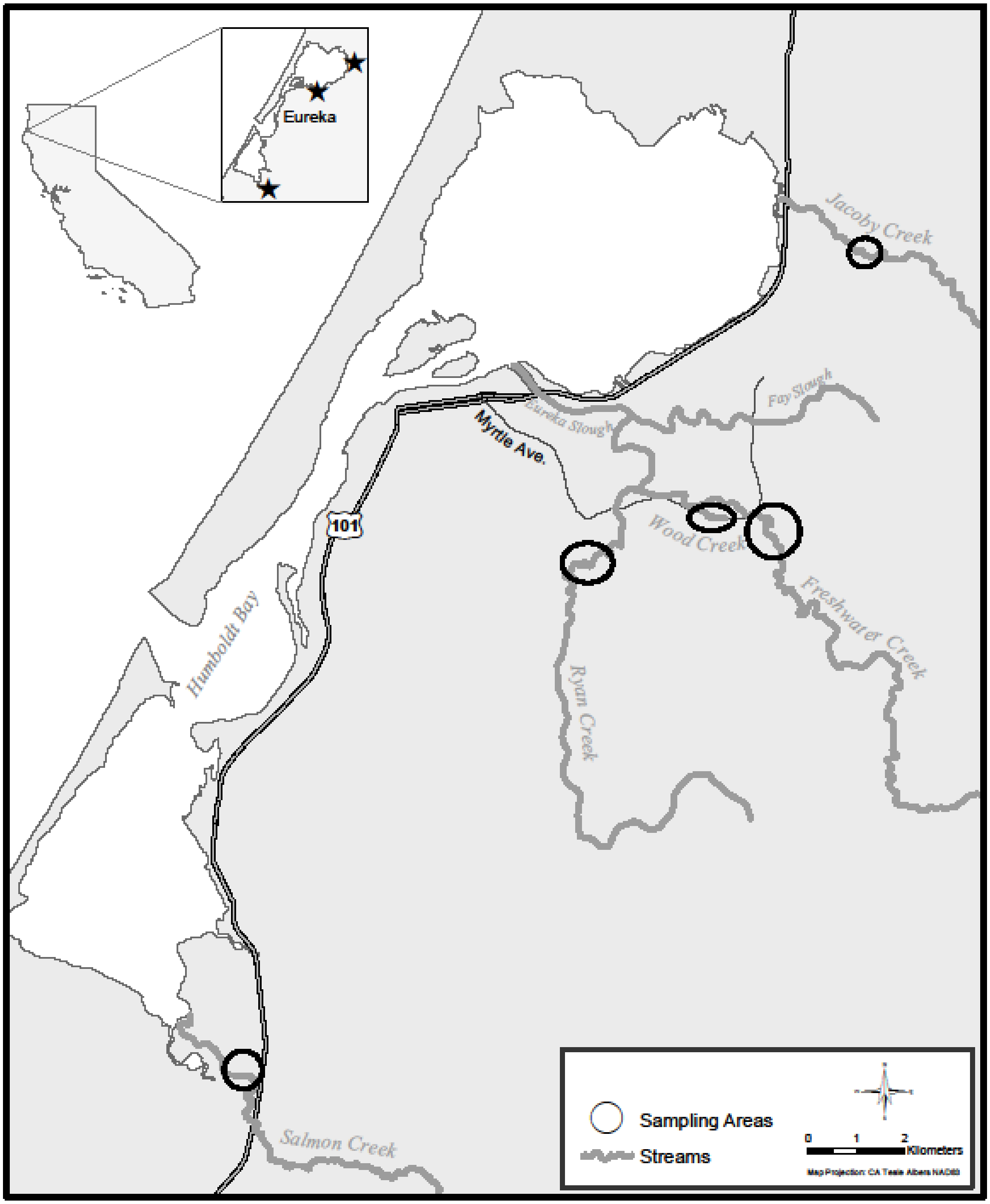

Figure 1. Sampling locations in the stream-estuary ecotone of Freshwater, Wood, Ryan, Salmon, and Jacoby creeks surveyed by California Department of Fish and Wildlife in 2011 and 2012, Humboldt Bay, California.

STUDY AREA

Humboldt Bay is located 442 kilometers north of San Francisco, CA. and its watershed area is 57,756 hectares (HBWAC 2005). Its three largest tributaries are Freshwater Creek, Elk River, and Salmon Creek (Figure 2). Numerous smaller tributaries, sloughs, and tidal streams also drain into Humboldt Bay (Figure 2).

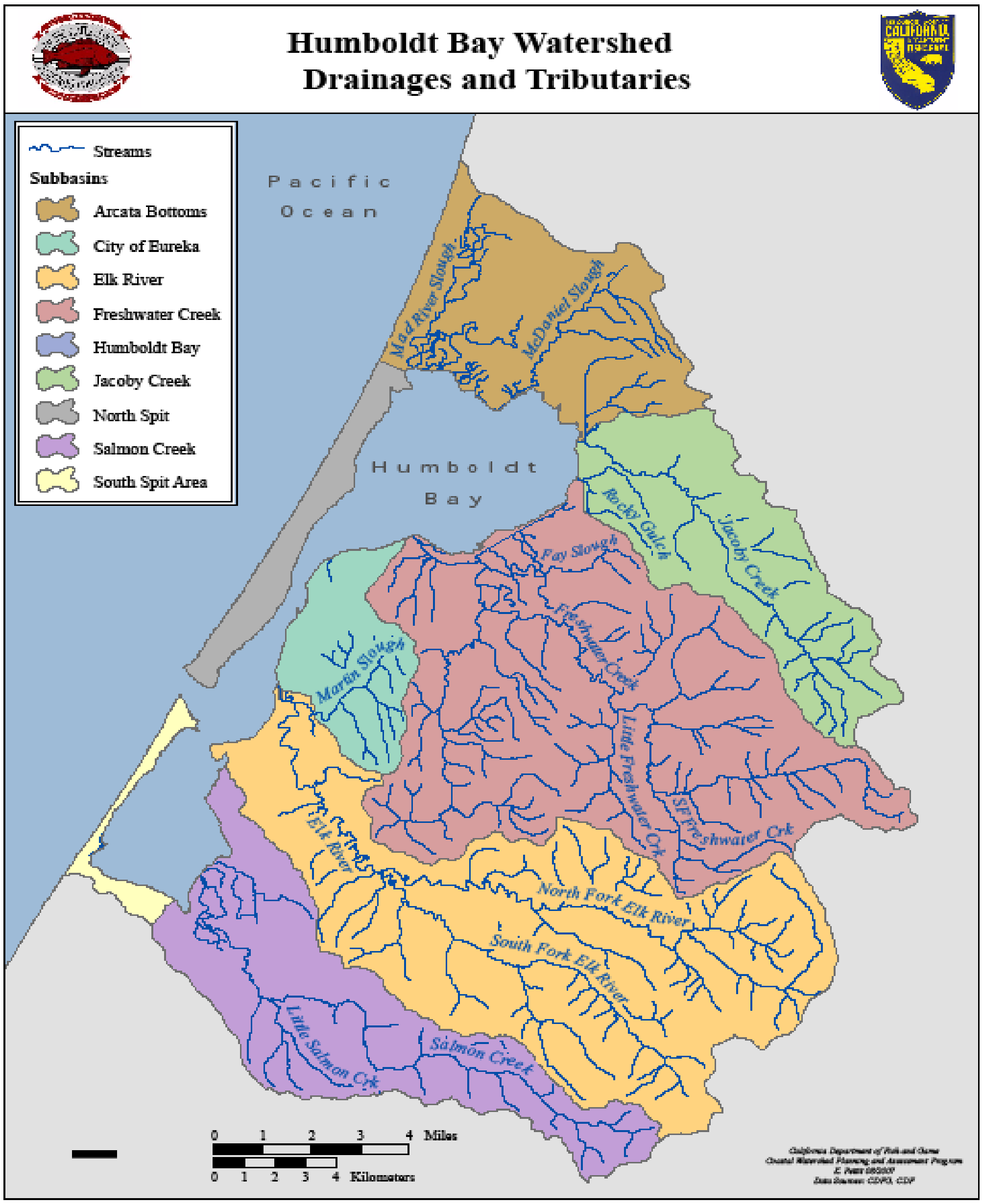

Figure 2. Map of Humboldt Bay, CA showing the names and locations of its largest tributaries.

Freshwater Creek Slough enters Humboldt Bay just north of Eureka via Eureka Slough. Freshwater Creek is a fourth order stream with a drainage area of approximately 9227 hectares. NSA observed tidal influence approximately nine kilometers upstream of the mouth of Eureka Slough at our sampling sites (Figure 3). The sampling area Freshwater Creek Slough is characterized primarily by tidal freshwater habitat with dense stands of riparian vegetation, primarily in the form of willow (*Salix* spp.) and alder (*Alnus* spp.) trees. Brackish water up to 20 parts per thousand (ppt) occurs during the summer and fall in the lower portion of this area but further penetration of brackish water is usually blocked by the concrete base of the Humboldt Fish Action Council (HFAC) weir at river kilometer (rKm) 8.7 (Figure 3).

Wood Creek is a small tributary that enters Freshwater Creek Slough at approximately rKm seven and drains about 150 hectares (Figure 3). Brackish water up to 25 ppt occurs during the summer and fall in much of the sampling area but it is primarily freshwater during winter and early spring. The Northcoast Regional Land Trust planned and implemented an estuarine enhancement project on the lower 14 hectares of Wood Creek near its confluence with Freshwater Creek Slough. The project included the construction an off channel pond to increase rearing habitat for juvenile salmonids. Cattle continue to grave on part of the property, and the stream channel is low gradient, tidally influenced, and has limited riparian development.

Ryan Creek is the largest tributary of Freshwater Creek, and its slough enters Freshwater Creek Slough at about rKm six and drains about 3,315 hectares (Figure 3). The lower one kilometer of Ryan Creek is confined by levees and there is limited riparian development. The sampling area is owned by Green Diamond Resources Company (GDRC) and about 1/3 of the sampling sites experience brackish water up to 20 ppt during the summer and fall. The remaining sampling sites occur upstream in tidal freshwater habitat with dense stands of riparian vegetation, primarily in the form of alder and young coniferous trees. We also sampled a large wetland adjacent to Ryan Creek that is periodically flooded during the winter (Figure 3).

Salmon Creek enters the bay at the extreme southern end of Humboldt Bay via Hookton Slough (Figure 4), and drains approximately 5060 hectares (HBWAC 2005). The tidal portion of Salmon Creek is contained within the Humboldt Bay National Wildlife Refuge (Refuge). Cattail Creek and an old tidal meander at the mouth of Cattail Creek named Long Pond are adjacent to Salmon Creek and are part of the Refuge complex (Figure 4). New tide gates are located at the mouths of Salmon Creek and Cattail Creek where they enter Hookton Slough. The tidal gates allow for effective fish movement and mute tidal influence in both creeks. Brackish water up to 30 ppt occurs from late spring to late fall in much of the sampling area, but the upstream portion is mostly fresh water during the winter and early spring. The Refuge implemented a large habitat restoration project in 2011 that included relocating and enlarging both creeks’ stream channels and constructing five off channel ponds on Salmon Creek to provide over winter habitat for juvenile salmonids.

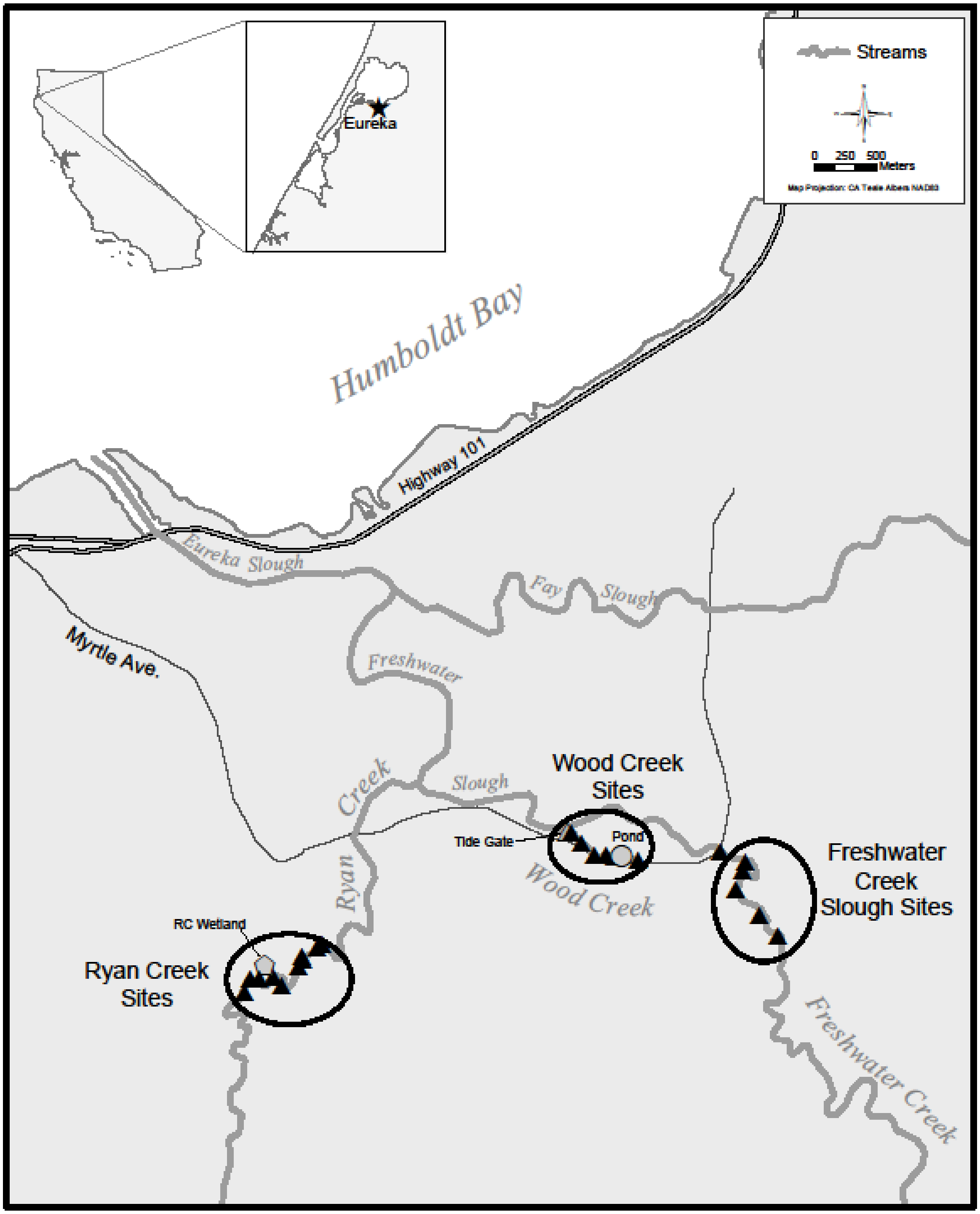

Figure 3. Sampling sites in the stream-estuary ecotone of Freshwater, Wood, and Ryan creeks surveyed by the California Department of Fish and Wildlife in 2011 and 2012.

Jacoby Creek enters the northern end of Humboldt Bay. The seasonal off channel pond on Jacoby Creek occurs upstream of tidal influence and remains freshwater until it dries up in the late summer or fall (Figure 1). Presently, the pond is disconnected from Jacoby Creek except during the highest winter flows. The pond will be modified in the summer of 2015 allowing for connectivity to the stream during the winter and spring flows (Love 2014). The stream channel is bordered by dense stands of riparian vegetation, primarily in the form of willow and alder trees. The pond has little riparian vegetation due to past cattle grazing.

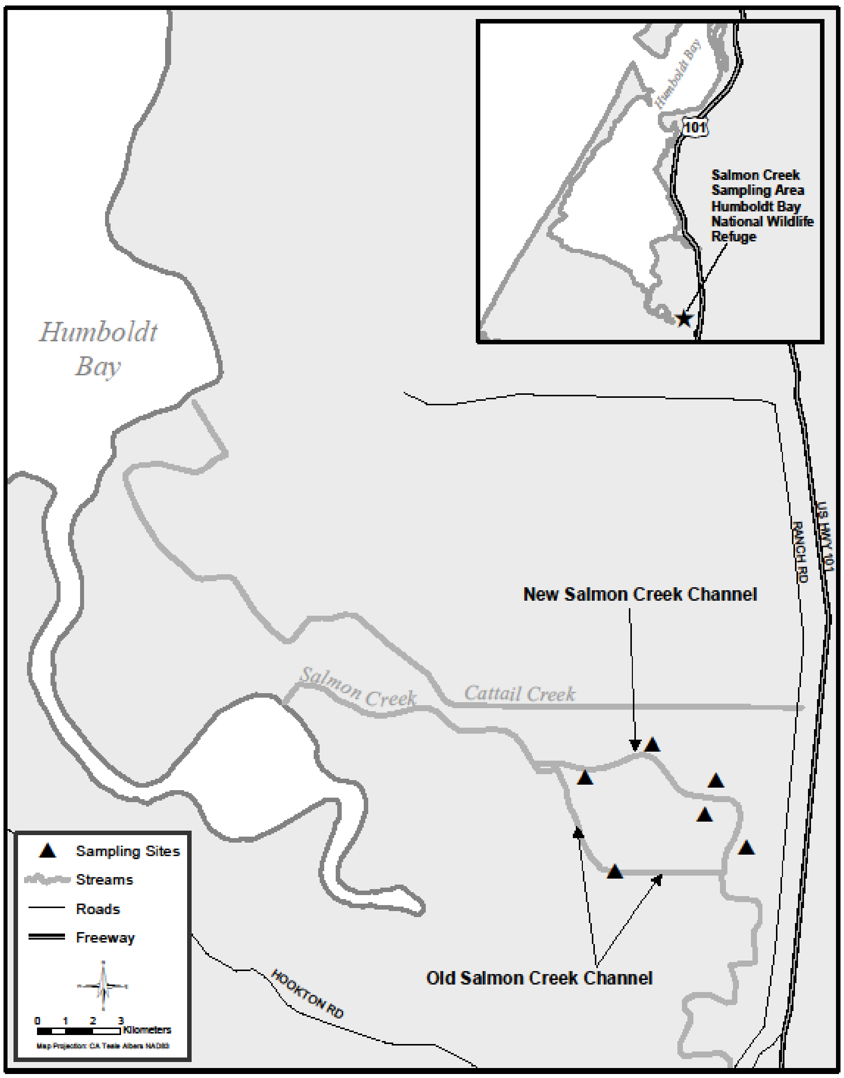

Figure 4. Sampling sites in the stream-estuary ecotone of Salmon Creek surveyed by California Department of Fish and Wildlife in 2011 and 2012.

METHODS

During 2011 and 2012, we conducted bi-weekly sampling for juvenile salmonids in Freshwater, Ryan, Salmon, and Cattail creeks, and the off channel pond in Wood Creek and monthly sampling in Wood, Cattail, and Jacoby creeks and Jacoby Creek pond (Table 1). Six sites in Freshwater Creek Slough were sampled with a 9.1 meter (m) X 1.2 m seine net, and a 30.5 m X 1.5 m seine net was utilized to sample the off channel ponds on Wood and Salmon Creeks. In addition, we used minnow traps baited with frozen salmon roe to sample nine sites plus an adjacent wetland in Ryan Creek, six sites in Wood Creek, four sites in Cattail Creek, one site in Jacoby Creek, and two sites in each of the constructed off channel ponds in Wood, Salmon, and Jacoby Creeks (Table 1). Minnow traps were used to sample heavily vegetated areas where we could not seine effectively. Prior to the Salmon Creek restoration project, sampling was conducted in the old Salmon Creek stream channel. After project completion in the fall of 2011 the old channel became a dead-end tidal channel, and most of our sampling effort shifted to the new off channel ponds. In September 2011, we completed sampling in Cattail Creek and Long Pond on the Refuge property to assess pre-project conditions prior to habitat restoration work in Salmon Creek estuary.

Table 1. The sampling methods, frequency, and duration for Freshwater, Wood, Ryan, Salmon, Cattail, and Jacoby creeks and Wood Creek and Jacoby Creek ponds sampled by California Department of Fish and Wildlife in 2011 and 2012.

Location	Method	Frequency	Duration
Freshwater Creek	9 m seine	Bi-weekly	2011-2012
Wood Creek	minnow traps	monthly	2011-2012
Wood Cr Pond	30 m seine and minnow traps	bi-weekly	2011-2012
Ryan Creek	minnow traps	bi-weekly	2011-2012
Salmon Creek Pond	30 m seine and minnow traps	bi-weekly	2011-2012
Cattail Creek	minnow traps	bi-weekly	2011
Jacoby Creek	minnow traps	monthly	2012
Jacoby Cr Pond	minnow traps	monthly	2012

Field crews anaesthetized, counted, and examined all juvenile salmonids for marks and tags. They also documented the life stage of each salmonid. Coho salmon were designated as “sub-yearling” or “yearling-plus” based on clear size differences between the smaller sub-yearling and larger yearling-plus fish. Coho salmon designated as sub-yearling fish prior to December 31 of each year were designated as yearling-plus fish starting January 1. For yearling-plus coho salmon, steelhead trout, and cutthroat trout, we also designated their development stage as parr (heavy parr marks present), pre-smolt (faded parr marks and silvery color), smolt (no parr marks visible and black fin edges), or adult. Crews also measured fork lengths (FL) to the nearest millimeter (mm), weights to the nearest 0.1 gram (g), and collected scales from the left side of all juvenile salmonids ≥ 50 mm except when the number of fish captured or environmental conditions made it dangerous to process the fish.

Passive Integrated Transponder (PIT) tags were applied to all healthy juvenile salmonids ≥ 55 mm FL to gather residency, movement, and growth information while they were in the SEE. The PIT tags were applied by making a small incision and inserting the tag into the body cavity. All fish ≥ 55 mm and ≤ 69mm FL received an 8.5 mm FDX tag and those ≥ 70 mm FL received an 11.5 mm HDX tag. Once processed, fish were allowed to recover and were released back into the sampling site. Salmonids already containing tags or marks were measured for FL, weighed, scale sampled on their right side, and their mark or tag number recorded. CDFW's Anadromous Fisheries Research and Monitoring Program (AFRAMP) and GDRC biologists applied PIT tags to juvenile salmonids in Freshwater Creek and Ryan Creek respectively. We kept records of all tag codes applied by our project and contacted AFRAMP and GDRC to identify all tag codes recovered.

The project maintained two PIT tag antenna arrays in Wood Creek; one at the entrance of the constructed off channel pond and one in the tide gate structure at the mouth of the creek (Figure 3). In December 2011, we installed PIT tag antennas at the opening of the second-most upstream pond in Salmon Creek (Figure 4). PIT tag detections were automatically stored on a data logger, and field staff downloaded these data every one to two weeks. The data were copied into Excel spreadsheets for future analyses.

We calculated the duration of estuarine residence for fish PIT-tagged in the SEE as the number of days between tagging and last capture or detection. For fish tagged outside the SEE (by other projects), we calculated estuarine residence as the number of days between first capture or detection in the SEE and last capture or detection. We calculated growth rates for fish PIT-tagged in the SEE as the change in FL between tagging and last capture divided by the number of days between tagging and last recapture. For fish tagged outside the SEE, growth rates were calculated as the change in FL between first and last captures in the SEE divided by the number of days between first and last captures.

We also conducted water quality sampling bi-weekly at the off channel ponds in Wood Creek and Salmon Creek, monthly in Wood Creek, and monthly in Jacoby Creek and off channel pond with YSI Model 85 or Professional Plus hand-held meters. Temperature, salinity, and dissolved oxygen data were collected in the newly constructed ponds and adjacent slough habitat. Due to stratification between fresh and brackish water, water samples were collected at surface, mid, and bottom elevations when water depths ≥

0.91 m, surface and bottom elevations when water depth was ≥ 0.46 m, and < 0.91 m, and bottom elevation when depths were < 0.46 m.

RESULTS

FRESHWATER CREEK SLOUGH

Freshwater Creek Slough 2011 and 2012

High stream flows during the spring of 2011 greatly curtailed our sampling effort in Freshwater Creek Slough; therefore, we captured very few salmonids prior to May (Table 2). The peak catch-per-unit-effort (CPUE) of 4.17 fish/set for sub-yearling coho salmon occurred in December (Table 2). Sub-yearling coho salmon monthly mean FL increased from 47 mm in May to 91 mm in November (Table 3). In 2011, yearling coho salmon were captured in February, May, and June. Peak monthly CPUE of 1.00 fish/set occurred in May (Table 2). The monthly mean FL was 109 mm in February and 113 mm in May (Table 3). Sub-yearling Chinook salmon CPUE in 2011 peaked in May (Table 2). The mean FL increased from 46 mm in May to 73 mm in July and August (Table 3). Juvenile steelhead trout were captured throughout the year with a peak CPUE of 0.64 fish/set in May (Table 2). The monthly mean FL ranged from 111 to 176 mm (Table 4). Small numbers of cutthroat trout were captured throughout the year with a peak CPUE of 0.25 fish/set in September (Table 2). The monthly mean FL ranged from 156 to 206 mm (Table 4).

In 2012, the peak monthly CPUE of 19.95 fish/set for sub-yearling coho salmon occurred in August (Table 5). Sub-yearling coho salmon monthly mean FL increased from 40 mm in May to 76 mm in November (Table 6). In 2012, we captured yearling coho salmon from January to June and one individual in November; peak monthly CPUE of 3.71 fish/set occurred in January (Table 5). The monthly mean FL increased from 81 mm in January to 105 mm in May (Table 6). Only one sub-yearling Chinook salmon (42 mm) was captured in 2012 (Tables 5 and 6), and it was . As in 2011, juvenile steelhead trout were captured throughout the year, but the peak CPUE of 0.73 fish/set was greater in 2012 and occurred in September (Table 5). Their monthly mean FL ranged from 83 to 168 mm (Table 7). Similar to 2011, small numbers of cutthroat trout were captured throughout the year with a peak CPUE of 0.33 fish/set in August, which was a slight increase and month than the previous year (Table 5). The monthly mean FL ranged from 143 to 247 mm (Table 7).

Table 2. Monthly effort (number of seine hauls) and catch-per-unit-effort (CPUE; number of fish per seine haul) of juvenile coho and Chinook salmon and steelhead and cutthroat trout captured by seine nets in Freshwater Creek Slough, 2011.

Month	Effort	Yearling Coho Salmon	Sub-yearling Coho Salmon	Steelhead Trout	Cutthroat Trout	Sub-yearling Chinook Salmon
January	24	0	0	0.08	0.04	0
February	12	0.17	0	0.17	0.08	0
March	0	-	-	-	-	-
April	0	-	-	-	-	-
May	22	1.00	1.36	0.64	0.13	0.82
June	24	0.04	1.38	0.58	0	0.67
July	24	0	3.25	0.54	0.17	0.50
August	36	0	3.06	0.17	0.14	0.08
September	24	0	1.79	0.42	0.25	0
October	12	0	1.75	0.08	0	0
November	8	0	1.50	0.38	0.13	0
December	24	0	4.17	0.08	0.13	0

Table 3. Number measured, mean fork-length (FL), and standard deviation (SD) of yearling coho salmon (1+ coho), sub-yearling (yoy) coho salmon (yoy coho), and sub-yearling (yoy) Chinook salmon (CH) captured by seine nets in Freshwater Creek Slough, 2011.

Month	No. 1+ Coho	Mean FL 1+ Coho	SD 1+ Coho	No. yoy Coho	Mean FL yoy Coho	SD yoy Coho	No. yoy CH	Mean FL yoy CH	SD yoy CH
January	-	-	-	-	-	-	-	-	-
February	2	109	3.54	-	-	-	-	-	-
March	-	-	-	-	-	-	-	-	-
April	-	-	-	-	-	-	-	-	-
May	22	113	16.92	30	47	6.20	18	46	4.31
June	1	97	-	33	55	9.18	16	55	8.08
July	-	-	-	78	67	8.98	12	73	5.91
August	-	-	-	110	75	8.50	3	73	10.41
September	-	-	-	43	82	7.50	-	-	-
October	-	-	-	21	83	8.31	-	-	-
November	-	-	-	11	91	9.18	-	-	-
December	-	-	-	100	85	13.55	-	-	-

Table 4. Number measured, mean fork-length (FL), and standard deviation (SD) of juvenile steelhead and cutthroat trout captured by seine nets in Freshwater Creek Slough, 2011.

Month	No. Steelhead Trout	Mean FL Steelhead Trout	SD Steelhead Trout	No. Cutthroat Trout	Mean FL Cutthroat Trout	SD Cutthroat Trout
January	2	176	34.65	-	-	-
February	2	145	23.33	1	183	-
March	-	-	-	-	-	-
April	-	-	-	-	-	-
May	14	117	22.08	3	206	13.08
June	14	115	23.23	-	-	-
July	13	111	15.60	3	178	36.10
August	6	120	15.96	4	156	13.28
September	10	136	21.87	3	168	33.78
October	1	149	-	-	-	-
November	3	143	24.99	1	156	-
December	2	129	1.41	-	-	-

Table 5. Monthly effort (number of seine hauls) and catch-per-unit-effort (CPUE; number of fish per seine haul) of juvenile coho and Chinook salmon and steelhead and cutthroat trout captured by seine nets in Freshwater Creek Slough, 2012.

Month	Effort	Yearling Coho Salmon	Sub-yearling Coho Salmon	Steelhead Trout	Cutthroat Trout	Sub-yearling Chinook Salmon
January	21	3.71	0	0.33	0.05	0
February	12	0.25	0	0.08	0	0
March	12	0.42	0	0.42	0.08	0
April	22	0.09	0	0.14	0.09	0
May	24	1.83	3.79	0.13	0	0
June	22	0.18	6.64	0.45	0	0.05
July	36	0	13.06	0.33	0.06	0
August	21	0	19.95	0.71	0.33	0
September	22	0	13.86	0.73	0.23	0
October	24	0	7.46	0.50	0.29	0
November	17	0.06	8.65	0.41	0.06	0
December	0	-	-	-	-	-

Table 6. Number measured, mean fork-length (FL), and standard deviation (SD) of yearling coho salmon (1+ coho), sub-yearling (yoy) coho salmon (yoy coho), and sub-yearling (yoy) Chinook salmon (CH) captured by seine nets in Freshwater Creek Slough, 2012.

Month	No. 1+ Coho	Mean FL 1+ Coho	SD 1+ Coho	No. yoy Coho	Mean FL yoy Coho	SD yoy Coho	No. yoy CH	Mean FL yoy CH	SD yoy CH
January	78	81	11.61	-	-	-	-	-	-
February	3	84	3.79	-	-	-	-	-	-
March	5	87	13.13	-	-	-	-	-	-
April	2	102	2.12	-	-	-	-	-	-
May	44	105	8.56	91	40	3.14	-	-	-
June	4	97	2.99	146	49	6.88	1	42	-
July	-	-	-	472	56	8.30	-	-	-
August	-	-	-	419	66	8.38	-	-	-
September	-	-	-	305	70	8.06	-	-	-
October	-	-	-	179	72	7.66	-	-	-
November	1	104	-	147	76	7.75	-	-	-
December	-	-	-	-	-	-	-	-	-

Table 7. Number measured, mean fork-length (FL), and standard deviation (SD) of juvenile steelhead and cutthroat trout captured by seine nets in Freshwater Creek Slough, 2012.

Month	No. Steelhead Trout	Mean FL Steelhead Trout	SD Steelhead Trout	No. Cutthroat Trout	Mean FL Cutthroat Trout	SD Cutthroat Trout
January	7	127	40.46	1	163	-
February	1	151	-	-	-	-
March	5	144	42.39	1	202	-
April	3	168	27.22	2	196	24.75
May	3	95	7.50	2	146	7.07
June	10	122	24.51	-	-	-
July	10	83	38.31	2	143	12.73
August	15	92	30.70	3	168	6.66
September	16	84	29.41	7	159	42.63
October	12	117	34.51	7	206	33.56
November	7	140	37.53	1	247	-
December	-	-	-	-	-	-

Recaptured PIT Tagged Fish 2011 and 2012

In 2011, PIT tags were applied to 520 sub-yearling coho salmon in Freshwater Creek Slough, and 74 fish (14.2%) were recaptured (Table 8). The mean length of estuarine residence for recaptured fish was 52 days and ranged from 12-165 days (Table 8[4]). The mean growth rate of recaptured sub-yearling coho was 0.25 mm/day and ranged from 0-0.93 mm/day (Table 8). PIT tags were applied to 11 yearling coho salmon in 2011, and a single fish was recaptured. The single recapture fish was at-large for 13 days and grew 4 mm (0.31 mm/day) during that time. We also recaptured six coho salmon that were tagged by AFRAMP in the Freshwater Creek basin; five in the fall of 2011 and one in the fall of 2010. We applied PIT tags to 41 juvenile steelhead trout in 2011 and recaptured five (12.2%) fish. Steelhead trout were at-large between 14-124 days and they grew 4-13 mm (0.06 to 0.24 mm/day) during that time. PIT tags were applied to seven cutthroat trout in 2011, and no fish were recaptured. Our project also captured another 12 juvenile steelhead trout and six cutthroat trout that were tagged by other projects in other locations in the Freshwater Creek basin. It is likely that some of the cutthroat trout captured by our project were resident adult fish.

In 2012, we applied PIT tags to 555 sub-yearling coho salmon in Freshwater Creek Slough and recaptured 303 (54.6%) fish (Table 8). The mean length of estuarine residence for recaptured fish was 58 days and ranged from 12-140 days (Table 8). The mean growth rate of recaptured sub-yearling coho salmon was 0.17 mm/day and ranged from 0.07-0.63 mm/day (Table 8). We applied PIT tags to an additional 116 yearling coho salmon but no yearlings were recaptured. However, 11 yearling coho salmon were recaptured that were tagged by our project as sub-yearlings in 2011 and three additional coho salmon were recaptured that were tagged by AFRAMP in the Freshwater Creek basin in the fall of 2011. These fish were at-large for 28-191 days and grew from 1-23 mm (0.04 to 0.17 mm/day) during that time). PIT tags were applied to 64 juvenile steelhead trout in 2012 and 17 fish (26.6%) were recaptured. They were at-large for 15-238 days and grew 1-38 mm (0.02 to 0.32 mm/day) during that time. We also captured one juvenile steelhead trout that we tagged in 2011; this fish was at large for 335 days and grew 37 mm (0.11 mm/day) during that time.

We also captured two steelhead trout that were tagged at the HFAC weir in 2011 that were at large 243 and 256 days and grew 35 mm (0.14 mm/day) and 55 mm (0.22 mm/day), respectively. PIT tags were applied to 14 cutthroat trout in 2012, and a single fish (7.1%) was recaptured. It was at-large for 14 days and grew 1 mm (0.07 mm/day). Four additional cutthroat trout were recaptured that were tagged by other projects in the Freshwater Creek basin. It is likely that some of the cutthroat trout captured by our project were resident adult fish.

[4] Table 8 includes PIT information from 2011 and 2012 and the previous five years.

Table 8. Summarized information for sub-yearling coho salmon PIT tagged by Natural Stocks Assessment Project in Freshwater Creek Slough including number tagged, number and percent recaptured, mean and range of days at liberty (DAL) of recaptured fish, and mean and range of recaptured coho salmon growth rate (mm/day).

Year	No. Tagged	No. Recaptured	Percent Recaptured	Mean DAL	Range DAL	Mean Growth Rate	Range Growth Rate
2006	237	57	24.1	33	5-106	0.15	0.00-0.29
2007	65	12	18.5	68	6-167	0.17	0.12-0.45
2008	11	0	0	-	-	-	-
2009	152	69	45.4	60	13-175	0.20	0.00-0.68
2010	60	12	20.0	41	16-113	0.23	0.12-0.48
2011	520	74	14.2	52	12-165	0.25	0.00-0.93
2012	555	303	54.6	58	12-140	0.17	-0.07-0.63

Wood Creek

Wood Creek 2011 and 2012

In 2011, juvenile coho salmon were the most abundant salmonids captured in Wood Creek and Wood Creek pond. We captured 28 yearling coho salmon, 88 sub-yearling coho salmon, one steelhead trout, and two cutthroat trout during minnow trapping in Wood Creek (Table 9). In Wood Creek, yearling coho salmon were captured from January to April, sub-yearling coho salmon from June to December, one steelhead trout in January, and two cutthroat trout in June. Peak catches of yearling and sub-yearling coho salmon occurred in March and August, respectively (Table 9). In Wood Creek pond, CPUE ranged from 0-9.00 fish/set for sub-yearling coho salmon and 0-3.33 fish/set for yearling-plus coho salmon with peak catches occurring in May and March, respectively (Table 10). In Wood Creek pond, we captured yearling coho salmon from February to April, sub-yearling coho salmon from March to May and again in December, and a cutthroat trout in February (Table 10). Monthly mean FL for yearling coho salmon varied from 92-115 mm (Table 11). Monthly mean FL for sub-yearling coho salmon increased from 39 mm in March to 90 mm in December (Table 11).

In 2012, juvenile coho salmon were the most abundant salmonids captured in Wood Creek and Wood Creek pond. We captured 65 yearling coho salmon, 17 sub-yearling coho salmon, and one cutthroat trout in minnow traps in Wood Creek (Table 12). In Wood Creek, yearling coho salmon were captured January to June with the exception of April when no yearling fish were caught, and sub-yearling coho salmon were caught from August to December. Peak catches of yearling and sub-yearling coho salmon occurred in February and December, respectively (Table 12). In Wood Creek, monthly mean FL for yearling coho salmon varied from 79-107 mm, while monthly mean FL for sub-yearling coho salmon increased from 40 mm in May to 71 mm in December (Table

13). In Wood Creek pond, CPUE ranged from 0-19.33 fish/set for sub-yearling coho salmon and 0-48.75 fish/set for yearling-plus coho salmon, with peak catches occurring in May and March, respectively (Table 14). Yearling coho salmon were captured from January to April and sub-yearling coho salmon from May to July and in December (Table 14).

Table 9. Monthly effort (number of traps) and number of juvenile salmonids captured by minnow traps in Wood Creek, 2011.

Month	Effort	Yearling Coho Salmon	Sub-yearling Coho Salmon	Steelhead Trout	Cutthroat Trout	Sub-yearling Chinook Salmon
January	16	4	0	1	0	0
February	8	4	0	0	0	0
March	8	12	0	0	0	0
April	8	8	0	0	0	0
May	8	0	0	0	0	0
June	8	0	8	0	2	0
July	8	0	6	0	0	0
August	8	0	39	0	0	0
September	8	0	3	0	0	0
October	8	0	21	0	0	0
November	8	0	0	0	0	0
December	8	0	11	0	0	0

Table 10. Monthly effort (number of seine hauls) and catch-per-unit-effort (CPUE; number of fish per seine haul) of juvenile salmonids captured by seine nets in Wood Creek pond, 2011.

Month	Effort	Yearling Coho Salmon	Sub-yearling Coho Salmon	Steelhead Trout	Cutthroat Trout	Sub-yearling Chinook Salmon
January	3	0	0	0	0	0
February	3	0.33	0	0	0.33	0
March	3	3.33	0.33	0	0	0
April	3	0.33	6.33	0	0	0
May	3	0	9.00	0	0	0
June	2	0	0	0	0	0
July	0	-	-	-	-	-
August	1	0	0	0	0	0
September	1	0	0	0	0	0
October	1	0	0	0	0	0
November	0	0	0	0	0	0
December	1	0	1.00	0	0	0

Table 11. Number measured, mean fork-length (FL), and standard deviation (SD) of yearling coho salmon (1+ coho), sub-yearling (yoy) coho salmon (yoy coho), and sub-yearling (yoy) Chinook salmon (CH) captured by minnow traps in Wood Creek, 2011.

Month	No. 1+ Coho	Mean FL 1+ Coho	SD 1+ Coho	No. yoy Coho	Mean FL yoy Coho	SD yoy Coho	No. yoy CH	Mean FL yoy CH	SD yoy CH
January	4	115	2.12	-	-	-	-	-	-
February	5	92	9.24	-	-	-	-	-	-
March	22	104	9.34	1	39	-	-	-	-
April	9	109	8.13	18	41	2.01	-	-	-
May	-	-	-	27	46	2.93	-	-	-
June	-	-	-	8	53	3.54	-	-	-
July	-	-	-	6	63	5.96	-	-	-
August	-	-	-	38	67	5.97	-	-	-
September	-	-	-	3	80	7.64	-	-	-
October	-	-	-	21	82	6.12	-	-	-
November	-	-	-	-	-	-	-	-	-
December	-	-	-	12	90	11.58	-	-	-

Table 12. Monthly effort (number of traps) and number of juvenile salmonids captured by minnow traps in Wood Creek, 2012.

Month	Effort	Yearling Coho Salmon	Sub-yearling Coho Salmon	Steelhead Trout	Cutthroat Trout	Sub-yearling Chinook Salmon
January	8	19	0	0	0	0
February	8	30	0	0	0	0
March	8	8	0	0	0	0
April	8	0	0	0	0	0
May	8	7	0	0	1	0
June	8	1	0	0	0	0
July	8	0	0	0	0	0
August	8	0	6	0	0	0
September	0	-	-	-	-	-
October	8	0	2	0	0	0
November	8	0	1	0	0	0
December	8	0	8	0	0	0

Table 13. Number measured, mean fork-length (FL), and standard deviation (SD) of yearling coho salmon (1+ coho), sub-yearling (yoy) coho salmon (yoy coho), and sub-yearling (yoy) Chinook salmon (CH) captured by minnow trap and seine in Wood Creek, 2012.

Month	No. 1+ Coho	Mean FL 1+ Coho	SD 1+ Coho	No. yoy Coho	Mean FL yoy Coho	SD yoy Coho	No. yoy CH	Mean FL yoy CH	SD yoy CH
January	20	88	11.48	-	-	-	-	-	-
February	45	79	8.06	-	-	-	-	-	-
March	203	81	8.34	-	-	-	-	-	-
April	26	85	6.29	-	-	-	-	-	-
May	7	90	13.30	58	40	2.70	-	-	-
June	1	107	-	15	50	6.40	-	-	-
July	-	-	-	2	50	0.71	-	-	-
August	-	-	-	6	56	4.02	-	-	-
September	-	-	-	-	-	-	-	-	-
October	-	-	-	2	72	8.49	-	-	-
November	-	-	-	1	83	-	-	-	-
December	-	-	-	23	71	9.82	-	-	-

Table 14. Monthly effort (number of seine hauls) and catch-per-unit-effort (CPUE; number of fish per seine haul) of juvenile salmonids captured by seine nets in Wood Creek pond, 2012.

Month	Effort	Yearling Coho Salmon	Sub-yearling Coho Salmon	Steelhead Trout	Cutthroat Trout	Sub-yearling Chinook Salmon
January	1	1.00	0	0	0	0
February	2	7.50	0	0	0	0
March	4	48.75	0	0	0	0
April	4	6.50	0	0	0	0
May	3	0	19.33	0	0.25	0
June	2	0	7.50	0	0	0
July	2	0	1.00	0	0	0
August	3	0	0	0	0	0
September	2	0	0	0	0	0
October	1	0	0	0	0	0
November	2	0	0	0	0	0
December	2	0	7.50	0	0	0

Recaptured PIT Tagged Fish 2011 and 2012

In 2011, we applied PIT tags to 69 juvenile coho salmon in Wood Creek and recaptured 11 fish (15.9%). The recaptured fish were at large 33-124 days, and they grew 10-30 mm during that time. These fish had mean growth rate of 0.24 mm/day (0.15-0.33 mm/day). We did not apply or recapture enough PIT tags from other species to calculate estuarine residence or growth rates.

In 2012, we applied PIT tags to 272 yearling coho salmon in Wood Creek and recaptured 15 fish (5.5%). The recaptured yearlings were at large 6-50 days, and they grew 1-16 mm during that time. These fish had growth rates ranging from 0.02-0.43 mm/day. We also recaptured three yearling coho salmon that were tagged in Wood Creek in 2011 as sub-yearling fish. They were at large 58-245 days. They grew 3-41 mm during that time, and their growth rates ranged from 0.05-0.22 mm/day. We also PIT tagged 35 sub-yearling coho salmon and did not recapture any of them. We did not apply or recapture enough PIT tags from other species to calculate estuarine residence or growth rates.

PIT Tag Antenna Detections 2010/11 Season

From October 2010 to August 2011 the pond antenna detected 55 coho salmon, two steelhead trout, and one cutthroat trout. Individual coho salmon were first detected on December 3, 2010 and last detected on June 1, 2011, though most had left the pond by the end of April. Of the 55 coho salmon detected in the pond, eight were tagged and released into the pond, 19 were NSA tagged fish from Wood Creek (16 tagged in 2011 and three tagged in 2010), and 28 were tagged upstream in Freshwater Creek basin by AFRAMP during the fall of 2010 (Table 15). Twenty-seven of the 55 coho salmon were detected in the pond on more than one day. These fish had an average time between first and last detection (a surrogate for residence time) of 36 days (1-121 days).

Both steelhead trout detected in the pond were first detected on November 7, 2010 and last detected on December 5, 2010 (28 days). They were detected at the tide gate antenna at the mouth of Wood Creek entering and leaving Wood Creek. One steelhead entered Wood Creek on October 26, 2010 and left March 13, 2011 (138 days) and the other entered October 25, 2010 and left March 14, 2011 (140 days). One detected steelhead trout was tagged at the HFAC weir site on May 8, 2010 and the other in Freshwater Creek Slough on August 31, 2010 which strongly suggests that these steelhead trout were rearing in the SEE for many months.

The cutthroat trout was detected on March 24 and 25, 2011 and then detected at the tide gate antenna on March 28, 2011. It was originally tagged in Wood Creek on July 1, 2010 suggesting it resided in the tidal portion of Wood Creek for almost nine months.

From September 2010 to August 2011, the tide gate antenna detected 451 coho salmon, 13 juvenile steelhead trout, one adult steelhead trout, and 17 cutthroat trout. Individual coho salmon were first detected on October 25, 2010 and last detected on July 2, 2011. Most coho salmon were first detected in November and December 2010 with another first detection peak in May, illustrating that a large redistribution of juvenile

Table 15. Origin of PIT tagged juvenile coho salmon tagged in Freshwater Creek (FW) basin detected at Wood Creek pond and tide gate antennas during October 2010 to October 2011, and October 2011 to October 2012.

Fish Origin	Pond 10/11	Pond 11/12	Tide Gate 10/11	Tide Gate 11/12
Stream-Estuary Ecotone	1	0	30	0
Lower Mainstem	6	26	49	75
Middle Mainstem	11	16	79	51
Upper Mainstem	6	12	59	34
Little Freshwater Cr	0	0	0	0
Cloney Gulch	4	6	45	23
So. Fork Freshwater Cr	0	10	13	31
FW Creek (total)	**28**	**70**	**275**	**214**
Wood Cr Pond	8	199	3	138
Wood Cr (tagged 2012)	-	12	-	44
Wood Cr (tagged 2011)	16	8	30	25
Wood Cr (tagged 2010)	3	0	5	0
Wood Cr (tagged 2009)	0	0	0	0
Ryan Sl	0	1	1	10
Ryan Creek	-	6	-	18
Ryan Screw Trap	-	0	4	43
FW Sl (tagged 2012)	-	5	-	31
FW Sl (tagged 2011)	0	3	2	36
FW Sl (tagged 2010)	0	0	8	0
FW Sl (tagged 2009)	0	0	0	0
HFAC Weir (tagged 2012)	-	2	-	156
HFAC Weir (tagged 2011)	0	0	122	0
HFAC Weir (tagged 2010)	0	0	1	1*
HFAC Weir (tagged 2009)	0	0	0	0
Estuary Ecotone (total)	**27**	**236**	**176**	**502**
Grand Total	**55**	**306**	**451**	**716**

* This was likely an adult coho returning to Freshwater Creek basin.

coho salmon occurred in the fall after the first rains followed by the traditional spring out-migration which peaked in May. Most individual fish were last detected in December and May, lending additional evidence that late fall and spring were the times of peak movement/emigration of coho salmon out of Freshwater Creek to the SEE.

Of the 451 coho salmon detected at the tide gate, 275 were tagged by AFRAMP upstream in Freshwater Creek basin during the fall of 2010 (Table 15). These 275 coho were comprised of 79 fish from the middle mainstem Freshwater Creek?, 59 from the upper mainstem, 49 from the lower mainstem, 45 from Cloney Gulch, 30 from the SEE, and 13 from the South Fork Freshwater Creek (Table 15). Remaining coho salmon were comprised of 123 fish tagged at the HFAC weir (122 tagged in 2011 and one tagged in 2010), five tagged in Ryan Creek (four by GDRC biologists at their screw-trap and one by NSA in Ryan Slough), 10 tagged by NSA in Freshwater Creek Slough (two in 2011 and eight in 2010), 35 tagged by NSA and released into Wood Creek (30 in 2011 and five in 2010), and three fish tagged by NSA and released into Wood Creek pond in 2011 (Table 15).

PIT Tag Antenna Detections 2011/12 Season

From August 2011 to July 2012 the pond antenna detected 306 coho salmon, one juvenile steelhead trout, and one cutthroat trout. Coho salmon were first detected on August 5, 2011 and all but three fish were detected beginning late November 2011. Coho salmon were last detected in the pond on June 11, 2012. A peak of first detected coho salmon appeared from November 2011 to January 2012 illustrating that a large redistribution of juvenile coho salmon occurred in the fall after the first rains. The largest peak of first detected coho salmon occurred in March 2012 and corresponded with the large numbers of coho salmon captured and tagged by NSA in Wood Creek pond.

The 306 coho salmon detected in the pond were comprised of 199 (65.0%) tagged and released into Wood Creek pond by NSA, 70 (22.9%) tagged by AFRAMP upstream in Freshwater Creek basin during the fall of 2011, 20 (6.5%) tagged by NSA and released into Wood Creek (12 tagged in 2012 and eight tagged in 2011), eight (2.6%) tagged by NSA in Freshwater Creek Slough (five tagged in 2012 and three tagged in 2011), seven (2.3%) tagged in Ryan Creek (six by GRDC biologists in the fall of 2011, and one by NSA in the SEE), and two (0.7%) tagged by AFRAMP at the HFAC weir (Table 15). One hundred twenty-nine of the 306 detected coho salmon (42%) were detected in the pond on more than one day. These fish had an average time between first and last detection (a surrogate for residence time) of 11 days (range 1-96 days).

From September 2011 to July 2012, the tide gate antenna detected 716 coho salmon, 19 juvenile steelhead trout, and 21 cutthroat trout. Individual coho salmon were first detected on September 2, 2011 and last detected on June 27, 2012. Most coho salmon were first detected from November 2011 to January 2012 and another peak of first detected coho salmon occurred in March and April 2012. This illustrates that a large redistribution of juvenile coho salmon occurs in the fall after the first rains followed by the traditional spring out migration.

The 716 coho salmon detected at the tide gate were comprised of 214 (30%) tagged by AFRAMP upstream in Freshwater Creek basin during the fall of 2011, 156 (21.8%) tagged by AFRAMP at the HFAC weir, 138 (19.3%) tagged and released by NSA into Wood Creek pond, 71 (9.9%) tagged in Ryan Creek (43 by GRDC biologists at their screw trap in the spring of 2012, 18 by GRDC biologists in the fall of 2011, and 10 by NSA in the stream-estuary ecotone), 69 (9.6%) tagged and released into Wood Creek by NSA (44 tagged in 2012 and 25 tagged in 2011), 67 (9.4%) tagged by NSA in Freshwater Creek Slough (31 tagged in 2012 and 36 tagged in 2011), and one tagged at the HFAC weir in 2010 and was returning to Freshwater Creek as an adult (Table 15).

Ryan Creek Slough

Ryan Creek Slough 2011 and 2012

In 2011, sub-yearling coho salmon were the most abundant salmonids captured in Ryan Creek Slough and the adjacent wetland (Table 16). NSA captured 12 yearling coho salmon, 228 sub-yearling coho salmon, 133 juvenile steelhead trout, and 68 cutthroat trout (Table 16). NSA captured yearling coho salmon in January, April, and May and sub-yearling coho salmon from June to December with peak catches occurring in January and November, respectively (Table 16). Monthly mean FL for yearling coho salmon varied from 100-122 mm (Table 17). The monthly mean FL of sub-yearling coho salmon increased from 61 mm in June to 89 mm in November (Table 17). Steelhead trout peak catches occurred in June and July and cutthroat trout peak catches occurred in June (Table 16). Monthly mean FL varied from 104-124 mm for steelhead trout and 119-176 mm for cutthroat trout (Table 18).

In 2012, juvenile coho salmon were the most abundant salmonids captured in Ryan Creek Slough and the adjacent wetland (Table 19). NSA captured 170 yearling coho salmon, 314 sub-yearling coho salmon, 81 steelhead trout, and 102 cutthroat trout (Table 19). NSA captured yearling coho salmon January to October and sub-yearling coho salmon from June to December with peak catches occurring in March and October, respectively (Table 19). Monthly mean FL for yearling coho salmon varied from 82-107 mm (Table 20). The monthly mean FL of sub-yearling coho increased from 54 mm in June and peaked at 83 mm in October (Table 20). Peak catches occurred in June for steelhead trout and May for cutthroat trout (Table 19). Monthly mean FL varied from 98-132 mm for steelhead trout and 115-163 mm for cutthroat trout (Table 21).

Juvenile coho salmon were captured year round and distributed fairly evenly throughout the Ryan Creek sampling sites (Table 22). We also captured them in the adjacent wetland but only during the winter and spring (Table 22).

Table 16. Effort (number of traps) and number of juvenile salmonids captured by minnow traps in Ryan Creek Slough, 2011.

Month	Effort	Yearling Coho Salmon	Sub-yearling Coho Salmon	Steelhead Trout	Cutthroat Trout	Sub-yearling Chinook Salmon
January	22	5	0	16	0	0
February	22	0	0	7	1	0
March	8	0	0	4	0	0
April	13	4	0	1	2	0
May	22	3	0	10	2	0
June	33	0	19	30	18	0
July	22	0	17	30	12	0
August	22	0	24	7	11	0
September	22	0	39	8	10	0
October	22	0	26	7	9	0
November	21	0	55	5	1	0
December	22	0	48	8	2	0

Table 17. Number measured, mean fork-length (FL), and standard deviation (SD) of yearling coho salmon (1+ coho), sub-yearling (yoy) coho salmon (yoy coho), and sub-yearling (yoy) Chinook salmon (CH) captured by minnow traps in Ryan Creek Slough, 2011.

Month	No. 1+ Coho	Mean FL 1+ Coho	SD 1+ Coho	No. Yoy Coho	Mean FL Yoy Coho	SD Yoy Coho	No. Yoy CH	Mean FL Yoy CH	SD Yoy CH
January	5	100	14.60				-	-	-
February	-	-	-				-	-	-
March	4	101	11.40				-	-	-
April	-	-	-				-	-	-
May	3	122	8.89				-	-	-
June	-	-	-	18	61	10.10	-	-	-
July	-	-	-	17	71	8.97	-	-	-
August	-	-	-	23	79	8.77	-	-	-
September	-	-	-	38	80	8.73	-	-	-
October	-	-	-	25	87	6.29	-	-	-
November	-	-	-	54	89	9.31	-	-	-
December	-	-	-	47	85	11.43	-	-	-

Table 18. Number measured, mean fork-length (FL), and standard deviation (SD) of juvenile steelhead and cutthroat trout captured by minnow traps in Ryan Creek Slough, 2011.

Month	No. Steelhead Trout	Mean FL Steelhead Trout	SD Steelhead Trout	No. Cutthroat Trout	Mean FL Cutthroat Trout	SD Cutthroat Trout
January	16	110	15.06	-	-	-
February	7	109	13.44	1	176	-
March	-	-	-	-	-	-
April	1	104	-	2	119	10.61
May	10	111	17.35	2	130	7.07
June	30	110	18.73	18	128	15.99
July	29	111	16.90	11	128	7.05
August	7	119	7.13	10	127	10.36
September	8	114	21.03	10	134	20.12
October	7	124	22.37	9	119	20.84
November	5	115	20.06	1	130	-
December	8	119	15.16	2	130	4.24

Table 19. Monthly effort (number of traps) and number of juvenile salmonids captured by minnow traps in Ryan Creek Slough, 2012.

Month	Effort	Yearling Coho Salmon	Sub-yearling Coho Salmon	Steelhead Trout	Cutthroat Trout	Sub-yearling Chinook Salmon
January	20	26	0	4	1	0
February	20	33	0	2	1	0
March	20	45	0	1	2	0
April	20	11	0	3	5	0
May	30	33	0	3	18	0
June	20	10	2	15	15	0
July	20	4	14	13	10	0
August	22	4	37	8	13	0
September	22	2	93	12	10	0
October	22	2	98	11	15	0
November	16	0	44	9	8	0
December	22	0	26	0	4	0

Table 20. Number measured, mean fork-length (FL), and standard deviation (SD) of yearling coho salmon (1+ coho), sub-yearling (yoy) coho salmon (yoy coho), and sub-yearling (yoy) Chinook salmon (CH) captured by minnow traps in Ryan Creek Slough, 2012.

Month	No. 1+ Coho	Mean FL 1+ Coho	SD 1+ Coho	No. yoy Coho	Mean FL yoy Coho	SD yoy Coho	No. yoy CH	Mean FL yoy CH	SD yoy CH
January	26	82	10.66	-	-	-	-	-	-
February	33	92	7.70	-	-	-	-	-	-
March	45	87	8.44	-	-	-	-	-	-
April	11	91	6.97	-	-	-	-	-	-
May	22	103	11.83	-	-	-	-	-	-
June	10	98	7.81	2	54	7.78	-	-	-
July	4	95	4.11	14	67	4.42	-	-	-
August	4	101	2.87	37	73	7.27	-	-	-
September	2	107	3.54	93	75	6.63	-	-	-
October	2	105	4.95	98	83	7.61	-	-	-
November	-	-	-	44	80	10.42	-	-	-
December	-	-	-	26	78	11.57	-	-	-

Table 21. Number measured, mean fork-length (FL), and standard deviation (SD) of juvenile steelhead and cutthroat trout captured by minnow traps in Ryan Creek Slough, 2012.

Month	No. Steelhead Trout	Mean FL Steelhead Trout	SD Steelhead Trout	No. Cutthroat Trout	Mean FL Cutthroat Trout	SD Cutthroat Trout
January	4	132	34.71	1	163	-
February	2	121	10.61	1	117	-
March	1	98	-	2	131	0.00
April	3	115	18.77	5	125	16.16
May	2	117	2.12	17	115	16.22
June	15	112	19.71	15	122	13.30
July	13	114	15.26	10	122	15.03
August	7	117	12.20	13	127	14.61
September	11	120	20.70	10	126	19.49
October	10	118	20.85	15	126	12.82
November	8	117	21.12	8	125	6.76
December	-	-	-	3	136	15.04

Table 22. Comparison of the monthly number of juvenile coho salmon captured by site groupings in Ryan Creek/Slough, 2011 and 2012.

	Sample Sites				
Date	**Downstream**	**Middle**	**Upstream**	**Wetland**	**Total**
01-11	1	1	2	1	5
02-11	0	0	0	0	0
03-11*	-	-	-	4	4
04-11*	0	0	0	0	0
05-11	2	1	0	0	3
06-11	6	4	9	0	19
07-11	6	6	5	0	17
08-11	9	8	7	0	24
09-11	9	9	21	0	39
10-11	10	11	5	0	26
11-11	18	19	18	0	55
12-11	29	13	5	1	48
01-12	0	3	3	20	26
02-12	3	6	24	0	33
03-12	0	2	21	22	45
04-12	2	2	1	6	11
05-12	5	13	13	3	34
06-12	3	5	4	0	12
07-12	8	5	5	0	18
08-12	14	12	14	0	40
09-12	29	55	11	0	95
10-12	26	45	29	0	100
11-12	1	12	31	0	44
12-12	7	7	3	9	26
Total	**188**	**239**	**231**	**66**	**724**

*High stream flows, limited sampling

Recaptured PIT Tagged Fish 2011 and 2012

In 2011, NSA applied PIT tags to 182 juvenile coho salmon in Ryan Creek Slough of which 36 (19.8%) were recaptured. The recaptured coho salmon had a mean residence time of 75 days and were at-large 14-225 days. They grew 1-36 mm and with a mean growth rate was 0.13 mm/day (0.04-0.31 mm/day). We applied PIT tags to 100 juvenile steelhead trout and recaptured 17 (17.0%). The recaptured steelhead trout had a mean residence time of 54 days and were at large 14-158 days. They grew 0-29 mm and their mean growth rate was 0.21 mm/day (0-0.64 mm/day). NSA applied PIT tags to 40 cutthroat trout and recaptured 17 (42.5%). The recaptured cutthroat trout had a mean residence time of 58 days and were at large 14-113 days. They grew 1-29 mm, and their mean growth rate was 0.17 mm/day (0.04-0.38 mm/day).

In 2012, NSA applied PIT tags to 229 sub-yearling coho salmon in Ryan Creek Slough and recaptured 59 (25.8%). The recaptured sub-yearling coho salmon had a mean residence time of 37 days and were at large 13-99 days. They grew -2-25 mm and their mean growth rate was 0.14 mm/day (-0.14-0.37 mm/day). NSA applied PIT tags to 134 yearling coho salmon and recaptured 16 (11.9%). The recaptured yearling coho salmon had a mean residence time of 48 days and were at large 11-110 days. They grew 1-31 mm and their mean growth rate was 0.22 mm/day (0.03-0.57 mm/day). We also captured five yearling coho salmon that we marked in Ryan Slough in 2011 as sub-yearling fish. They were at large 53-225 days, grew 3-26 mm, and their growth rate ranged from 0.06-0.15 mm/day.

NSA applied PIT tags to 54 juvenile steelhead trout and recaptured 16 (29.6%). The recaptured steelhead trout had a mean residence time of 57 days and were at-large 13-125 days. They grew 0-27 mm and their mean growth rate was 0.24 mm/day (range 0-0.69 mm/day). We also captured one steelhead trout that we marked in Ryan Creek Slough in 2011. It was at large 83 days and grew 0 mm. NSA applied PIT tags to 65 cutthroat trout and recaptured 18 (27.7%). The recaptured cutthroat trout had a mean residence time of 66 days and were at large 12-155 days. They grew 3-42 mm and their mean growth rate was 0.26 mm/day (0.07-0.57 mm/day).

SALMON CREEK

Salmon Creek 2011 and 2012

During 2011, NSA minnow trapped five sub-yearling coho salmon and 77 juvenile steelhead trout in the old stream channel and new off channel ponds (Table 23). Coho salmon were caught in July and October, and the steelhead trout were caught every month but February, September, and November. We also seined Salmon Creek and captured juvenile steelhead trout January through June (except February) and again in December (Table 24). Our CPUE ranged from 0-6.00 fish/set with peak catches occurring in March (Table 24). Monthly mean FL varied from 107-153 mm for steelhead trout and 82-87 mm for sub-yearling coho salmon (Table 25). NSA completed sampling in Cattail Creek and Long Pond in September and did not capture any juvenile salmonids during the year.

In 2012, we captured 101 yearling coho salmon and six juvenile steelhead trout seining the new ponds. This was more coho salmon than we captured the previous seven years combined. We captured coho salmon from January through June, except for April, and our CPUE ranged from 0-5.56 fish/set with peak catches occurring in March (Table 26). We captured steelhead trout in January and March, with a peak CPUE of 0.40 fish/set in January (Table 26). We also minnow-trapped five yearling coho salmon and eight juvenile steelhead trout in the new off-channel ponds and no salmonids in the old Salmon Creek stream channel (Table 27). Coho salmon were captured in March and steelhead trout were captured January to April. Monthly mean FL varied from 73-106 mm for yearling-plus coho salmon and 129-154 mm for steelhead trout (Table 28).

Table 23. Monthly effort (number of traps) and number of juvenile salmonids captured by minnow traps in Salmon Creek estuary, 2011.

Month	Effort	Yearling Coho Salmon	Sub-yearling Coho Salmon	Steelhead Trout	Cutthroat Trout	Sub-yearling Chinook Salmon
January	4	0	0	6	0	0
February	3	0	0	0	0	0
March	2	0	0	6	0	0
April	3	0	0	2	0	0
May	10	0	0	22	0	0
June	10	0	0	30	0	0
July	5	0	2	3	0	0
August	3	0	0	1	0	0
September	2	0	0	0	0	0
October	7	0	3	4	0	0
November	16	0	0	0	0	0
December	19	0	0	3	0	0

Table 24. Monthly effort (number of seine hauls) and catch-per-unit-effort (CPUE; number of fish per seine haul) of juvenile salmonids captured by seine nets in Salmon Creek estuary, 2011.

Month	Effort	Yearling Coho Salmon	Sub-yearling Coho Salmon	Steelhead Trout	Cutthroat Trout	Sub-yearling Chinook Salmon
January	6	0	0	0.33	0	0
February	6	0	0	0	0	0
March	1	0	0	6.00	0	0
April	3	0	0	0.33	0	0
May	6	0	0	0.67	0	0
June	4	0	0	0.25	0	0
July	2	0	0	0	0	0
August	2	0	0	0	0	0
September	0	-	-	-	-	-
October	0	-	-	-	-	-
November	11	0	0	0	0	0
December	12	0	0	0.25	0	0

Table 25. Number measured, mean fork-length (FL), and standard deviation (SD) of yearling coho salmon (1+ coho), sub-yearling (yoy) coho salmon (yoy coho), and steelhead trout (SH) captured by minnow trap and seine in Salmon Creek estuary, 2011.

Month	No. 1+ Coho	Mean FL 1+ Coho	SD 1+ Coho	No. yoy Coho	Mean FL yoy Coho	SD yoy Coho	No. SH Trout	Mean FL SH Trout	SD SH Trout
January	-	-	-	-	-	-	8	108	33.84
February	-	-	-	-	-	-	-	-	-
March	-	-	-	-	-	-	12	120	30.90
April	-	-	-	-	-	-	3	110	36.76
May	-	-	-	-	-	-	26	109	18.36
June	-	-	-	-	-	-	31	107	11.80
July	-	-	-	2	82	8.49	3	109	8.62
August	-	-	-	-	-	-	1	128	-
September	-	-	-	-	-	-	-	-	-
October	-	-	-	3	87	2.52	4	129	16.78
November	-	-	-	-	-	-	-	-	-
December	-	-	-	-	-	-	3	153	61.17

Table 26. Monthly effort (number of seine hauls) and catch-per-unit-effort (CPUE; number of fish per seine haul) of juvenile salmonids captured by seine nets in Salmon Creek ponds, 2012.

Month	Effort	Yearling Coho Salmon	Sub-yearling Coho Salmon	Steelhead Trout	Cutthroat Trout	Sub-yearling Chinook Salmon
January	10	0.20	0	0.40	0	0
February	10	0.90	0	0	0	0
March	9	5.56	0	0.22	0	0
April	6	0	0	0	0	0
May	12	3.17	0	0	0	0
June	8	0.25	0	0	0	0
July	8	0	0	0	0	0
August	8	0	0	0	0	0
September	8	0	0	0	0	0
October	4	0	0	0	0	0
November	12	0	0	0	0	0
December	6	0	0	0	0	0

Table 27. Monthly effort (number of minnow traps) and number of juvenile salmonids captured by minnow traps in Salmon Creek estuary, 2012.

Month	Effort	Yearling Coho Salmon	Sub-yearling Coho Salmon	Steelhead Trout	Cutthroat Trout	Sub-yearling Chinook Salmon
January	28	0	0	1	0	0
February	28	0	0	1	0	0
March	28	5	0	5	0	0
April	28	0	0	1	0	0
May	38	0	0	0	0	0
June	26	0	0	0	0	0
July	26	0	0	0	0	0
August	26	0	0	0	0	0
September	26	0	0	0	0	0
October	26	0	0	0	0	0
November	42	0	0	0	0	0
December	36	0	0	0	0	0

Table 28. Number measured, mean fork-length (FL), and standard deviation (SD) of yearling coho salmon (1+ coho), sub-yearling (yoy) coho salmon (yoy coho), and steelhead trout captured by minnow trap and seine in Salmon Creek estuary, 2012.

Month	No. 1+ Coho	Mean FL 1+ Coho	SD 1+ Coho	No. yoy Coho	Mean FL yoy Coho	SD yoy Coho	No. SH Trout	Mean FL SH Trout	SD SH Trout
January	2	73	3.54	-	-	-	6	131	80.55
February	9	77	4.50	-	-	-	1	135	-
March	55	83	6.52	-	-	-	7	129	24.33
April	-	-	-	-	-	-	1	154	-
May	37	106	7.92	-	-	-	-	-	-
June	3	101	4.16	-	-	-	-	-	-
July	-	-	-	-	-	-	-	-	-
August	-	-	-	-	-	-	-	-	-
September	-	-	-	-	-	-	-	-	-
October	-	-	-	-	-	-	-	-	-
November	-	-	-	-	-	-	-	-	-
December	-	-	-	-	-	-	-	-	-

Recaptured PIT Tagged Fish 2011 and 2012

In 2011, we applied PIT tags to four sub-yearling coho salmon and recaptured one. It was at-large 85 days and grew 8 mm (0.09 mm/day). We also applied PIT tags to 96 juvenile steelhead trout and recaptured 11 (11.5%). The steelhead trout were at-large 13-225 days and grew 4-87 mm (0.04-0.46 mm/day). All but one of the steelhead trout were marked and recaptured in the site where they were originally tagged. The one steelhead trout that moved was marked in the old stream channel in May 2011 and recaptured in one of the new off-channel ponds in January 2012. It was at large 223 days and grew 87 mm (0.39 mm/day).

In 2012, we applied PIT tags to 94 yearling coho salmon and recaptured nine (9.6%). Coho salmon were at large 11-15 days and grew 5-10 mm (0.40-0.67 mm/day). All nine recaptured coho salmon were tagged and recaptured in the new off-channel ponds. We applied PIT tags to13 juvenile steelhead trout and did not recapture any of them. We did recapture one steelhead trout in a pond that we marked in the old Salmon Creek stream channel in June 2011 (see above).

PIT Tag Antenna Detections 2011/12 Season

We installed a PIT tag antenna at the opening of the second-most upstream pond in December of 2011. Between December 2011 and July 2012, NSA detected 80 coho salmon and 16 steelhead trout at the antenna site. Individual coho salmon were first detected on January 17, 2012 and last detected on July 6, 2012. Of the 80 coho salmon detected in the pond, 71 were tagged and released into the pond, seven were tagged in the adjacent pond downstream, one was tagged in the second pond downstream, and one was tagged in the old Salmon Creek stream channel in 2011. Seventy of the coho salmon were detected in the pond on more than one day. These fish had an average time between first and last detection (a surrogate for residence time) of 17 days (range 1-83 days). All of the coho salmon were originally tagged in the estuary so these fish had an average estuarine residence time of 18 days (range 1-104 days).

Individual steelhead trout were first detected on December 2, 2011 and last detected on May 25, 2012. Of the 16 steelhead trout detected in the pond, nine were tagged and released into the pond, one was tagged in the adjacent pond downstream, and six were tagged in the old Salmon Creek stream channel in 2011. Fourteen of the steelhead trout were detected in the pond on more than one day. These fish had an average time between first and last detection (a surrogate for residence time) of 36 days (range 1-130 days). All of the steelhead trout were originally tagged in the estuary so these fish had an average estuarine residence time of 125 days (range 3-315 days).

JACOBY CREEK POND

We sampled Jacoby Creek pond with minnow traps monthly from October to December 2012 and did not capture any fish. The pond was dry until the first significant rains in

November 2012. Even after rain and high stream flows filled the pond, dissolved oxygen (DO) levels were too low to support salmonids in November and December. However, DO was adequate from January to March 2013.

Wood Creek and Salmon Creek Off Channel Pond Water Quality

We found similar water quality patterns in off-channel ponds in Wood and Salmon creeks (Table 29). The off-channel ponds contained brackish water up to 25 ppt, until high winter stream flows flushed the salt water from the ponds in the winter. The ponds remained primarily fresh water during the winter and spring, until low stream flows allowed saltwater to once again reach the ponds in the late spring and summer. The ponds stratified so that brackish water was found along the bottom while remaining fresh near the surface. Water salinity tended to be higher and more persistent in the more downstream ponds on Salmon Creek (Table 29). Water temperatures in the ponds also followed a seasonal pattern, in that they were cool (i.e. 10-15°C) in the winter and spring but became too warm (i.e. >17°C) to support juvenile salmonids in the summer (Table 29). DO was often extremely low (<2 mg/l) in the warm brackish layer of the ponds during the summer and fall, especially in Wood Creek.

Meromixis, the warming and depletion of oxygen in the brackish layer of the water column, is often seen in lagoons along the California coast (Zedonis et al. 2007; Atkinson 2010). The ponds provide good water quality during the winter and spring and support juvenile salmonids rearing over winter in the SEE but become too warm and brackish with low dissolved oxygen during much of the summer and fall.

Past studies in the SEE of Humboldt Bay found that juvenile coho salmon preferred freshwater habitat with water temperatures ≤17°C (Wallace 2006; Wallace and Allen 2007, 2009, 2012). Bjornn and Reiser (1991) reported that preferred water temperatures were 12-14°C for Chinook and coho salmon and 10-13°C for steelhead trout and that conditions become life-threatening when temperatures exceeded 23-25°C. They also reported that salmonids function without impairment at DO levels near 8mg/l and were probably limited by levels <5mg/l. In the SEE of Humboldt Bay, juvenile coho salmon do not appear to rear in water >17°C while juvenile steelhead and cutthroat trout are often captured in areas as warm as 21°C (Wallace 2006; Wallace and Allen 2007, 2009, 2012). These same studies also typically captured juvenile salmonids in areas where DO levels were 5-7mg/l and often captured juvenile coho salmon in areas as low as 3.5 to 5mg/l. Ruggerone (2000) reported that juvenile coho salmon tolerated lower DO levels than other salmonids, often as low as 4mg/l.

Table 29. Typical differences in water temperature, salinity in parts per thousand (ppt), and dissolved oxygen in milligrams per liter (mg/l) in Salmon Creek at high (March 21, 2012) and low (June 13, 2012) stream flows and in Wood Creek at high (March 2, 2012) and low (June 5, 2012) stream flows.

Salmon Creek March 21, 2012 Water Quality Site	**Depth (feet)**	**Water Temperature (° C)**	**Salinity (ppt)**	**Dissolved Oxygen (mg/l)**
Pond 1 (time 1020 hrs)				
West Transect				
surface	0.5	10.1	0.1	9.92
middle	2.3	10.0	0.1	9.25
bottom	4.5	10.0	0.1	9.74
Pond 2 (time 1145 hrs)				
West Transect				
surface	0.5	10.7	0.1	7.98
middle	2.0	10.5	0.1	9.23
bottom	4.0	10.4	0.1	8.42
Pond 4 (time 1030 hrs)				
Inside Transect				
surface	0.5	10.3	0.1	9.13
middle	2.0	10.2	0.1	9.46
bottom	4.0	10.3	0.1	8.83
Salmon Creek June 13, 2012 Water Quality Site	**Depth (feet)**	**Water Temperature (° C)**	**Salinity (ppt)**	**Dissolved Oxygen (mg/l)**
Pond 1 (time 0945 hrs)				
West Transect				
surface	0.5	13.7	2.2	8.68
middle	2.0	16.4	12.0	6.03
bottom	4.0	19.8	22.0	6.68
Pond 2 (time 1040 hrs)				
West Transect				
surface	0.5	14.7	1.1	6.13
middle	1.5	15.2	1.1	6.82
bottom	3.0	19.5	13.8	6.54
Pond 4 (time 1245 hrs)				
Inside Transect				
surface	0.5	17.4	2.1	8.63
middle	-	-	-	-
bottom	2.0	25.7	24.5	7.61
Wood Creek March 2, 2012 Water Quality Site	**Depth (feet)**	**Water Temperature (° C)**	**Salinity (ppt)**	**Dissolved Oxygen (mg/l)**
surface	0.5	6.9	0.2	6.30
middle	2.0	10.0	4.4	5.79
bottom	4.0	13.4	6.8	0.78
Wood Creek June 5, 2012 Water Quality Site	**Depth (feet)**	**Water Temperature (° C)**	**Salinity (ppt)**	**Dissolved Oxygen (mg/l)**
surface	0.5	14.9	2.4	5.46
middle	2.0	18.8	16.5	4.89
bottom	4.0	17.6	16.6	3.32

Discussion

This paper presents two years of data from an on-going ten year study of juvenile salmonid use of the SEE of Humboldt Bay. In Freshwater Creek Slough, CDFW has its longest continuous juvenile salmon data set in Humboldt Bay, NSA captured relatively large numbers of sub-yearling coho salmon in 2011 and especially 2012 compared to past years (Table 30). The CPUE of sub-yearling coho salmon in 2012 was by far the highest ever recorded by our project (Table 30). Also, 2011 and 2012 were the first years that peak CPUE of sub-yearling coho salmon occurred in any month besides June or July. Conversely, the mean monthly FL of sub-yearling coho salmon was smaller in 2011 and especially 2012 than most other years suggesting high sub-yearling coho density inhibits their growth in the SEE (Figure 5). PIT tagged sub-yearling coho salmon mean residence times of nearly two months (ranging up to six months), and growth rates of about 0.2 mm/day of in the SEE of Freshwater Creek Slough were similar to past years (Table 8).

NSA found that in 2011 and 2012 juvenile salmonids were also rearing in the SEE of Wood Creek and Ryan Creek and that fish would move throughout the entire Freshwater-Wood-Ryan SEE. Residence times of PIT tagged juvenile coho salmon ranged from 6-245 days in Wood Creek and 13-225 days in Ryan Creek. Residence times of PIT tagged juvenile steelhead trout ranged from 14-335 days in Freshwater Creek and 13-158 days in Ryan Creek. PIT tagged cutthroat trout reared for 14-155 days in Ryan Creek. We detected tagged juvenile salmonids from throughout the Freshwater and Ryan Creek basins at our PIT tag antennas on Wood Creek (Table 15). Also, GDRC biologists captured juvenile salmonids tagged by NSA and AFRAMP in Freshwater Creek and Slough at their migrant traps in Ryan Creek. These observations demonstrate that juvenile salmonids rear and move throughout the entire Freshwater-Wood-Ryan SEE. Therefore, it is important to maintain and enhance connectivity between the streams entering the SEE.

This and earlier studies by NSA (Wallace 2006; Wallace and Allen 2007, 2009, 2012; CDFG 2006, 2007, 2008, 2009, 2010) showed that sub-yearling and yearling coho salmon, as well as a wide size range of juvenile steelhead trout routinely reared in the SEE for months. There appears to be at least three basic life history strategies exhibited by juvenile coho salmon in Humboldt Bay tributaries (Wallace 2006; Wallace and Allen 2007, 2009, 2012; CDFG 2006, 2007, 2008, 2009, 2010).

One strategy is sub-yearling coho salmon move to the SEE during spring and reside there throughout the summer and fall with at least some continuing to rear in the SEE throughout the winter and into the spring. The second strategy is as stream flows increase in the fall or winter, there is a large-scale redistribution of coho salmon from stream habitat downstream to the SEE of Humboldt Bay tributaries. The capture and detection of PIT tagged fish by NSA has documented the arrival of "stream-rearing" coho salmon to the SEE in the fall and winter in Freshwater and Ryan creeks. Juvenile coho salmon throughout the Humboldt Bay watershed redistribute themselves, primarily downstream, to over-winter in low gradient habitat of the SEE of Humboldt Bay. This “fall redistribution” of coho salmon into winter habitat has been observed by other researchers throughout the Pacific Northwest (Koski 2009) including the Klamath River Basin (Soto et al. 2008; YTFP 2009;).

The SEE provides rearing habitat for a large portion of juvenile salmonids in Humboldt Bay tributaries. By operating two downstream migrant traps on Freshwater Creek, one just upstream of the SEE and the other in the SEE, CDFW estimated the numbers of smolts passing each site and found that about 40% of coho salmon smolts and 80-90% of large steelhead trout smolts originated from the SEE of Freshwater Creek in 2007 and 2008 (Ricker and Anderson 2011). Our studies also showed that juvenile salmonids using this habitat experienced faster growth, obtained a larger size, and therefore likely were larger when entering the marine environment (Wallace 2006; Wallace and Allen 2007, 2009, 2012; CDFG 2006, 2007, 2008, 2009, 2010).

However, there does appear to be density dependent growth in at least Freshwater Creek Slough. This study found that monthly mean FL of sub-yearling coho salmon was negatively correlated to their June-September CPUE (Table 30 and Figure 5). This suggests that in summers of high sub-yearling coho salmon abundance in the SEE, growth rate is muted compared to lower abundance years. Restoring and increasing SEE habitat could result in greater numbers of juvenile coho salmon rearing in the ecotone or at least lowering the density of rearing coho salmon resulting in larger sized fish entering the winter season.

Poor over-winter survival has been suggested as limiting production of juvenile salmonids in Freshwater Creek (Ricker and Anderson 2011) and coho salmon in other watersheds throughout the Pacific Coast of North America (Nickelson et al. 1992; Quinn and Petersen 1996; Ebersole et al. 2006). For example, Ricker and Anderson (2011) found coho salmon smolt production estimates from Freshwater Creek in the spring were relatively stable across years at around 3,000 fish even though the abundance of yoy coho salmon the previous fall varied greatly. This led them to conclude that over-winter habitat was limited most years capping the production of juvenile coho salmon in the stream portion of Freshwater Creek. They speculated that many fish moved downstream to the SEE in the fall and winter prior to installation of smolt traps in March.

Numerous studies have concluded that low gradient habitats such as the SEE, as well as marshes, wetlands, off-channel pools, and beaver ponds provide favorable over-winter habitat resulting in faster fish growth in coho salmon, higher over-winter survival rates, and larger sized smolts than other stream habitats (Quinn and Petersen 1996; Miller and Sadro 2003; Ebersole et al. 2006; Ricker and Anderson 2011). Ricker and Anderson (2011) found over-winter survival in low-gradient reaches 2-6 times higher than the other sampled reaches. In addition, increasing aquatic habitat connectivity between rearing habitats can increase survival and the resiliency of populations (Bisson et al. 2009). In tributaries entering Humboldt Bay, most of the low-gradient over-winter habitat appears to occur in the SEE (Wallace 2006; Wallace and Allen 2007, 2009, 2012; Ricker and Anderson 2011), with the best examples being non-natal tidal tributaries that are connected to streams containing “source” populations of salmonids (e.g. non-natal Wood Creek connected to source population in Freshwater Creek).

Table 30. Effort, number captured, and catch-per-unit-effort of sub-yearling coho salmon in Freshwater Creek Slough during June-September, 2006-2012.

Year	Effort (No. Seine Hauls)	No. Fish Captured	Catch-per-unit-effort (No. fish/haul)
2006	204	420	2.06
2007	168	101	0.60
2008	188	11	0.06
2009	104	247	2.38
2010	87	73	0.84
2011	108	264	2.44
2012	101	1,340	13.27

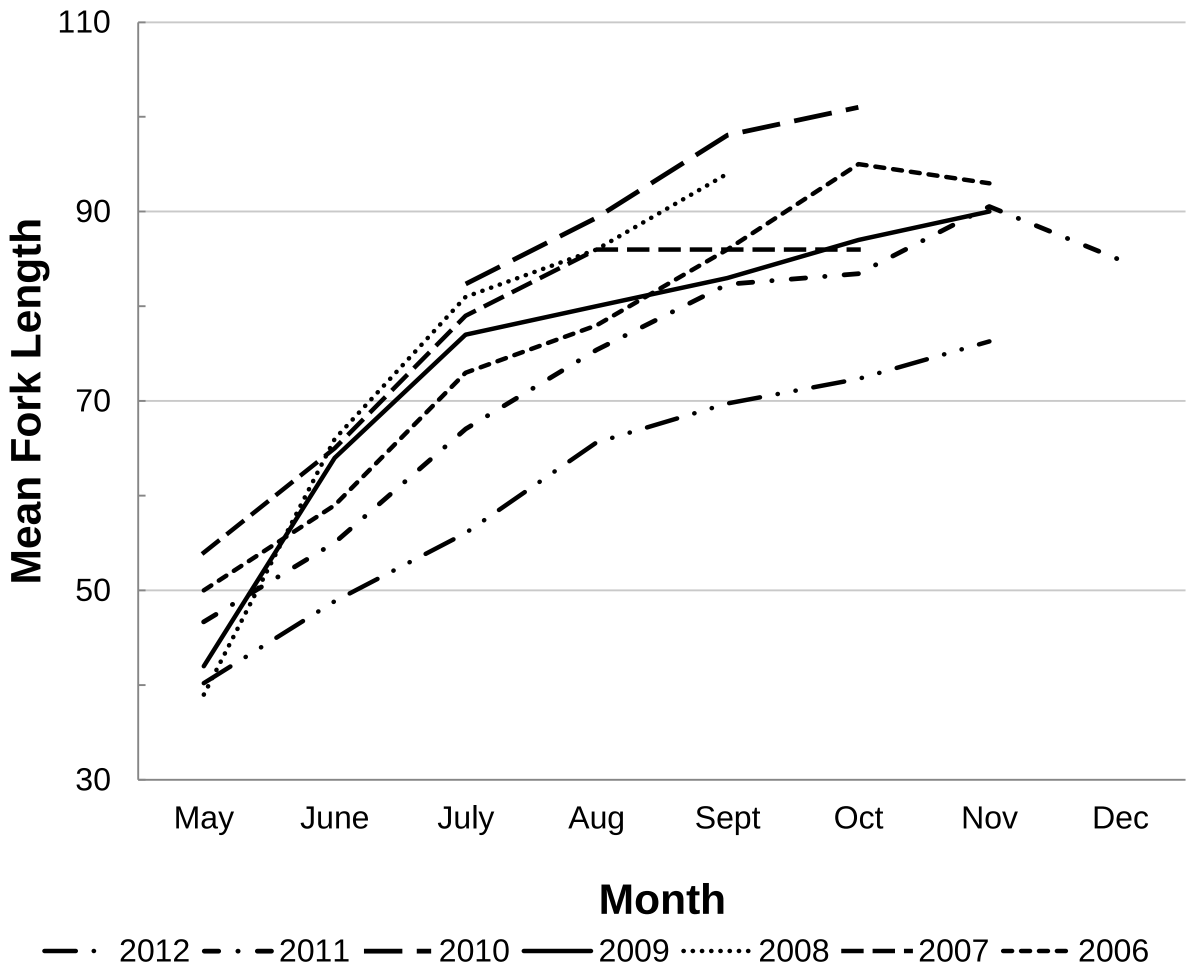

Figure 5. Mean monthly fork lengths of sub-yearling coho salmon captured in Freshwater Creek Slough, 2006-2012.

Restoring estuary function has also been recognized as a major recovery task for listed salmon and steelhead trout by CDFW and National Marine Fisheries Service (NMFS). It appears the habitat restoration projects in the Humboldt Bay SEE are benefitting juvenile salmonids. This study has shown that juvenile salmonids, especially coho salmon, utilize newly constructed off-channel habitat constructed in Wood and Salmon creeks and reared in these habitats for weeks to months. In Salmon Creek, off-channel ponds were constructed in 2011, and NSA captured more juvenile coho salmon in the ponds the first year after they were constructed than the previous seven pre-project years combined. We also documented heavy use of the newly constructed pond in Wood Creek and that growth rates in the pond was higher than surrounding habitat (Wallace 2010). It is not known how these ponds will be utilized over time and as they change, so efforts to continue monitoring habitat conditions and fish utilization is highly recommended.

Recent reports have documented a coast-wide pattern of juvenile coho salmon utilizing estuaries (Miller and Sadro 2003; Koski 2009; Jones et al. 2014) and have determined that movement to the estuary or other off-channel habitats increases their life history diversity and population resilience increasing the chance to recover these species (Koski 2009). Since the ability to restore complex estuarine ecosystem functions is contingent upon a landscape perspective to restoration planning (Simenstad et al. 2000) and will likely not be achieved through isolated manipulation of individual elements (National Research Council 1992), fishery managers and restoration scientists will need to take several actions.

The actions include gauging the relative success of these restoration projects, developing appropriate habitat criteria targets, determining which restoration techniques work best, and determining how these restoration projects ties into the greater ecosystem functions. By first recognizing, and then understanding the role of the entire estuarine rearing stage in juvenile salmonid life history, we will be better able to form effective restoration and management practices to help recover anadromous salmonids.

The SEE surrounding Humboldt Bay is important to juvenile salmonids, especially coho salmon, because 1) it supports multiple life stages; 2) juvenile salmonids rear in the ecotone for significant periods of time; 3) a significant portion of the populations utilizes the ecotone; and 4) salmonids rearing in the ecotone grow faster and larger than their cohorts rearing upstream in stream habitat.

Management Recommendations

Several on-going and new activities should be undertaken to both better understand the ecological relationship of Humboldt Bay's SEE and how such relationships can better guide recovery and management actions in the future.

- Juvenile salmonids in SEE of Humboldt Bay should continue to be monitored on a year-round basis to determine seasonal and annual variation in their use of this habitat.

- Surveys in Humboldt Bay should be conducted to determine if juvenile salmonids use the bay for rearing, and if so, determine how long do they stay and what habitats (e.g. eel grass beds) they utilize.

- An inventory of small streams entering the tidal portion of the major Humboldt Bay tributaries should be made to determine if they could provide suitable summer rearing habitat for sub-yearling coho salmon and other estuarine species. The establishment of cool freshwater habitat at the mouths of small streams entering the SEE could potentially increase the rearing area for sub yearling coho salmon during the summer and probably more importantly provide refuge from high velocity flows for yearling coho salmon in the winter and early spring.

- Habitat adjacent to Humboldt Bay tributaries in the SEE should be restored as the opportunity arises, because juvenile salmonids will use available tidal sloughs, off-channel ponds, and very small non-natal tributary habitat adjacent to the mainstem streams and sloughs.

- One cohort of invasive Sacramento pikeminnow was captured in an off-channel pond in the SEE of Elk River in 2008 and again in 2010. CDFW and others conducted a large eradication effort that was hopefully successful in removing them from the system. Since numerous plans to construct off-channel ponds are now planned or implemented to increase coho salmon over-winter rearing habitat around Humboldt Bay, continued, periodic, monitoring of all off-channel ponds is needed in insure Sacramento pikeminnow or other invasive predators do not colonize these habitats around Humboldt Bay.

- SEE habitat restoration projects should be monitored to assess their effectiveness and provide information and guidance to CDFW, NMFS, and the restoration community to improve future restoration activities.

- Fisheries and natural resource managers should examine return rates of PIT tagged salmonids to determine if they can assess marine survival rate of juvenile salmonids reared in SEE versus fish that did not rear in SEE.

ACKNOWLEDGMENTS

Thank you to Eric Ojerholm for being a great field crew leader and to Jane Sartori and Melissa Reneski for their expert fieldwork. Thank you to Mark Zuspan for setting up and maintaining the PIT tag antenna arrays. Also thank you to M. McDowall, G. Morningstar, B. Crouch, C. Meredith, T. Newhouse, M. Gilroy, and G. Garman for assisting with fieldwork. Thank you to Seth Ricker, Michelle Gilroy, and Justin Garwood for helping with project design, discussing ideas, and sharing their knowledge about salmonid ecology. Thank you to Linda Miller for creating the maps in this report. Thank you to three anonymous reviewers who provided many comments that greatly improved the quality of this report. This project was funded by Aid in Sport Fish Restoration Project # F-137-R and the California Department of Fish and Wildlife's Fishery Restoration Grants Program. Fisheries Technicians and administrative support was provided by the Pacific States Marine Fisheries Commission under contracts P0810517 and P0610522. Finally, thank you to the Northcoast Regional Land Trust, Jacoby Creek Land Trust, USFWS Humboldt Bay National Wildlife Refuge, Cities of Eureka and Arcata, Green Diamond Resources Company, and the other private landowners for allowing us to access their property. The manuscript of this Fisheries Administrative Report was reviewed and edited by Kevin Shaffer, Dr. Russ Bellmer, and three Department of Fish and Wildlife anonymous, peer reviewers. The manuscript was submitted June 2013 and reviewed by Kevin Shaffer, Dr. Russ Bellmer and 3 Department anonymous, peer reviewers.

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