The Role Of The Klamath River Mainstem Corridor In The Life History And Performance Of Juvenile Coho Salmon (*Oncorhynchus kisutch*)

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REPORT AUTHORSHIP

The study is jointly managed and overseen by the Karuk and Yurok tribes. The order of authorship on jointly authored reports as part of this study is rotated annually between the two staffs.

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The Role Of The Klamath River Mainstem Corridor In The Life History And Performance Of Juvenile Coho Salmon (*Oncorhynchus kisutch*)

1.0 Introduction

In 2006, the U.S. Bureau of Reclamation (USBR) funded the Karuk and Yurok tribes to initiate a multi-year study to assess key aspects of seasonal life history tactics of juvenile coho (*Oncorhynchus kisutch*) within the mainstem Klamath River corridor. The study began with a focus on just overwintering habitats in and along the mainstem river. Phase 1 tasks covered the period between October 2006 through March 2007. Following Phase 1, the scope of the study was enlarged to address habitat utilization patterns of pre-smolt juvenile coho in all seasons.

The Phase 1 report, submitted in December 2008, presented results through May 2007. Data gathered in April-May of 2007 were included so that the report covered both the overwintering and smolt phases for the same cohort of fish. The performance of overwintering fish often cannot be assessed until their seaward migration—hence the reporting period was broadened for the sake of completeness.

This report presents results for Year 2 of the project and covers the period May 2007 through May 2008. It generally addresses life history patterns and habitat use of juvenile coho produced in brood year 2006. These fish were the progeny of parents that spawned in winter 2006-07, emerged from the gravel as fry in spring 2007, then emigrated seaward as smolts in spring 2008. The reporting period is extended for certain aspects of the results to include some data collected in June and July of 2008 due to a protracted smolt migration that occurred that year.

The purpose of the study is to assess how juvenile coho seasonally utilize the range of habitats that exist within the mainstem Klamath River corridor prior to seaward smolt migration. The term "mainstem Klamath River corridor" is meant to encompass the main river channel and its side channels, off-channel habitats (alcoves, ponds, and groundwater channels associated with the floodplain), lower reaches of small tributaries—including their confluences with the mainstem, and the estuarine zone from the head of tidal influence to the river mouth.

The primary purpose of activities covered during this reporting period was twofold: (1) to continue to investigate methods for effective assessment, particularly within the mainstem river; and (2) to make progress on assessing life history and habitat use patterns within the mainstem corridor. Phase 1 activities had been aimed at performing a reconnaissance of potential types of coho overwintering habitats within the mainstem corridor and to evaluate various methods of capture and marking that could be effective at assessing overwintering habitat use. During the course of Phase 1, certain activities were expanded to initiate a level of semi-continuous monitoring at one site to begin assessing movement patterns. Those activities were continued, and broadened, during Year 2.

Knowledge gained through this study is deemed critical in understanding the role of mainstem corridor habitats to the overall performance of Klamath River wild coho. Such understanding is needed to evaluate the implications of flow regulation to the performance of juvenile coho that use the mainstem river for some portion of their life history. In addition, the study will provide needed information to guide the development of potential habitat enhancement and restoration projects to improve the survival of juvenile coho that use mainstem corridor habitats. Moreover, project results will provide valuable information in recovery planning for Klamath coho, which is a listed species within the Klamath watershed under the ESA.

1.1 Background

Seasonal distribution and habitat use patterns of pre-smolt juvenile coho within the mainstem river corridor of a large river like Klamath are related to flow and temperature patterns, as well as to the types and distribution of available habitats (Lestelle 2007). Significant movements of juvenile coho in Pacific Northwest rivers often occur on increasing or declining limbs of either the temperature or flow pattern or both. Movements are believed to be triggered or strongly influenced by these patterns. Figure 1 displays patterns of water temperature (Mike Deas, *personal communications*) and river flow (derived using USGS data) for the lower Klamath River. Evidence exists that juvenile coho movements within the mainstem corridor of this river are related to these patterns.

These movement patterns of juvenile coho can generally be described as follows. Immediately following emergence from spawning gravels during spring[1], some coho fry disperse downstream. In rivers fed by snow-pack, this dispersal can be facilitated in part by spring runoff. Some of these fry move into the mainstem river, where they might find low-velocity habitats to colonize. Such habitats in mainstem rivers are primarily edge units along the river shoreline or within backwater units (Beechie et al. 2005; Lestelle 2007). Some of these dispersing fry can also move into off-channel habitats, such as ponds and floodplain channels, if available. Once this initial dispersal ends and fry find suitable habitats, movement to new locations slows significantly and they begin rearing within localized areas. Subsequently, as water temperatures increase, and if reaching high enough levels, the juveniles can initiate another movement in search of thermal refuge. This pattern of movement in response to high water temperatures is strongly evident in the Klamath basin (Sutton et al. 2002; Deas and Tanaka 2006; Sutton 2007; Sutton 2009). Within the mainstem corridor, some juveniles find thermal relief either at sites of cold water seeps in the mainstem river or in the lower reaches of cool water tributaries.

After temperatures in the mainstem river reach critical thresholds for juvenile coho, it appears that the redistribution ceases—though it is expected that some fish would attempt to move if conditions of flow or temperature pose likely death.[2] Sites that juvenile coho inhabit at this time

[1] / Spawning principally occurs in tributaries to mainstem rivers for wild fish, but it also occurs to a more limited extent in some areas of mainstem rivers under certain conditions.

[2] / While the redistribution on a large scale (i.e., between mainstem reaches) seems to stop, some movement appears to continue at a smaller scale between habitat units. Observations suggest that some fish move daily between the lower end of some cool water tributaries and adjacent habitat units in the mainstem according to the diurnal temperature pattern, thereby taking advantage of the greater food supply in the mainstem river as temperatures allow. Summer temperatures in the mainstem can also decline during summer thunderstorms or other weather related cold spells, allowing for some amount of movement on a somewhat larger scale. We have observed such

must necessarily also provide low-velocities, such as those occurring within edge units and backwaters within the mainstem river. The suitability of rearing sites in summer, and especially in winter, is strongly determined by water velocity—slow being better.

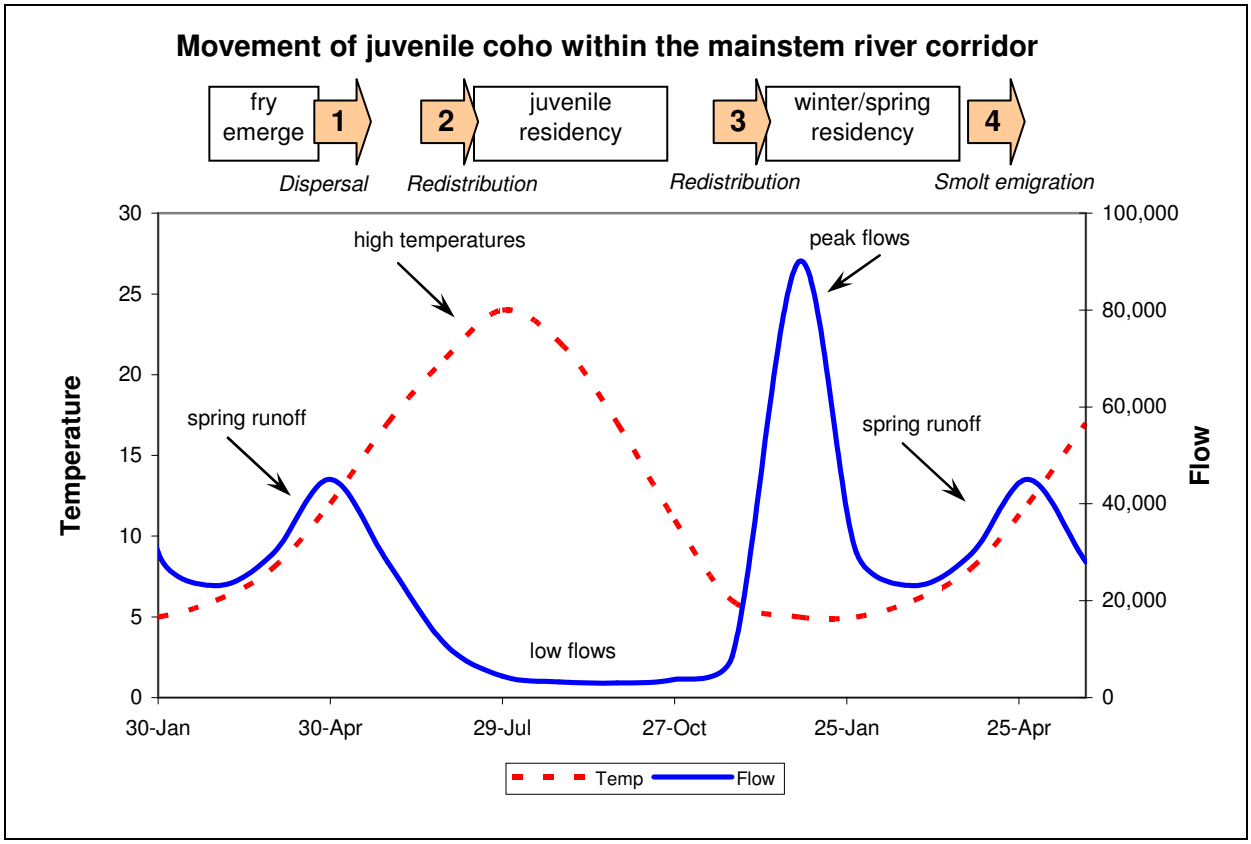


Figure 1. Movement patterns of juvenile coho expected within the mainstem Klamath River corridor corresponding to temperature and flow patterns. (1) Fry that disperse from natal tributaries enter the mainstem corridor during spring runoff. (2) Some juveniles within corridor habitats move again in early summer with rising water temperatures in search of thermal refuge. Little movement is believed to occur for the remainder of summer. (3) Another redistribution is expected to occur in fall and early winter during periods of increased flows as juveniles search for suitable overwintering habitats. Rate of movement slows significantly following the bulk of redistribution with stable residency following. (4) Smolt migration begins in early spring.

As water temperatures decline in September, juvenile coho generally remain associated with the localized areas in which they had been rearing. No extensive movement pattern is evident at this time in Pacific Northwest streams, though some movement over short distances is known to occur (Kahler et al. 2001). We hypothesize that limited movement would occur if the fish had been concentrated into thermal refugia that do not have adequate cover or food.[3] Within the mainstem corridor, juvenile coho during the late summer period are most likely to be found in edge and backwater units of the mainstem river, in some off-channel habitats having access

movement in one case by documenting travel of one fish (PIT tagged) of approximately 12 miles between two tributaries (Tom Martin and Fort Goff creeks) to the mainstem river.

[3] / The documented movement by the PIT tagged fish mentioned in footnote 2 provides evidence for this hypothesis.

during earlier movements (and suitable temperatures during the hot part of summer), and in the lower portions of both non-natal and natal tributaries. Their distribution and abundance at this time are the result of prior movements and various factors affecting survival, including the severity of summer high temperatures and low flows.

With the advent of fall rains and increasing flows, some juvenile coho are known to undertake another redistribution movement to find habitats more suited to overwintering (Peterson and Reid 1984; Soto et al. 2008). These movements are known to cover up to 40 miles in some rivers and it is suspected that distances traveled might exceed 250 miles in some cases, such as in the Fraser River (see discussion in Lestelle 2007). Large numbers of fish have been found immigrating into very small off-channel habitats adjacent to mainstem rivers. This redistribution is one of the most remarkable aspects of juvenile coho life history that has been observed. One of the primary objectives of this study in the Klamath River is to learn the extent and importance of such movements in this river. We found during Phase 1 that overwintering movements appear to be an important life history tactic for survival in the Klamath basin.

Once the fall-early winter redistribution is over, juvenile coho remain relatively stable in their habitat residency through the remainder of winter and into spring. Following a spurt of high growth in early spring, surviving juvenile coho begin the smolt transformation and start their seaward migration, which typically peaks in April and May in the Klamath basin.

This study is designed to improve understanding about these life history tactics within the mainstem Klamath River corridor.

1.2 Project Objectives

The objectives of this multi-year study are as follows:

1. Identify and describe habitats used by juvenile coho seasonally within the mainstem Klamath River corridor;
2. Assess seasonal movement patterns of juvenile coho into and out of habitats being used within the mainstem corridor;
3. Assess relative rates of seasonal utilization by juvenile coho within the range of habitats in the mainstem corridor;
4. Assess measures of seasonal performance of juvenile coho to the extent feasible (growth, survival, length of residency in different habitats); and
5. Assess the significance of life history tactics that use the corridor to the overall Klamath coho populations.

Objective 1 addresses the question: What habitats are used by juvenile coho within the mainstem corridor during spring of fry emergence, summer, late summer/early fall, and winter? These habitats are to be identified and described.

Objective 2 addresses the question: What are the seasonal movement patterns by juvenile coho into and out of the types of habitats that occur within the mainstem corridor? This objective aims to describe temporal and spatial patterns of movement associated with mainstem corridor

habitats, and to learn how these patterns correspond with environmental factors, such as flow and temperature.

Objective 3 addresses the question: To what extent are the different habitats in the mainstem corridor utilized by juvenile coho and how does utilization vary by season? This objective aims to assess in a relative way the magnitude of use of the different habitats within the corridor, e.g., which habitats have the most affinity for juvenile coho. (This objective does not aim to assess the relative extent that corridor habitats are used by the Klamath basin coho population as a whole, since the scope of the study does not extend outside the mainstem corridor. The results of this study will be useful, however, in considering this aspect as more is learned about coho production levels in the various subbasins.)

Objective 4 addresses the question: How well do juvenile coho perform by season in different types of habitat within the mainstem corridor? Performance can be measured by survival, growth and size, and length of residency within a habitat.[4] This objective aims to learn, using one or more of these performance measures, the relative benefit to performance that different habitats provide within the mainstem corridor.

Objective 5, which has been added to the project based on discussions with Keith Schultz of the Bureau of Reclamation, addresses the question: What is the overall importance to the performance of Klamath coho populations of life history tactics that use the mainstem corridor to complete their life cycle prior to smolt emigration? Some juvenile coho use various habitats within the corridor during summer and/or winter prior to exiting the river as smolts. But if the number of these fish is very small compared to those that rely on rearing within natal tributary streams, then the overall importance of the corridor to the populations could be relatively minor. No determination has been made of the relative numbers of fish that might be successfully using corridor habitats to complete their life cycles. However, even if the numbers of fish that use the corridor are relatively small compared to those relying entirely on natal tributary habitats, survival within corridor habitats could be high compared to that in natal tributaries, or growth enhancement by corridor habitats could boost marine survival rates compared to that experienced by fish that smolt from natal tributaries. This objective, therefore, would aim to determine the overall importance of corridor habitats to the performance and recovery of Klamath coho populations. Objective 5 would help priortize recovery actions that focus habitat restoration on habitats within the corridor.

Objectives 1-4 were addressed during Year 2 activities. Objective 5 is to be taken up as the project continues to go forward and new information is collected. It is envisioned that Objective 5 will be addressed in part in the Year 3 report, which will be completed during 2010. As the

[4] / Survival and growth (or size) during a season or life stage are direct measures of how well animals perform in their environment. These performance measures, when combined across all life stages, determine how successful different life history strategies are in sustaining themselves and in contributing to overall population viability. These two measures, however, are difficult to assess for fish that move between habitats during a season. Survival is particularly difficult to measure in most types of riverine settings. The third measure listed, length of residency, can serve as an index of habitat quality (hence, survival). High residence time (or fidelity) is considered to be indicative of comparatively favorable rearing conditions under certain environmental conditions (based on Van Horne 1983, Winker et al. 1995, and Bell 2001; see discussion in Hillemeier et al. 2007).

project progresses beyond Year 3 it is expected that this objective will become more of the focus of field research.

1.3 Organization of Report

The report is organized into four sections:

1. Introduction;
2. Project design and approach;
3. Identification and description of river corridor habitats;
4. Assessment of juvenile movement patterns;
5. Assessment of habitat utilization rates; and
6. Assessment of seasonal performance.

2.0 Project Design and Approach

The project has been designed to extend over a minimum of three years—having begun in 2006. Year 1 was aimed at a reconnaissance of potential overwintering habitats within the Klamath River corridor and at methods evaluation (Soto et al. 2008). Year 2 (May 2007-May 2008) focused on continuing methods evaluation and at making progress towards Objectives 1-4. Year 3 (May 2008-May 2009) will continue to make progress towards Objectives 1-4, while beginning to assemble information to aid in addressing Objective 5.

The project is expected to continue beyond Year 3, as it is apparent that to adequately address the objectives requires consideration of interannual variation in environmental factors—such as flow—in conjunction with variability in spawning escapement. Data summarized in Section 3.0 show that extreme variation in flow conditions occurs between years, which likely affects the extent that certain life history tactics are manifested in any given year. This matter is discussed further in Section 3 of this report.

Coho spawning escapements are also known to vary widely in the Klamath basin, and spatial distribution of spawners can vary significantly between years. Of the three coho brood lines (Klamath coho spawners are almost entirely 3-year olds, which means there are three more or less distinct brood lines in the population), one brood line appears to be much stronger than the other two, at least in the Mid-Klamath area. The strong brood line occurred in brood year 2007 (producing the 2009 smolts) and is expected again in 2010. This means that within the three initial years planned for the study, only one is expected to provide information from a strong brood year. Results reported in this report, as well as those in the Phase 1 report, represented relatively weak brood years.

The project was designed to be collaborative with other studies in the basin, particularly with those that use PIT tag technology for assessing coho movement patterns. Studies being conducted by the CDFG in the Shasta River provide the means to PIT tag juvenile coho in the Shasta River, which is useful for helping to assess movements of those fish downstream into the Klamath River corridor as part of our study.

The study is being conducted in the mainstem Klamath River between the river mouth and the confluence of the Shasta River. Responsibilities have been divided so that Yurok staff are responsible for work conducted downstream of Trinity River, while Karuk staff are focusing on areas upstream of that point (Figure 2). Personnel from both staffs assist one another in carrying out certain sampling (electrofishing with a boat unit) within the mainstem river. A scientific advisor with extensive experience in studying coho life history is providing assistance in study design, implementation, and analysis.

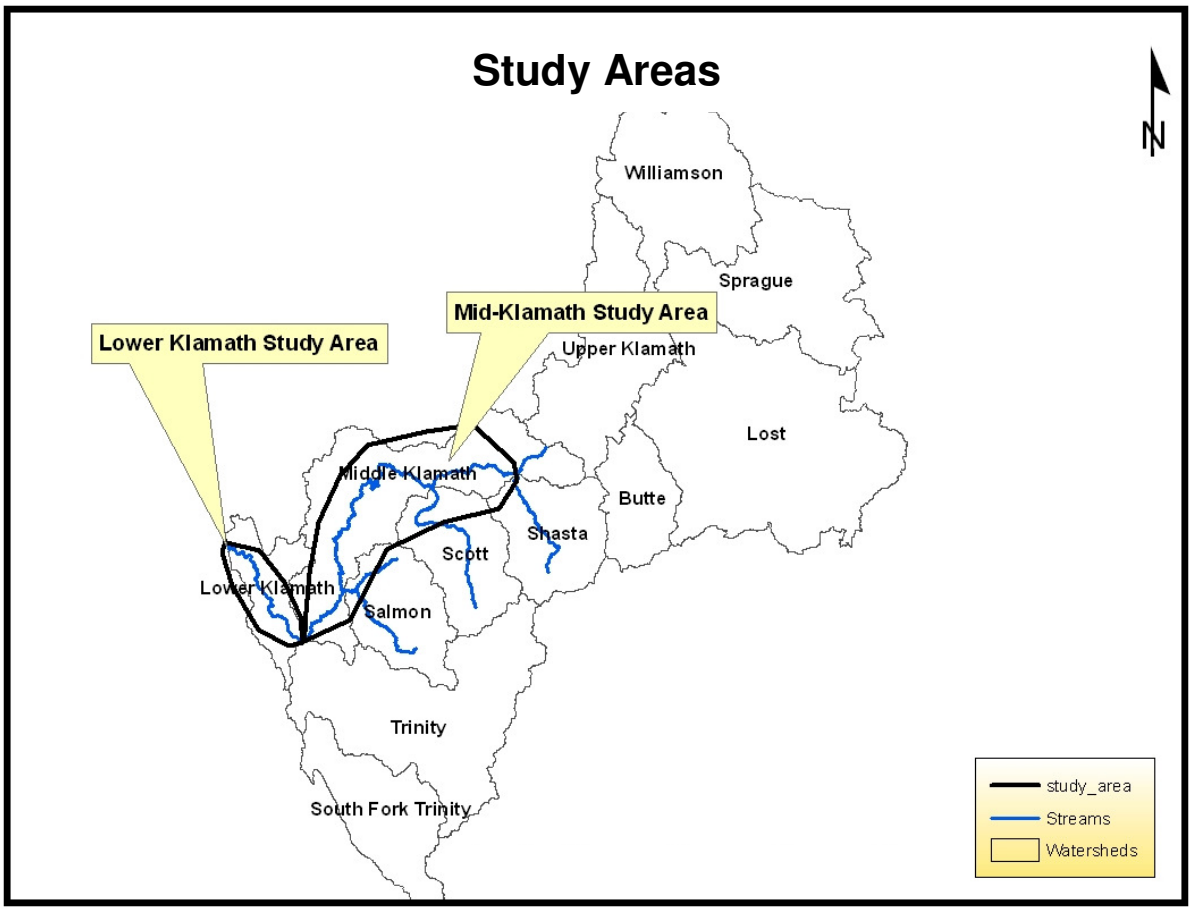


Figure 2. Study areas within the mainstem Klamath River corridor. Yurok staff are responsible for activities in the lower river study area. Karuk staff are responsible for activities in the mid-Klamath study area. Subbasins within the watershed are also delineated.

The sampling design for the project is formulated around the major events that affect movement and habitat use patterns (Figure 3). Due to the widely different characteristics of the mainstem river compared to the other adjoining habitats within the mainstem corridor (i.e., lower ends of tributaries and off-channel habitats), different strategies for sampling in these areas need to be applied.

Sampling within the mainstem river is conducted during specific time windows following periods of expected redistributions (Figure 3). During these time windows, residency within the various habitat types is expected to be relatively stable. Within off-channel habitats and the lower portions of non-natal and natal tributaries, sampling using capture gear or by snorkel

observations occurs during both the periods of movement and the time windows when stable residency should prevail (Figure 3). Sampling at these locations (i.e., out of the mainstem) during expected periods of movement provides empirical data on movement timing and relative extent of movement.

Marking and tagging of fish and their subsequent recovery are key components of all aspects of the project. Years 1 and 2 were aimed at developing the techniques and the overall distribution of effort of marking/tagging and recapture activities to lead to a major emphasis on assessing movement patterns in Year 3 (May 2008-May 2009). It is noted, however, that methods development continued into Year 3 as several stationary PIT tag detectors were installed to aid in the assessing movement patterns from PIT tagged fish.

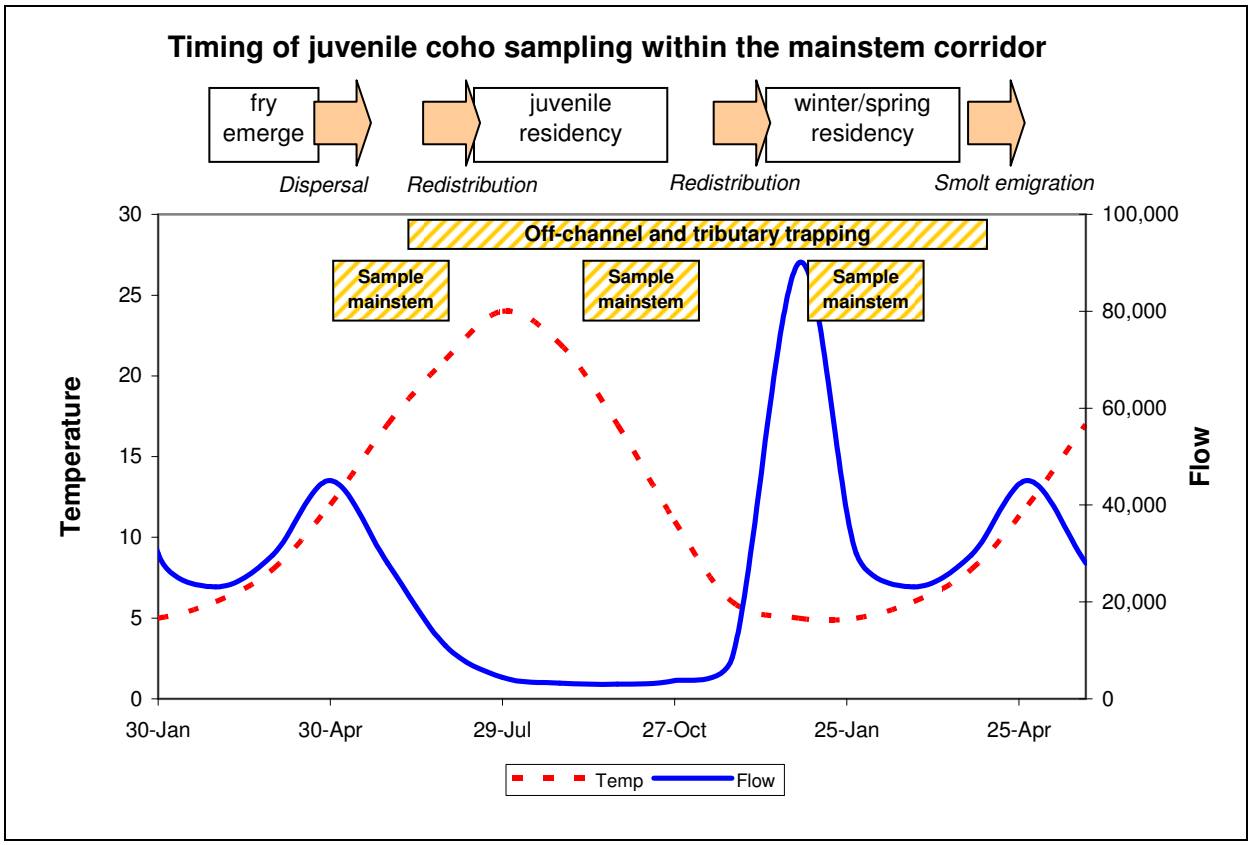


Figure 3. Timing of sampling within the mainstem Klamath River corridor during spring, summer, fall, and winter seasons. Off-channel sites and the lower portions of selected tributaries are to be sampled using a variety of capture and observation methods. Mainstem river habitats are to be sampled during three periods: (1) following fry dispersal and prior to the redistribution associated with rising temperature; (2) after temperature related movements have ceased and prior to the fall/winter redistribution; and (3) following the fall/winter redistribution.

3.0 Identification and Description of River Corridor Habitats

This section provides general descriptions of different types of habitats used within the mainstem corridor by juvenile coho during spring, summer, fall, and winter prior to their seaward emigraion as smolts. The presentation follows closely from what was presented in the Phase 1 report. The descriptions provided here are meant to show the kinds of habitats within the corridor and how they vary longitudinally along the river. More complete descriptions of these habitats as they provide both summer and winter use for juvenile coho is still under development and will be provided in the Year 3 report.

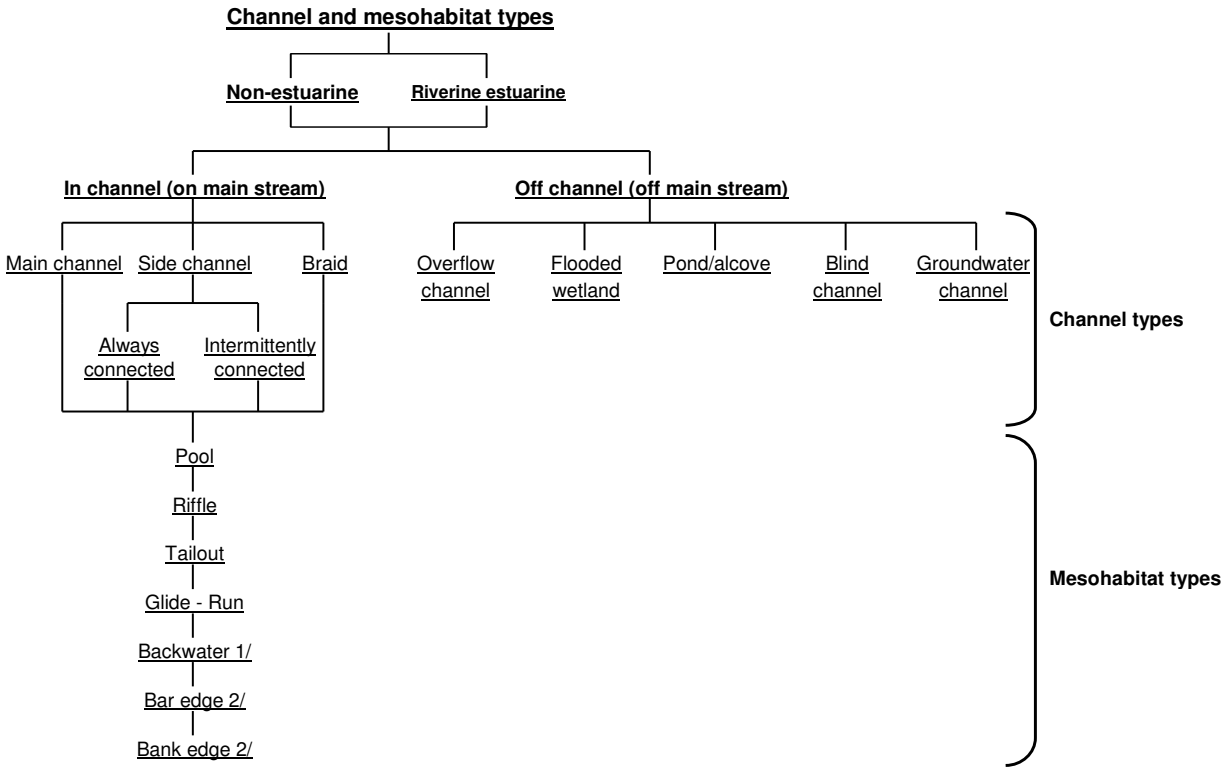
3.1 Methods

Habitat types used by juvenile coho within the river corridor can be classified by their channel type and, at least for in-channel habitats, by mesohabitat type (Figure 4). Those within the Klamath River estuary can generally be classified by the same types, since the estuary is largely contained within the forested riverine/tidal zone, where habitat types are comparable to those upstream, though often on a larger scale.[5]

The habitats are identified as being within the mainstream of the river or on the floodplain of the river. In broad terms, therefore, we classify habitats as being in-channel or off-channel with respect to the active flowing stream. In-channel habitats include those within the mainstem channel, including its side channels. Side channels are classified as being always connected across all flows at both the upstream and downstream ends of the channel, or as being intermittently connected depending on flow. Mesohabitat types of interest within the in-channel portion of the stream include not just pool and riffle features, but also backwater units, bank edges, and bar edges. Backwater units and edge habitats are of particular relevance to coho utilization due to their low velocities and potential for having cover structure.

Off-channel features are of particular interest in this study due to their strong attraction for juvenile coho, especially in winter (Lestelle 2007). These geomorphic features tend to be associated with the inside of meander bends. While scientists find it helpful to categorize them into types (such as shown in Figure 4), they really are a continuum of features caused by channel migration and floodplain formation (as illustrated, for example, in Figure 5). Off-channel features are referred to in this study as simply "floodplain channels" due to uncertainty about distinguishing characteristics. Our understanding of these sites is expected to improve as more observations are made across a wider range of flows than occurred during the winters of 2006-07 and 2007-08. Ron Sutton with the Bureau of Reclamation, in conjunction with Karuk tribal staff, is currently conducting a more in-depth investigation of one of the sites described herein (Sandy Bar floodplain channel) to assess its characteristics over a range of flows.

[5] / The forested riverine/tidal zone is the most upstream zone within a river-mouth estuary, such as the Klamath estuary. This zone, while tidally influenced, has little or no salinity, depending on river flow. The dominant vegetation types are forested wetlands (Hayman et al. 1996; Haas and Collins 2001).



1/ Backwater units often form at mouths of remnant channels. Confluences of small tributaries (either intermittent or perennial) may also form backwater units adjoining the larger channel. Expansion eddy units, as defined by Schwartz and Herricks (2005), are considered backwater units here.
2/ Slow velocity channel margin units. These sites include deflection eddy units and hydraulic dead zone units associated with margins as defined by Schwartz and Herricks (2005).

Figure 4. Channel and mesohabitat types. The distinction between an intermittently connected side channel and an overflow channel depends on frequency of connection to the main stream. Due to uncertainty about connection frequency, we sometimes refer to these channels as simply floodplain channels in this report.

To the extent feasible, those habitat types that might be used by juvenile coho during the fall-winter seasons, excluding periods of active migration, were identified within the study reaches and generally described. Photos served to document physical characteristics of the sites. Most of the sites were visited multiple times during the winters of 2006-07 and 2007-08 to learn how flow dynamics affect habitat characteristics.

To aid in understanding the effects of flow on habitats of interest, we characterized patterns of flow variation within each of the study areas. This allowed us to assess how typical the flows were in the first two years of study compared to a longer period of record, and to compare flow patterns between study areas. Differences in flow patterns between the study areas likely affect habitat presence (i.e., whether off-channel sites become sufficiently watered every year), stability, and accessibility to juvenile coho. We examined variation in annual peak flow, peak flows with recurrence intervals of both 1.5 and 2.0 years, and interannual variation in daily flow patterns. Bankfull discharge occurs with a recurrence interval of every 1.5-2.0 years on average for most rivers (Leopold et al. 1964). It is the flow level that generally governs the size and shape of the channel (Gordon et al. 2004), and serves to provide connectivity to various types of off-channel habitats. How peak flow in any given year compares to bankfull flow might also serve as

an index on the severity of high flow events in regards to both survival and extent of movement by overwintering juvenile coho. Hydrographs for the first two years of study are presented in the results to highlight how representive these years were to other years.

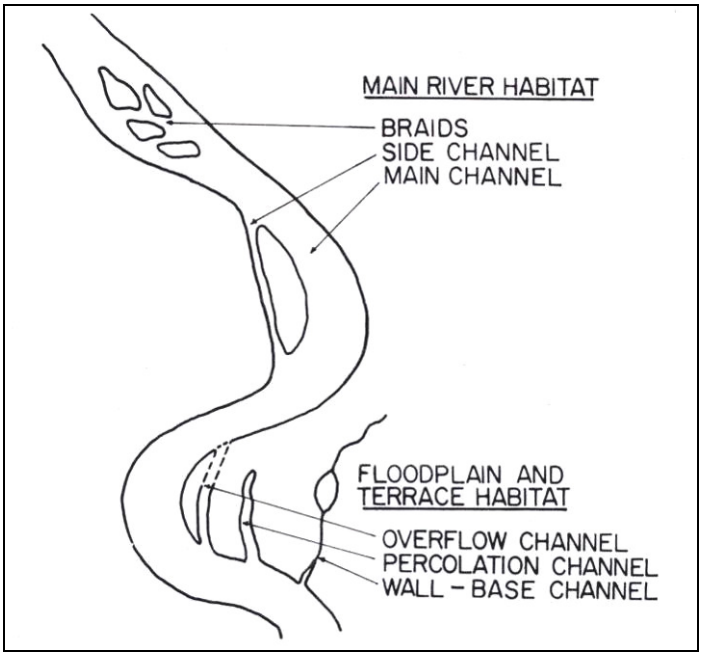


Figure 5. Main river and off-channel channel types as described by Peterson and Reid (1984) with reference to use by juvenile coho in the Pacific Northwest. These same channel types are evident within the Klamath basin.

To compare interannual variation in annual peak flows between sites, we computed both coefficient of variation (C_v) and the index of variation (I_v), as described in Gordon et al. (2004). The former is a more commonly used measure of variability in flow, while the latter metric, also called the flash flood index, has been related to some general characteristics of flow patterns deemed useful here (see Earth Systems Institute 2005). High values of I_v are characteristic of semi-arid to arid regions and reflect low frequency of flood flows but which are severe in magnitude relative to more normal peak flows. Low values of I_v are more characteristic of coastal wet regions where flood flows are more common. Hence we would expect that values of I_v would increase moving from the coastal area to the interior of the Klamath basin.

We used data from four stream gauges for assessing flow patterns:

- Indian Creek at Happy Camp (USGS 11521500)(Indian Creek enters the Klamath River at RM 111);
- Seiad Valley gauge on the mainstem Klamath (USGS 11520500)(RM 129);
- Orleans gauge on the mainstem Klamath (USGS 11523000)(RM 59); and
- Terwer gauge near town of Klamath on the mainstem Klamath (USGS 11530500)(RM 6).

The Indian Creek gauge served as a way of examining tributary runoff localized to the mid portion of the middle Klamath study area. The Seiad Valley and Orleans gauges on the mainstem Klamath served to assess changes in flow patterns between the middle and lower parts of the

middle Klamath study area. The Terwer gauge, located just upstream of the Klamath estuary, served to assess flow patterns in the lower Klamath study area.

At the time of preparing this report, USGS had not yet reported the peak flows for the gauge sites of interest for Water Year (WY) 2008 (October 1, 2007-September 30, 2008), even though preliminary daily average values were available on the USGS web site. For this report, we estimated the peak flows from linear regressions of peak flows versus the maximum daily average value using data for WYs 1997-2007. Each of the regressions was highly significant with r^2 values exceeding 0.98 for each mainstem site and 0.92 for Indian Creek.

3.2 Results

We present results of our analysis of flow patterns for each of the study areas, followed by descriptions of habitats found to be used during summer or winter by juvenile coho within the mainstem Klamath River corridor. Results presented here add to the information contained in the Phase 1 report. The third year report will provide a synethesis of information for the various habitat types.

3.2.1 Flow Variation

The severity of fall and winter high flow events on the mainstem Klamath River in 2007-08 was significantly less than what occurs during an average fall and winter (Table 1). Peak flows at the three mainstem stream gauges and in lower Indian Creek were approximately 40% of the median (2-yr recurrence interval) peak flows for each station for the periods of record. Peak flows were also less than flow levels estimated for the 1.5 recurrence intervals. Hence, bankfull flows did not occur at any of these sites during fall and winter 2007-08. Peak flows during the first year of study (2006-07) were also less than median peak flows. Thus the first two years of study did not exhibit more typical flow patterns that occur in these areas.

Peak flow patterns for the periods of record for the four stream gauges are shown in Figures 6 and 7. It is noteworthy how much peak flows along the mainstem Klamath River increase moving downstream from the interior region to the river mouth. The median peak flow increases by more than a factor of 3 between the Seiad Valley and Orleans gauges, a distance of 70 river miles, then by another factor of 2.4 between Orleans and the river mouth, a distance of roughly 50 river miles. These increases are principally due to the entry of major tributaries, notably, Indian Creek, Clear Creek, Salmon River, Trinity River, and Blue Creek.

Table 1. Peak flows in Water Year 2008 at four stream gauging stations in the Klamath basin, estimated peak flows with 1.5 and 2.0 year recurrence intervals (RI), and average peak flows. Seiad Valley, Orleans, and Klamath are located on the mainstem Klamath River. All flow units are in cfs.

Site	WY 2008 peak 1/	1.5 yr RI	2.0 yr RI	Average peak	Water years 2/	Drainage area (mi^2)
Seiad Valley	7,842	13,495	19,700	30,902	1952 - 2006 3/	6,940
Orleans	28,759	57,229	67,600	96,273	1952 - 2006 3/	8,475
Klamath	73,910	136,279	164,500	194,800	1963 - 2006 4/	12,100
Indian Cr	2,881	4,680	6,780	8,220	1956 - 2006 5/	120

1/ Peak flows for WY 2008 estimated as described in text.
2/ Statistics computed with peak flow data reported by USGS.
3/ Years prior to 1952 were not included in the analysis because that period appeared to reflect a different climate regime.
4/ Years prior to 1963 were excluded due to the completion of Lewiston Dam on the upper Trinity River in 1962 and the corresponding change in the flow regime in that river.
5/ Period of continuous record.

Measures of variability in annual peak flow between the gauge sites are consistent with differences expected between coastal and interior regions (Table 2). The index of variability (I_v) value at the Seiad Valley gauge exceeds 0.40, while the index value decreases at Orleans and drops again near the river mouth. Earth Sciences Institute (2005) states that values in the range 0.4-0.9 are characteristic of semi-arid to arid areas, while values less than 0.4 occur within Pacific Northwest coastal areas. Values greater than 0.4 indicate that floods occur infrequently but are severe relative to median peak flow events when they occur. Values less than 0.4 indicate more frequent flood levels with severity closer to the median condition. Indian Creek, which is located within the interior though not in the highly arid region to the east, has an I_v more similar to the coastal region, indicating more frequent flooding than what occurs on the mainstem upstream of this point. Hence, tributaries in the western half of the middle study area have peak flow patterns more comparable to the coastal area, while the peak flow pattern for the mainstem displays a transition between the coast and the arid region to the east.

Table 2. Measures of flow variability at four stream gauging stations in the Klamath basin: coefficient of variation (C_v) and index of variation (I_v) on annual peak flows and the high flow to low flow ratio using the median annual peak flow (i.e., 2.0 yr recurrence interval). Seiad Valley, Orleans, and Klamath are located on the mainstem Klamath River. Flow units are cfs. High flow/low ratio also given for site below Iron Gate Dam.

Site	C_v	I_v	Low flow 1/	2.0 yr RI	High flow/low flow ratio
Below IG Dam					6.5
Seiad	108.9%	0.42	1,068	19,700	18.4
Orleans	76.6%	0.36	1,612	67,600	41.9
Klamath	65.9%	0.32	2,761	164,500	59.6
Indian Cr	81.4%	0.34	37	6,780	184.2

1/ Average of lowest reported flow for WYs 1998-2007.

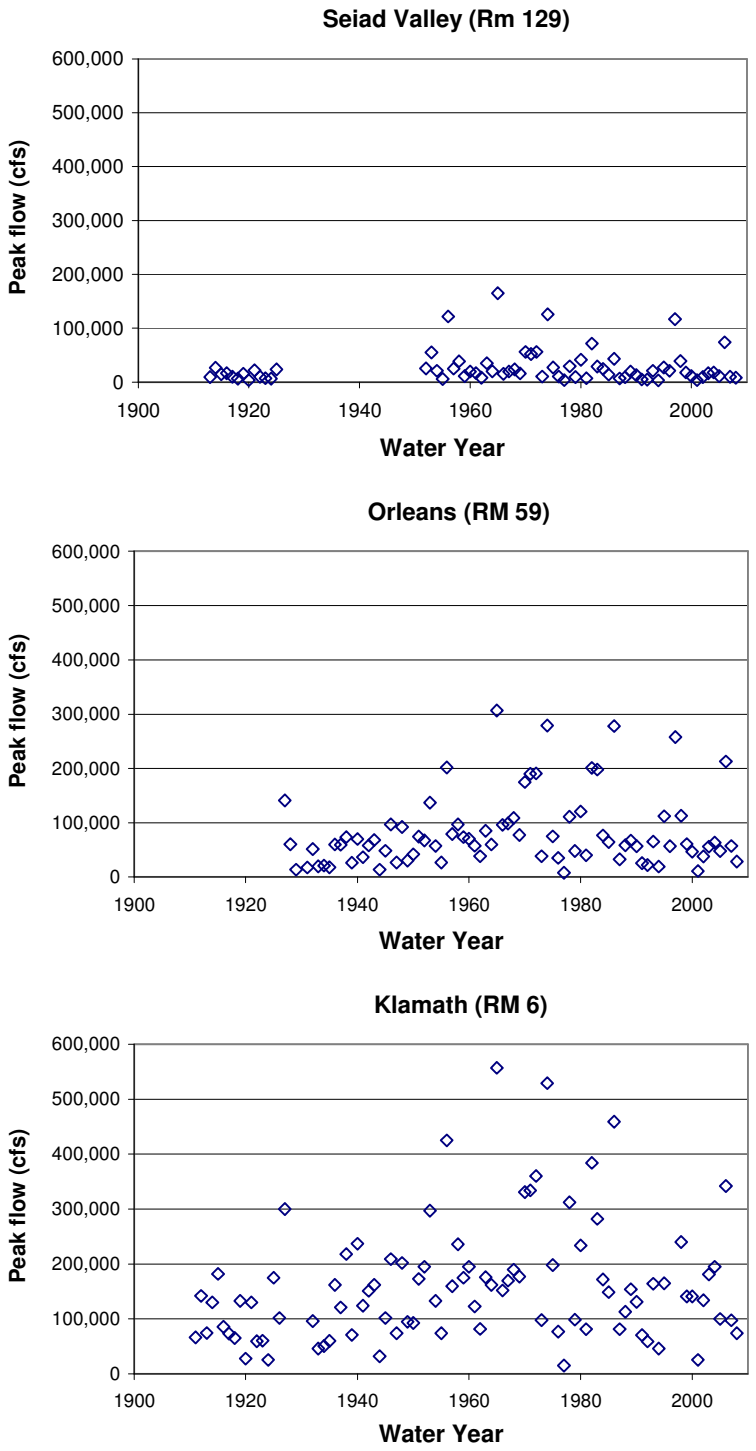


Figure 6. Annual peak flows at Seiad Valley (RM 129), Orleans (RM 59), and Klamath (RM 6) on the mainstem Klamath River. The most recent data point displayed for each site is WY 2008.

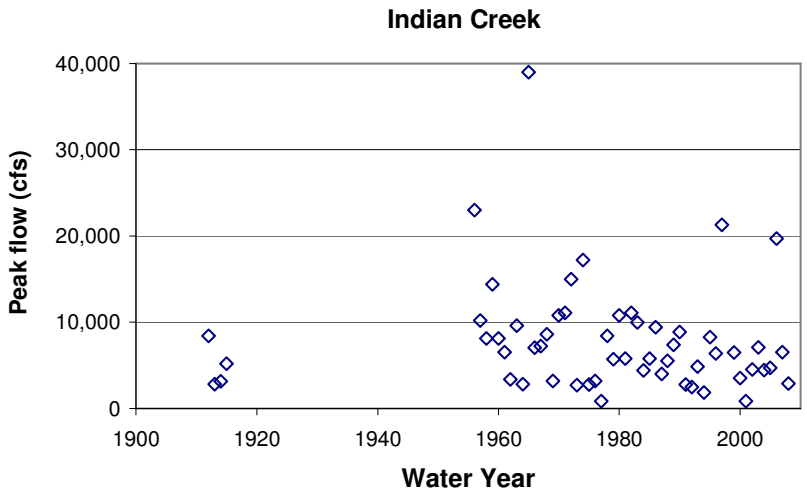


Figure 7. Annual peak flows in lower Indian Creek, which enters the Klamath River at RM 111. The most recent data point displayed is for WY 2008.

The patterns of variation in annual peak flow along the mainstem Klamath River correlate to peak flow/low flow ratios seen at each of the mainstem stream gauges (Table 2). The ratios—computed using median annual peak flow—show increasing values moving downstream on the mainstem Klamath River. The median annual peak flow at Seiad Valley is 18X the average low flow at that point, while near the river mouth, the median peak flow is 60X the average low flow. Orleans shows an intermediate value. The annual peak below Iron Gate Dam is about 6X the average low flow at that point. The peak flow/low ratio in Indian Creek—exceeding 180— is significantly higher than seen in the mainstem, illustrating a strong response to storm events that occur on average every other year. These differences in high flow to low flow ratios may lead to different patterns of residency and movement by juvenile coho between the areas during fall and winter.

Patterns of average daily flows for each of the four stream gauges over the most recent 11 years (WYs 1998-2008) are presented in Figures 8-11. The patterns seen in WY 2008, which affected overwintering during the period reported on in this report, are seen to contain the second lowest amounts of runoff for the 11 years illustrated. The first year of the study was also a low runoff year. It bears noting the fundamental difference in the patterns between the most upstream gauge and the lowermost one. The largest magnitude of runoff occurs during fall and winter in the lower river downstream of Trinity River, where the spring runoff pulse is comparatively much less.[6] In contrast, the magnitude of the fall and winter runoff at Seiad Valley is more comparable to the spring runoff pulse with only occasional years showing a much greater response during winter. The patterns at Orleans are intermediate between the Seiad Valley and Klamath gauges. The patterns in Indian Creek tend to be more like those at the Klamath gauge than at the Seiad Valley gauge.

[6] / It should be noted that the spring runoff pulse in the lower Klamath River has been affected by the Trinity River Diversion (TRD) project in the upper Trinity River. The largest effect of the TRD to the Trinity River's flow regime occurs in the spring, during filling of Trinity Reservoir. Construction of the TRD was completed in 1962. See NRC (2004) for a concise description of how the Klamath River hydrograph has been affected by the TRD.

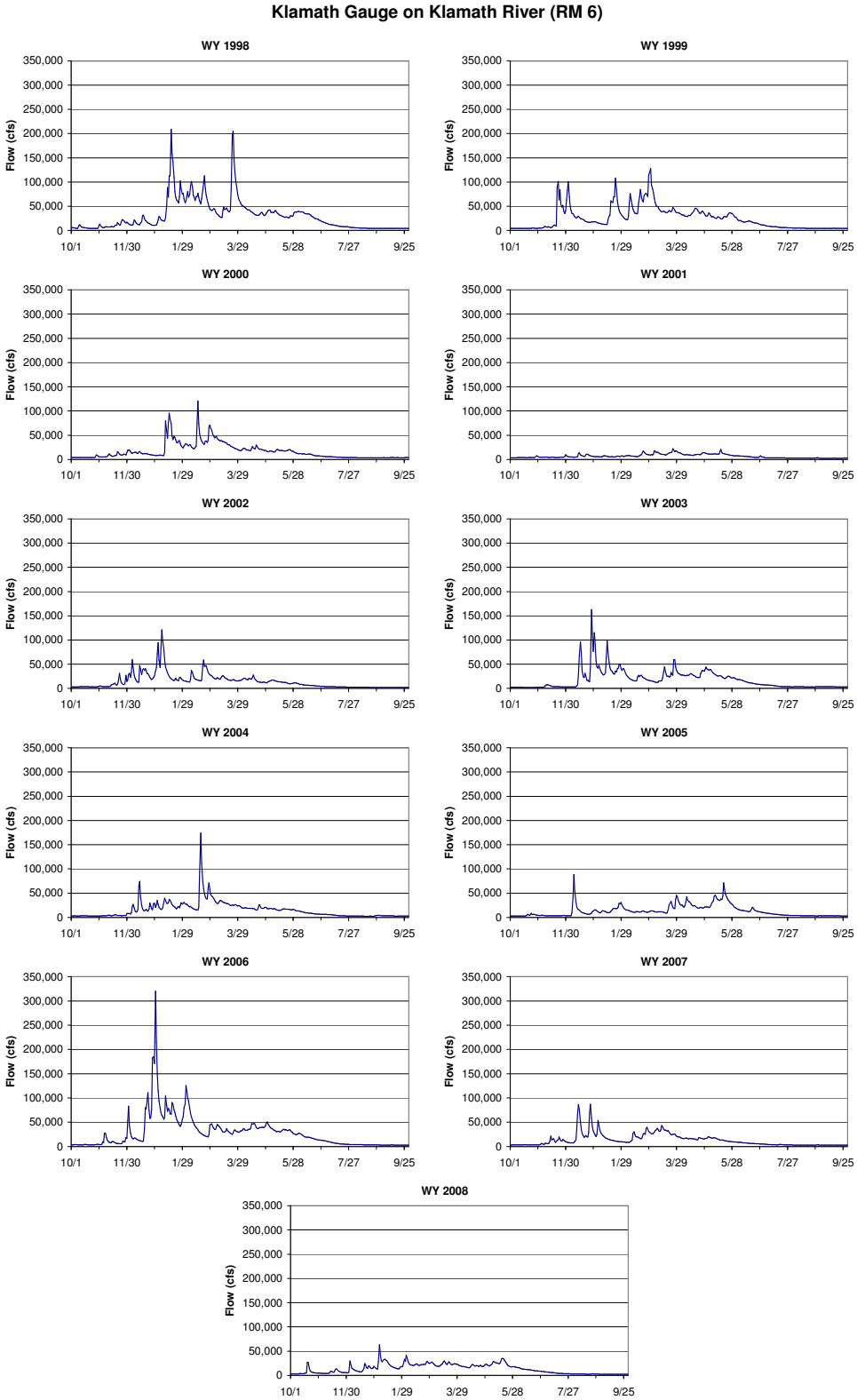


Figure 8. Daily flow at the Klamath gauge site on the mainstem Klamath River (RM 6) in WYs 1998-2008. Gauge site is USGS 11530500.

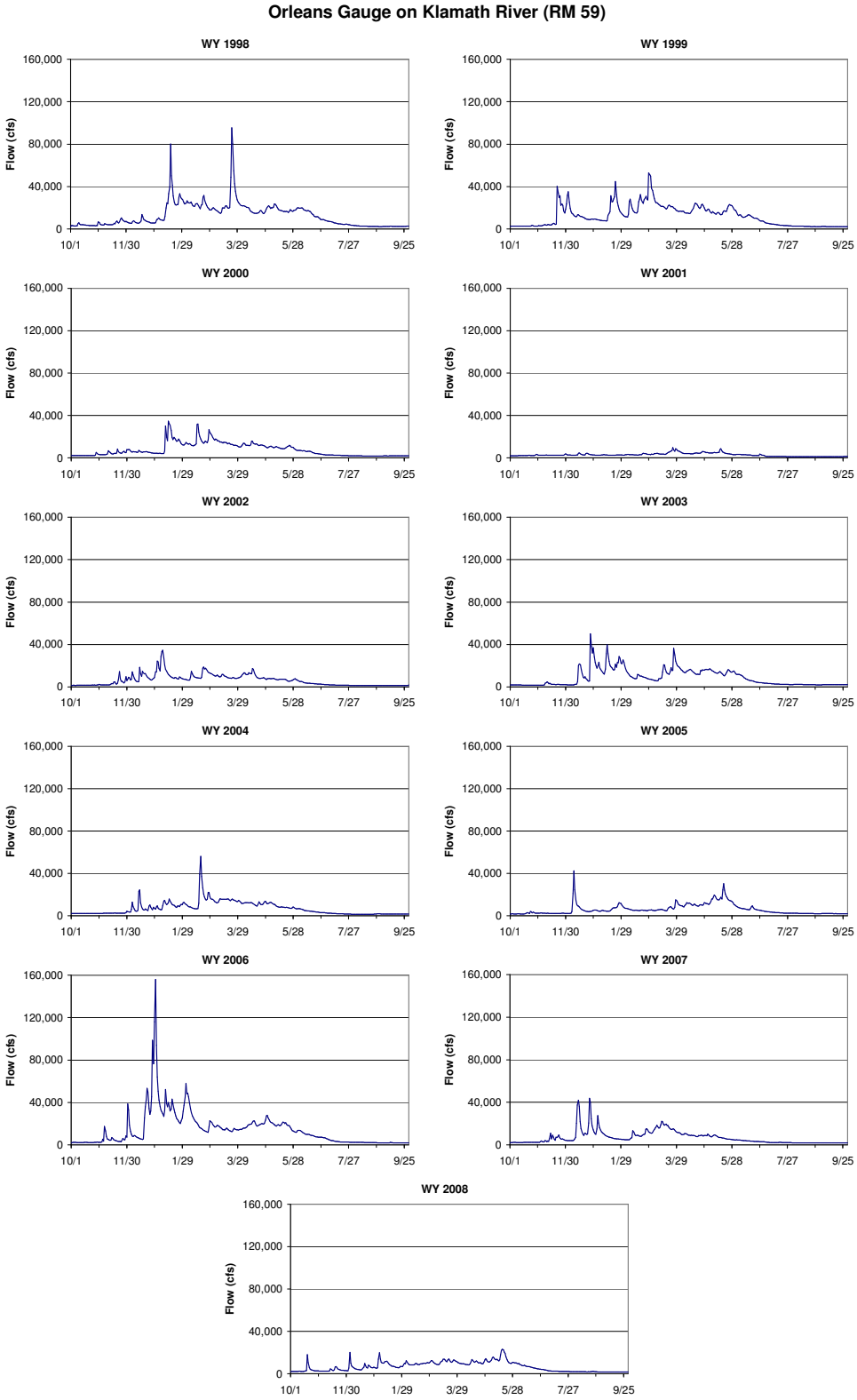


Figure 9. Daily flow at the Orleans gauge site on the mainstem Klamath River (RM 59) in WYs 1998-2008. Gauge site is USGS 11523000.

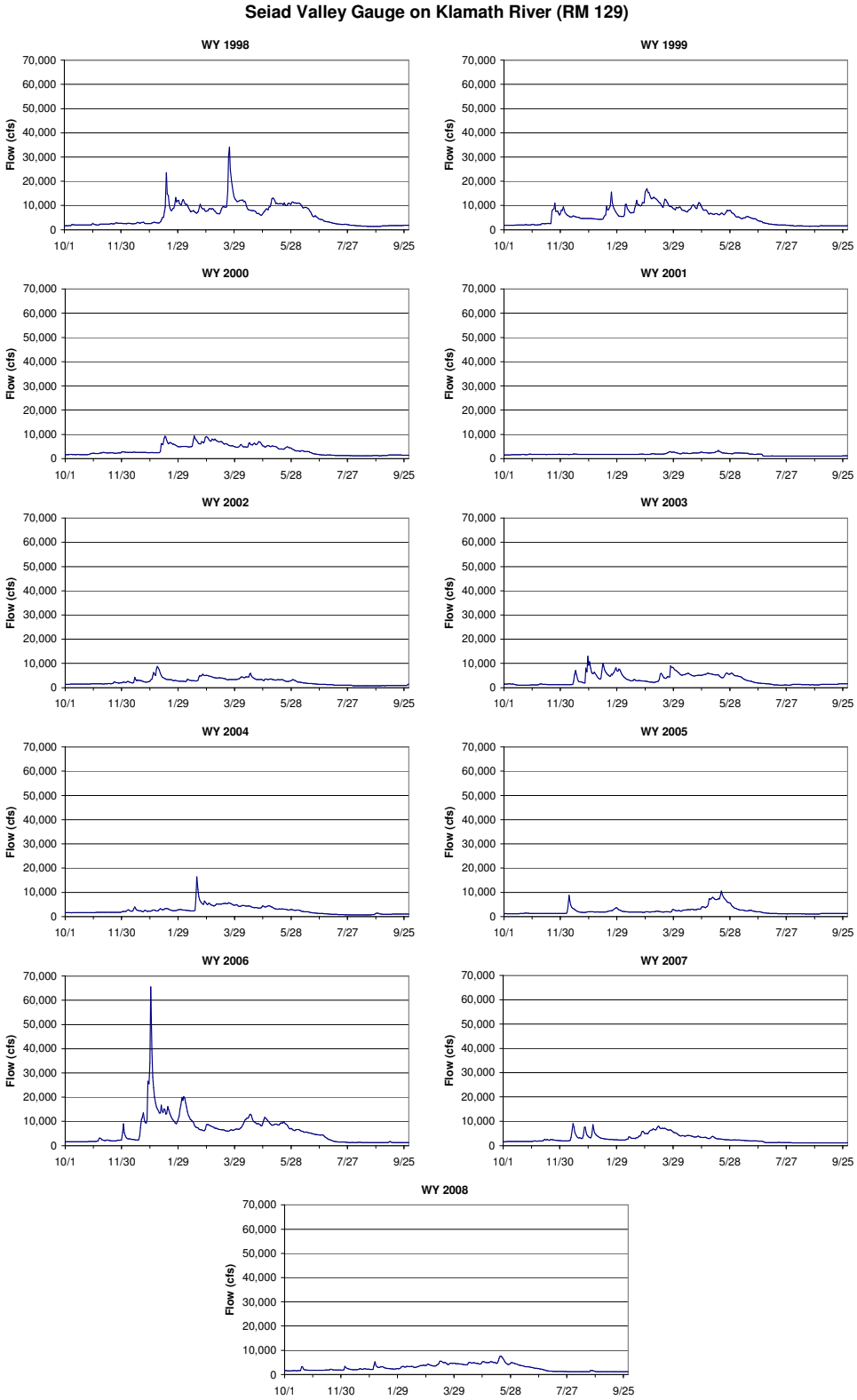


Figure 10. Daily flow at the Seiad Valley gauge site on the mainstem Klamath River (RM 129) in WYs 1998-2008. Gauge site is USGS 11520500.

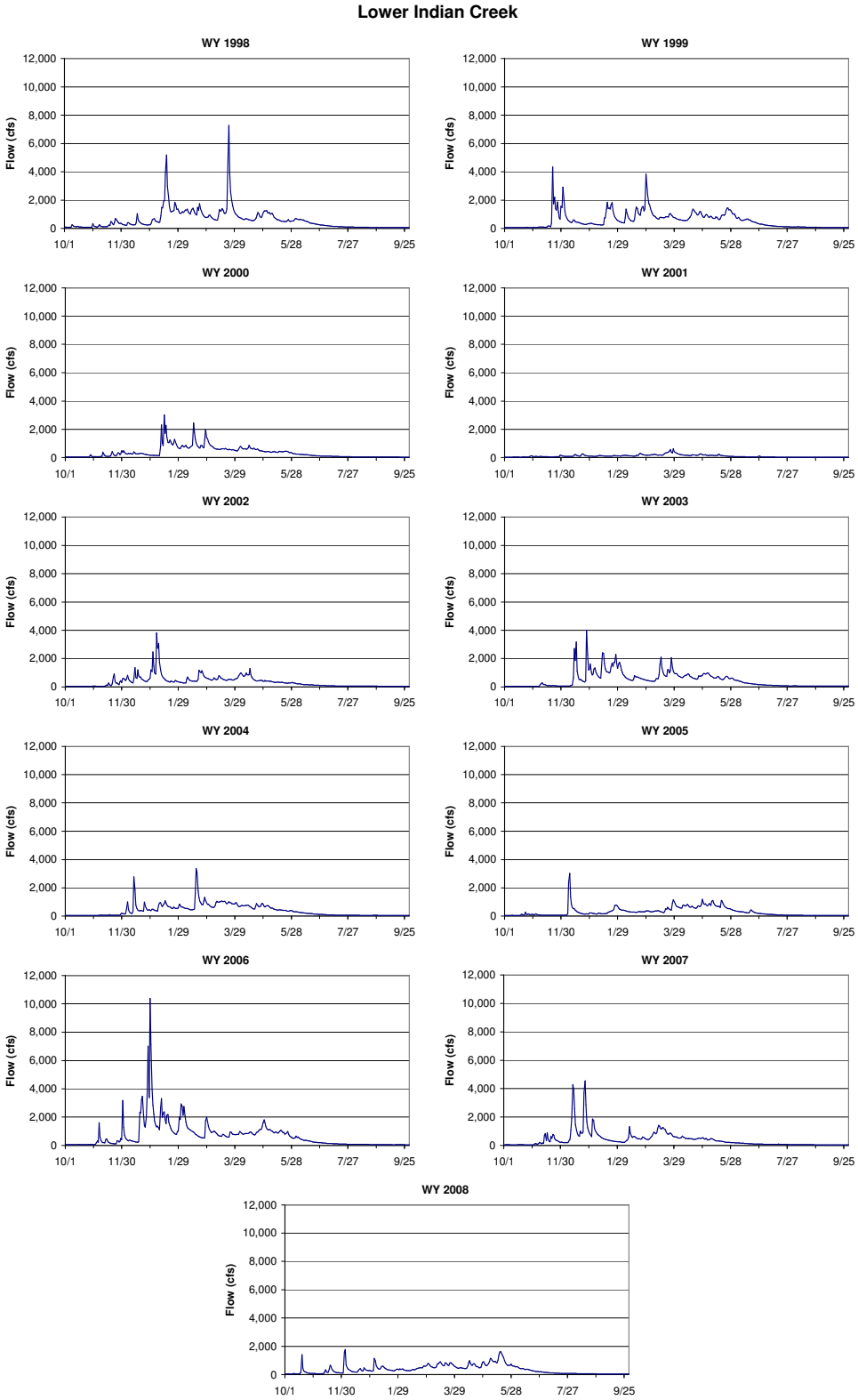


Figure 11. Daily flow on lower Indian Creek in WYs 1998-2008. Gauge site is USGS 11521500.

These flow patterns reflect fundamental differences in geology and climate between the coastal and interior regions of the Klamath basin. Unlike most large watersheds, the Klamath basin has its greatest relief and topographic complexity in the lower half rather than in the upper half of the basin (NRC 2004). The mountainous lower basin produces a rain shadow effect in the upper basin and in the Shasta Valley, resulting in a low mean annual precipitation with about half falling as snow. These characteristics, combined with extensive marshes and lakes, volcanic geology, and flow regulation, produce low runoff yields with high hydraulic retention times in the upper basin. In contrast, the lower basin has much greater precipitation, reaching 100 in/yr in the coastal region. Runoff patterns there tend to produce large peak flows during winter associated with major storm events, together with a somewhat smaller, more predictable runoff pulse in spring with snowmelt.

In summary, very different characteristics in annual peak flow and interannual flow variation exist within and between the study areas, corresponding to climate and geological patterns within the basin. These characteristics are expected to have a strong influence on habitat features and on patterns of habitat residency and movement by juvenile coho during fall and winter.

The flow patterns that occurred during the first two years of the study exhibited exceptionally low amounts of runoff, particularly during fall and winter. Low runoff was likely a determinant to the amount of movement by juvenile coho during these years.

3.2.2 Middle Klamath River Study Area

The middle Klamath River study area is bounded by the Shasta River (RM 177) upstream and the Trinity River downstream (RM 43). This section of the report begins with a general description of some of the dominant characteristics of the mainstem river within the study area relevant to juvenile coho life history, followed by examples of major habitat features and types found within the study area (Figure 12). The examples are presented as they occur along the mainstem river beginning upstream, except for examples of bank edge and mainstem backwater pools , which are given at the end of the section. While most of the material presented in this section was also submitted as part of the Phase 1 report, the work used to collect the information was performed during both Year 1 and Year 2.

Habitat examples covered here are:

- Seiad Creek;
- Cade Creek;
- Bulk Plant backwater and floodplain channel;
- Independence Creek floodplain channel;
- Sandy Bar Creek floodplain channel; and
- Mainstem river backwater pools and bank edge habitats.

3.2.2.1 General Characteristics of the Mainstem Klamath River

The Klamath River channel varies between being moderately to strongly confined over most of the distance between Shasta River (RM 177) and Trinity River (RM 43)(Figure 13). No patterns are evident for either increasing or decreasing channel slope or bankfull width over this distance

(Figure 14), based on information presented in Stillwater Sciences (2004) as originally provided in Ayres (1999).

Channel slopes averaged over one mile distances vary between about 0.1-0.5% over most of the study area. There are several pockets of lower channel slope between approximately RM 75 and RM 120; Happy Camp is located at approximately RM 111. Across the entire study area distance, the gradient is consistently lowest between approximately RM 105 to RM 120. This suggests that bank edge habitats suitable for holding juvenile coho may be relatively more abundant (on a per mile basis) in this 15 mi section compared to other sections. The steepest section of river occurs upstream of RM 60 in the vicinity of Ishi Pishi Falls (RM 67). The pattern of channel slopes changes markedly at the confluence of Trinity River (RM 43), where gradient begins to steadily decline over the remaining distance to the river mouth.

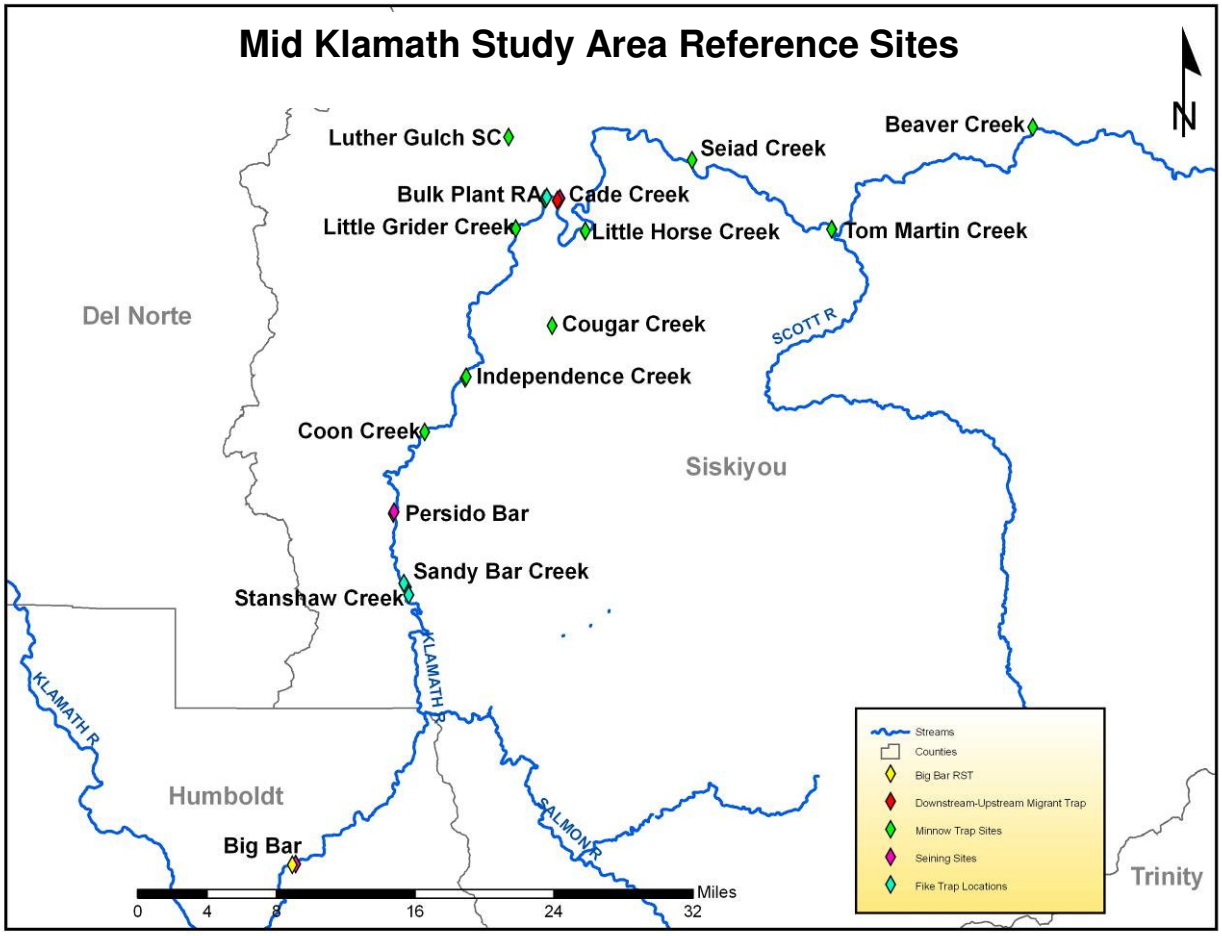


Figure 12. Habitat and fish sampling sites in the middle Klamath River study area. The town of Happy Camp is located immediately downstream of the sampling site marked as "Bulk Plan RA."

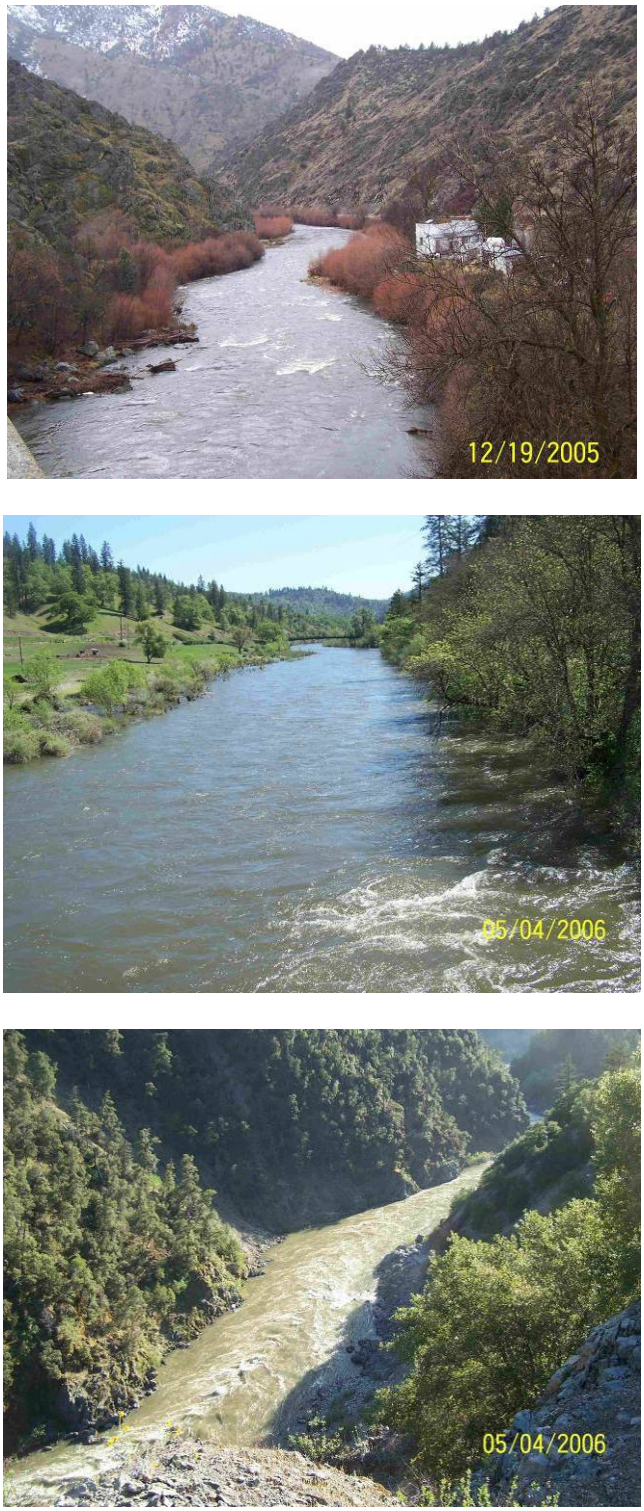


Figure 13. Examples of reach characteristics of the mainstem Klamath River within the middle study area: (top) near the mouth of the Shasta River (RM 177), upstream of Scott River (near RM 147), and within the gorge downstream of Clear Creek (downstream of RM 99). The bottom two pictures were taken during exceptionally high spring runoff.

Bankfull channel width is typically between 100-200 ft throughout most of the study area distance, interspersed with some reaches of greater width (Figure 14). This consistent range of variation—despite the very large increase in winter flow volume that occurs moving downstream—is due to periodic meander bends in lower slope areas set within a well defined range in valley confinement over the entire distance. Corresponding to the set of reaches where channel gradient is lowest (between RM 105-120), average bankfull width is greatest (approximately 200 ft) compared to other reaches. This correspondence further suggests that the relative abundance of bank edge habitats suitable for holding juvenile coho is likely greater in this section of river compared to others during high flow events. It bears noting that since bankfull channel width shows no pattern of increasing width moving downstream between about RM 160 and the Trinity River (RM 43)—and winter flows increase dramatically over this distance—that both water depth and velocity are likely to generally increase during high runoff moving downstream. However, there are short sections of channel with low slopes and relatively wide valley confinement, such as in the vicinities of Orleans, Sandy Bar, and Independence Creek, as well as others, which may contain bank edge habitats suitable for holding juvenile coho. While such habitats may become more dispersed downstream of RM 120, their relative importance may increase as they become less frequent.

3.2.2.2 Seiad Creek

Seiad Creek (RM 129) is a small to moderately sized tributary that enters the Klamath River in the middle section of the study area (Figure 15). The stream supports coho spawning but it is also likely used by non-natal juvenile coho within its lower reaches. We highlight it here to represent the group of tributaries within the study area that likely support both natal and non-natal coho use. Other tributaries within this group include Beaver, Horse, Grider, West Grider, Fort Goff, Thompson, China, Indian, Elk, Independence, Dillon, Camp, Red Cap, Slate, and Aikens creeks, among others. We suspect that non-natal use in some of these streams likely occurs primarily in summer, when juvenile coho are seeking thermal refugia from high temperatures in the mainstem river. These streams that would be used primarily as thermal refugia are relatively steep within the river corridor. Some streams, like Horse, Grider, and West Grider creeks, in addition to Seiad Creek, enter the Klamath River within relatively wide valley areas of the river corridor, and appear to offer some suitable overwintering habitat (Figure 15b), despite these streams being subject to high runoff during winter. Further assessment work is required to determine relative usage of these streams within the river corridor for overwintering. We also note that those streams entering the Klamath River within wide valley locations have been particularly subject to land use practices in their lower reaches, such as in Seiad Creek (Figure 15).

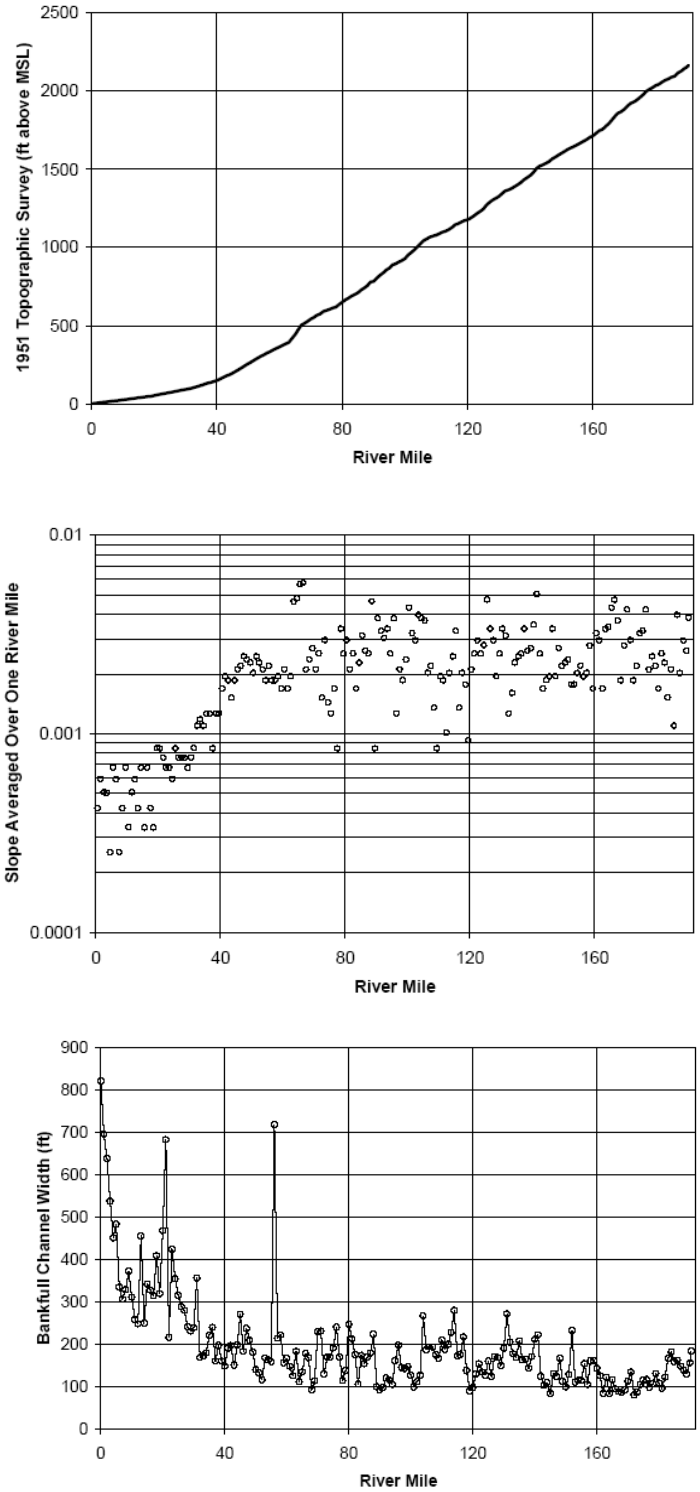


Figure 14. (top) Longitudinal profile of the Klamath River downstream of Iron Gate Dam (RM 190); (middle) channel gradient averaged over 1-mile distances; (bottom) bankfull channel widths based on 1998 1:7,500 aerial photographs. Selected reference sites are: Shasta River – RM 177, Scott River – RM 143, Seiad Valley – RM 129, Indian Creek – RM 111, Orleans – RM 59, Trinity River – RM 43. Taken from Stillwater Sciences (2004).

Figure 15. Lower reaches of Seiad Creek within the mainstem Klamath River corridor. Top picture is a channelized and diked reach during a period of high runoff.

3.2.2.3 Cade Creek

Cade Creek (RM 112) is a small tributary entering the Klamath River in the middle section of the study area that supports non-natal coho production (Figure 16). Spawning and juvenile rearing surveys indicate that the stream is only rarely, if at all, used for spawning. We have documented relatively extensive use of the stream by non-natal juvenile coho during summer, when up to 1700 ft of the lower stream is used as a thermal refuge from high temperatures in the mainstem

river (Karuk Tribe, unpublished data). The timing and pattern of utilization by juvenile coho in summer confirms that Cade Creek is not their natal stream. The stream's characteristics suggest that it may also be used by non-natal juveniles for overwintering, even though it is subject to high flow runoff during winter storms. The stream is similar in size and channel characteristics to streams used for overwintering by non-natal juvenile coho on the west side of the Olympic Mountains in Washington State (Scarlett and Cedarholm 1984 and observations by L. Lestelle). There is a general lack of large wood in the stream, however, which would tend to limit use and survival of juvenile coho that overwinter there. In addition, it has been determined that the culvert near the mouth of the stream is likely a partial barrier to upstream movement by juveniles during some flows (Karuk Tribe, unpublished data). Culverts like this one in small streams within the mainstem river corridor pose passage difficulties to juvenile coho during high flow events.

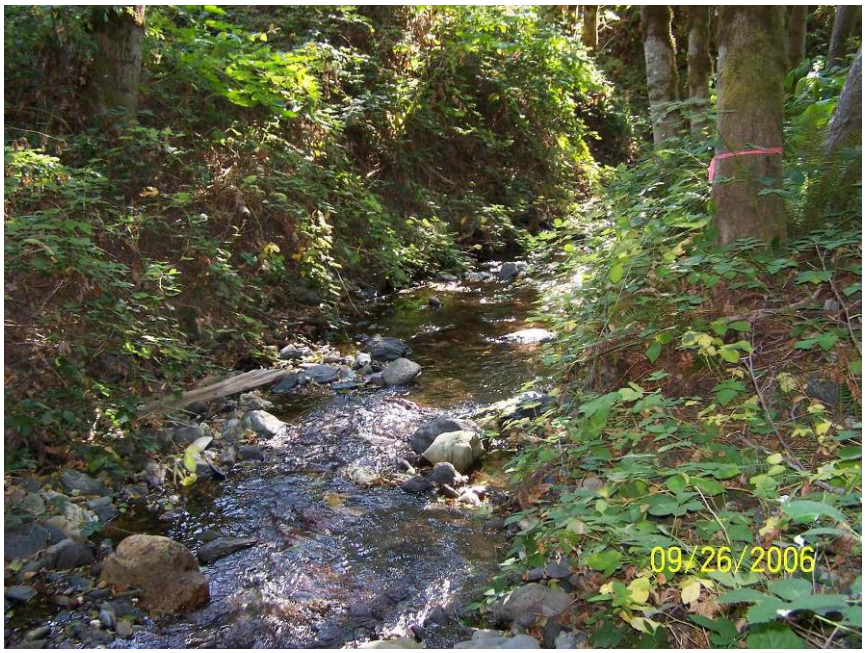


Figure 16. Lower Cade Creek.

3.2.2.4 Bulk Plant Backwater and Floodplain Channel

The Bulk Plant backwater and associated floodplain channel is located on the upstream edge of the town of Happy Camp at approximately RM 112 on the Klamath River. A backwater pool is formed at the upstream end of the floodplain channel (Figure 17a), unlike the more common location of backwater pools at the lower end of such channels. When river flow increases, the backwater pool expands downstream into the top of the floodplain channel, seen in Figures 17b and 17c. Due to uncertainty about the frequency that the floodplain channel connects from its head end to its bottom end, it is unclear whether the channel is best characterized as a side channel or an overflow channel. The channel did not connect throughout its length during either the winter of 2006-07 or 2007-08. Gravel extraction activities on the river bar have created a somewhat artificial situation that influences channel connectivity, and it appears that the channel may be operating principally as an overflow channel. Overflow channels only connect at flow

levels higher than the 2-year recurrence flow and fish that move into them during those periods may be subject to stranding. We conducted a rescue effort on stranded juvenile coho at this site in one previous year. It bears noting that the physical condition of those fish was found to be very good.

Figure 17. Bulk Plant backwater pool and floodplain channel on January 25, 2007 (Klamath River flow at Seiad Valley gauge at 2,450 cfs): (a) backwater pool at top end of the floodplain channel; (b) upstream section of the floodplain channel in January 2007; ***continued to next page*.**

Figure 17 continued – (c) aerial view of the Bulkplant floodplain channel and backwater unit.

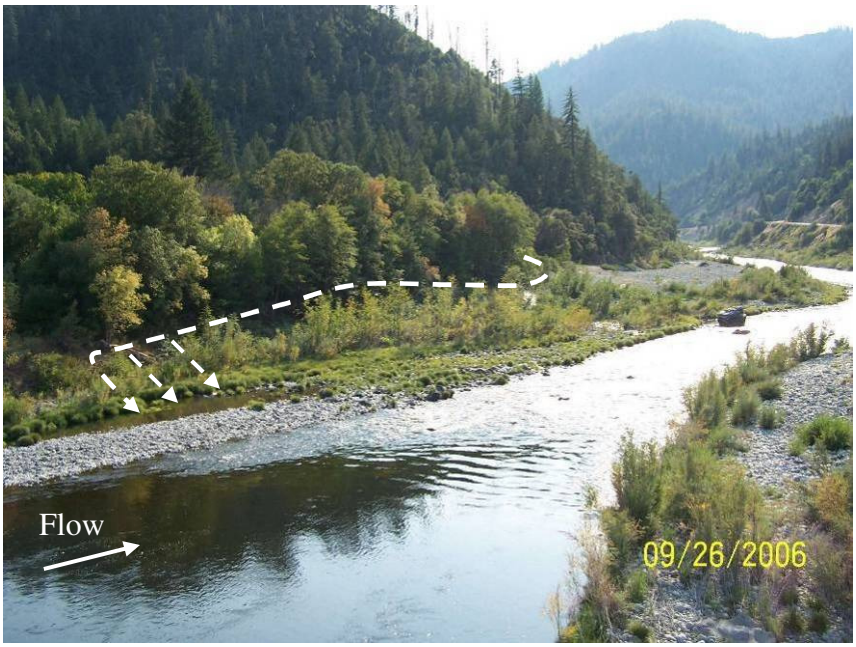
3.2.2.5 Independence Creek Floodplain Channel

The lower reach of Independence Creek (RM 94) flows through what appears to be an overflow channel on the inside edge of a meander bend of the Klamath River (Figures 18). This type of geomorphic feature along the Klamath River, where a tributary flows into an overflow channel or intermittent side channel, occurs in a number of locations along the river. It is the most common way that pond-like habitat is formed on the floodplain of the Klamath River between Iron Gate Dam and the upper end of the estuarine zone.

We refer to this type here as a tributary-fed floodplain channel, which occurs on the inside edge of meander bends where a small tributary enters. The development of a point bar will sometimes leave relict channel patterns on the inside edge of the bar or meander (Figure 5)(Mount 1995; Ward et al. 2002). Where hyporheic flow is pronounced, these relict channel patterns can form groundwater channels, which provide both summer and winter refuge habitat for juvenile coho. In the Klamath River mainstem corridor, where groundwater channels are not commonly found, these relict channel features on the inside edge of point bars can retain flow if they occur where a tributary enters, such as at Independence Creek. Summer temperatures remain relatively cool at this site and afford good thermal refuge for juvenile coho seeking such habitat.

The pattern of flow at the Independence Creek floodplain channel is unique compared to other similar features in the Klamath River corridor. The topography of the point bar at Independence Creek results in a flow direction through the floodplain channel moving toward the top end of the point bar (Figure 18c and d), which is the opposite direction that normally occurs in this type of feature.

Figure 18. Independence Creek floodplain channel: (a and b) channel near its confluence with the mainstem river in winter; *continued to next page*.



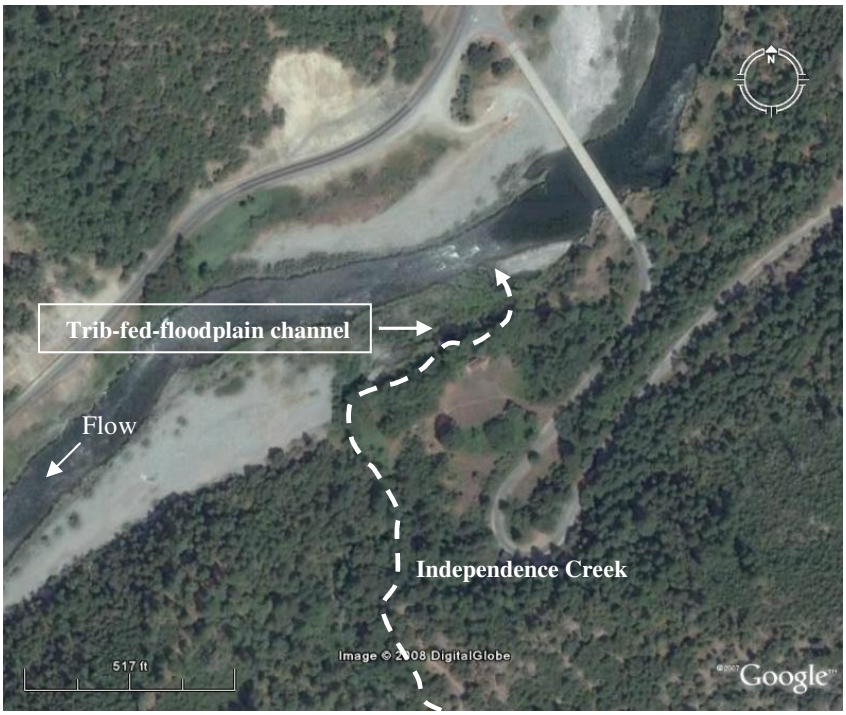


Figure 18 continued – (c and d) channel orientation within the mainstem river corridor.

Flow dynamics within this floodplain channel are subject to flow fluctuations in Independence Creek, as well as to periodic inundation from the river. Because Independence Creek can discharge relatively high flows, and the entire length of the floodplain channel is affected by this stream, the quality of this site for overwintering appears to be less than at some other tributary-fed floodplain channels in the basin.

Some natal production of coho has been observed in Independence Creek, but non-natal use was documented to occur here in summer of 2007, when a large number of young-of-the-year moved into the site. This site is being used for semi-intensive monitoring as part of this project.

3.2.2.6 Sandy Bar Creek Floodplain Channel

This site is another example of a tributary fed-floodplain channel, located at RM 78 on the Klamath River (Figure 19). Sandy Bar Creek is a small stream with a relatively high channel slope that is not used by spawning coho. All of the juvenile coho that inhabit the channel are, therefore, non-natal fish. Non-natal fish were found to rear at this site during fall, winter, and summer in both Year 1 and Year 2 of this study. This site is being used for intensive monitoring as part of this project to assess movement patterns, habitat utilization rates, and performance.

Sandy Bar Creek enters the floodplain channel roughly halfway through the channel's length. The floodplain has characteristics of both an intermittently connected side channel and an overflow channel. At higher flows, when the channel is still disconnected at its upper end to the river, some surface river water moves across the point bar and enters the floodplain channel slightly downstream of where Sandy Bar Creek joins the channel (Figure 19b).

This floodplain channel contains several depressions that cause it to retain surface water brought in by Sandy Bar Creek. This results in the formation of two large ponds, one immediately upstream of where Sandy Bar Creek enters the channel (Figure 19c) and the other downstream of the creek. The upper pond is most sheltered from high flow effects from Sandy Bar Creek, as well as from relatively high mainstem river flows. The lower end of the floodplain channel can disconnect from the mainstem river once flows in the creek drop to summer low flow. On-going monitoring of this site is planned to help us better understand connectivity between the channel and the mainstem river, as well as velocity and flow characteristics within the channel as a function of river and creek flow.

It bears noting that at higher flows, a backwater pool forms in the Klamath River immediately downstream of where the floodplain channel joins the river (Figure 19d). This backwater pool expands to a very large size, covering the lower portion of the point bar, during high flow events.

Another tributary-fed floodplain channel at Stanshaw Creek is located less than 1 mile downstream of the Sandy Bar channel. Characteristics of that floodplain channel are nearly identical to those at Sandy Bar.

Figure 19. Sandy Bar floodplain channel: (a) ponded area looking downstream from immediately below where Sandy Bar Creek enters the channel in September 2006; (b) same site and orientation in January 2007, some river flow is entering the channel from right just off the picture; ***continued to next page*.**

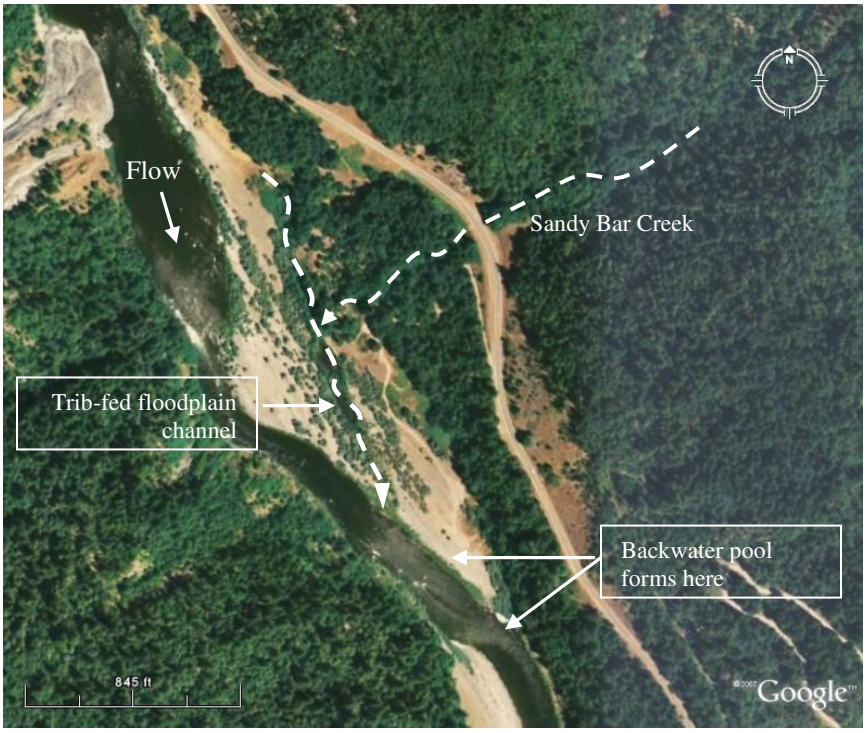


Figure 19 continued – (c) ponded area immediately upstream of where Sandy Bar Creek enters the floodplain channel in September 2006; (d) aerial view of the channel and location of backwater pool on the mainstem river downstream of the channel.

3.2.2.7 Mainstem River Backwater Pools and Edge Habitat

The mainstem Klamath River in the middle study area contains backwater pools at certain flow levels that appear to be suitable for overwintering coho, as well as bank edge habitats that should support overwintering. The backwater pool units are not abundant and different types exist. One example is the backwater unit at the top end of the Bulk Plant floodplain channel (Figure 17a)(RM 112). It appears that this particular backwater pool becomes most distinct at relatively low flows, whereas at flows approaching flood stage it would be subject to increased velocities due to its location on the outside edge of the meander bend (Figure 17c). Winter flows at this site are relatively mild compared to conditions downstream. This suggests that this backwater pool may be used frequently for overwintering.

A more classic backwater unit, located at the downstream end of a point bar, was present in past years at the Beaver Creek thermal refuge (Figures 12 and 20), located at RM 161 on the mainstem river. Juvenile coho have been observed at this site during summer (e.g., Deas and Tanaka 2006), but the backwater unit was destroyed during the flood of 2005-06 and it has not reformed. While the site continues to provide a limited amount of thermal refuge habitat for coho, its function for overwintering appears to have been much reduced. It is noteworthy, however, that winter flow fluctuations in this area of the watershed are small and the need for velocity refuge should therefore be much reduced in a typical year.

Another example of a backwater unit is the one that forms at the downstream end of the Sandy Bar channel and point bar (Figure 19d). The Sandy Bar site exemplifies a backwater unit that expands and contracts tremendously as a function of river flow (Figure 21), illustrating that its importance may only come into play at very high flows. The dynamic nature of these sites, particularly downstream of about RM 110, suggests that these sites may provide a function as "stop-over" sites for fish that are in the process of seeking suitable overwintering habitat during periods of high flow. The third year of study will examine the use of backwater units as stop-over habitats.

Examples of bank edge habitat in the upper half of the study area are shown in Figure 22. Bank edge habitat is known to be used to some extent by overwintering juvenile coho in some large rivers (e.g., Beechie et al. 2005). In the upper half of the study area, i.e., upstream of about RM 110 (at Happy Camp), severe high flows are less frequent and bank edge habitats appear to be more suitable for overwintering than those further downstream. Also, as noted earlier, the reaches near Happy Camp tend to have a lower channel slope with greater bankfull widths compared to reaches downstream to the Trinity River. Bank edges illustrated in Figure 22 appear to provide potential overwintering habitat.

Figure 20. Backwater pool on the mainstem Klamath River immediately downstream of Beaver Creek (RM 161). This site was a known thermal refuge during summer for juvenile coho, as reported in Deas and Tanaka 2006. The photos here were taken in December 2005, just prior to the backwater being obliterated by flood flows at the end of December.

Figure 21. Backwater pool on the mainstem Klamath River immediately downstream of the Sandy Bar floodplain channel (RM 78): (a) remnant of the pool unit as it existed during late summer-early fall flows in 2006; (b) view looking upstream of the dry sand bed of where the pool expands to during high flows—the (a) photo was taken shooting downstream from where the three individuals are standing in (b).

Figure 22. Representative bank edge habitats along the mainstem Klamath River during winter flows. All four photos were taken in reaches between Shasta River and Happy Camp—*continued to next page.*

Figure 22 – continued. Bank edge habitats within the middle river study area (upstream of RM 110).

3.2.3 Lower Klamath River Study Area

The lower Klamath River study area is bounded by the Trinity River (RM 43) upstream and the river mouth at its lower end. This section of the report begins with a general description of some of the dominant characteristics of the mainstem river within the study area relevant to juvenile coho life history. This is followed by descriptions of examples of major habitat features and types found within the study area (Figure 23). The examples are presented as they occur along

the mainstem river beginning upstream, except for examples of bank edge habitats, which are given at the end of the section.

Habitat examples covered here are:

- Roaches and Tectah Creek confluences (upstream of area shown on Figure 23);
- Tarup Creek floodplain channel and ponds;
- McGarvey Creek;
- Resighini floodplain channel and ponds;
- Waukell Creek and Junior Creek Pond;
- Richardson Creek ponds;
- Salt Creek-Spruce Creek complex;
- South Slough complex; and
- Mainstem river bank edge habitats.

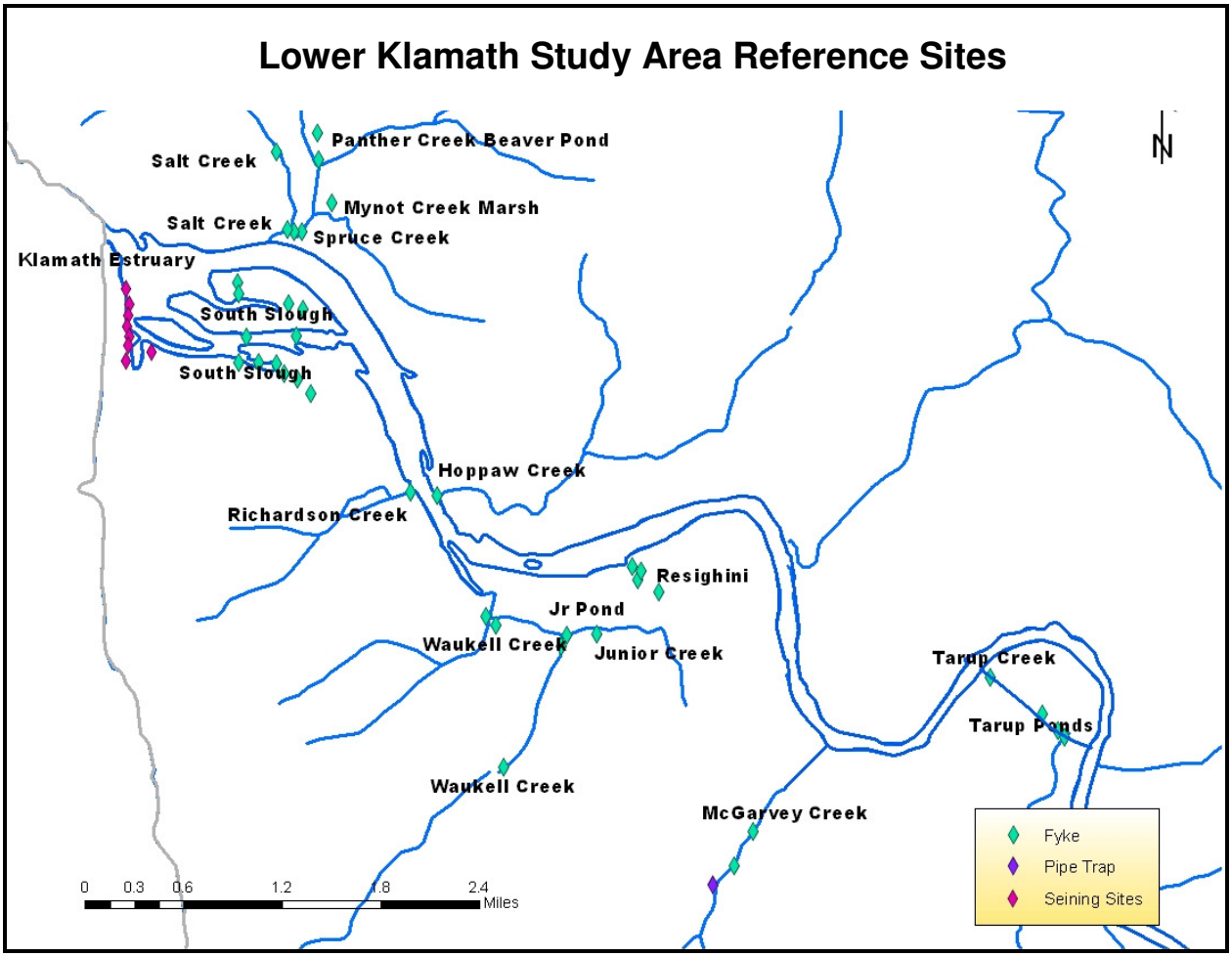


Figure 23. Habitat and fish sampling sites in the lower Klamath River study area. Roaches and Tectah creeks are located upstream of the section of river shown in the map. The map shows one stream mouth confluence for the Salt Creek complex, though there are actually two separate mouths—one for Salt Creek and one for Hunter Creek, which is the main stream fed by Spruce, Mynot, and Panther creeks.

3.2.3.1 General Characteristics of the Mainstem Klamath River

The channel characteristics of the mainstem Klamath River downstream of the Trinity River (RM 43) show distinct changes from those upstream of that point. Channel slope begins to flatten and bankfull width increases (Figure 14). These patterns—decreasing slope with increasing width—continue to the river mouth. Peak flows significantly increase with the input of Trinity River. The scale of the river's physical features are dramatically larger than those upstream of Trinity River (Figure 24).

The river channel through most of the lower study area remains moderately to strongly confined like most of the middle study area. Upstream of the estuarine zone, much of the river's shorelines is comprised of bedrock, boulders, or large sweeping point bars (Figure 24).

As the river flows, valley width of the mainstem corridor begins to widen appreciably at about RM 8. Particularly noteworthy is the presence of three very large meander bends between that point and the river mouth (Figure 25a). The point bar features located on the south side of the river contained by these meander bends are of special interest because of the floodplain channels that cut through their inner edges. The scale of these features grows from the most upstream of the three point bar features to the most downstream one located near the mouth. It was evident at the outset of this study that potentially good overwintering habitats for juvenile coho might be concentrated at these locations.

The most downstream of these three meander bends is contained by the estuarine zone (Figure 25b). The inside of this meander bend is composed of a very large point bar type feature covered by a riparian forest, which is dissected by a number of side channels and overflow channels. This floodplain channel complex is influenced by fluctuations in both river flow and tidal energy. Saltwater intrusion apparently only affects the lower ends of these channels during some periods (Hiner and Brown 2004), but not during late fall through spring when river flows are elevated. Tidal influence still affects the channels even without saltwater intrusion.

This general pattern of features within the mainstem corridor between the Trinity River and the river mouth suggests that the quantity and quality of overwintering habitat for juvenile coho increases in a downstream direction. Some of these sites also offer thermal refuge habitat during periods of elevated temperature.

3.2.3.2 Roaches Creek and Tectah Creek Confluences

The confluences of some small tributaries within the mainstem corridor downstream of Trinity River form habitat units that resemble backwater pools when mainstem river flows are elevated. This condition is especially pronounced when tributary flow is low and river flow is high, such as occurs during late winter and spring snow melt, as seen at Roaches Creek (RM 31.5) and Tectah Creek (RM 22.1)(Figure 26). Both of these sites appear to offer suitable velocity refuge for juvenile coho under some range of flow conditions. It is noteworthy that the transitory nature of these habitats would not be conducive to a stable residency pattern for juvenile coho throughout the winter. These sites may be most useful as stop-over sites—providing temporary refuge—for juvenile coho moving downstream in search of more stable overwintering habitat.

Figure 24. Examples of reach characteristics of the mainstem Klamath River within the lower study area: (a) large river features within a confined channel with a small floodplain near RM 22; (b) large and steep river bars located downstream of RM 22.

Figure 25. Aerial views of the lower Klamath River: (a) approximately the lower 12 miles of mainstem river showing the three prominent point bar-type features; (b) the estuarine zone and the channel complex associated with the South Slough.

Further work is needed to describe the characteristics of these types of habitats as a function of flow—both in the mainstem river and the tributaries. While these sites appear to offer suitable refuge under some conditions, their dynamics in size and flow velocity are not yet understood.

Figure 26. Tributary confluences along the lower Klamath River: (a) Tectah Creek (RM 22.1) and Roaches Creek (RM 31.5). Photos taken during spring runoff on May 5, 2006 (Klamath River flow at Klamath gauge at 36,700 cfs). The clear water—compared to the highly turbid mainstem river—has very low velocity due to the impounding effect of high mainstem flow on the tributary flow.

3.2.3.3 Tarup Creek Floodplain Channel and Ponds

The Tarup Creek floodplain channel and ponds are located on the most upstream of the three meander bends described earlier (Figure 25a and Figure 27a). This channel feature is a tributary-fed floodplain channel similar to those described in the middle study area at Sandy Bar and Stanshaw creeks—only on a much large scale. Tarup Creek is a small tributary that feeds the upper end of this large floodplain channel and flow is very low in late summer.

This floodplain channel forms three ponded areas identified in Figure 27a. The ponds are quite large and are present throughout the late fall, winter, and spring (Figure 27b and c). Some parts of the ponds remain watered through the summer, which is probably the result of shallow hyporheic flow. Further work is needed to assess water quality at the site during summer.

Connectivity of this channel at its upper end to the mainstem river only occurs at very high flows, the level of which has not been identified. It was not been determined whether connection occurred on the upper end in winter 2006-2007. It is certain that connectivity did not occur in winter 2007-08. The ponds associated with the channel appear to provide good overwintering habitat for juvenile coho due to the general lack of connectivity at the upper end, thereby providing a large amount of slackwater as velocity refuge.

We surmise that connection of the floodplain channel at its lower end to the mainstem river remains intact through most of a typical winter. Connection with the mainstem is lost at some point on the receding hydrograph, though we have not identified the point at which this occurs. Stranding of juvenile coho that enter the ponds for overwintering may occur to some extent as a result of disconnection between the channel and the mainstem river. Any improvements that could be made to maintain longer connectivity between ponds and at the egress to the mainstem river during spring would likely be beneficial to the coho populations that use the ponds for overwintering.

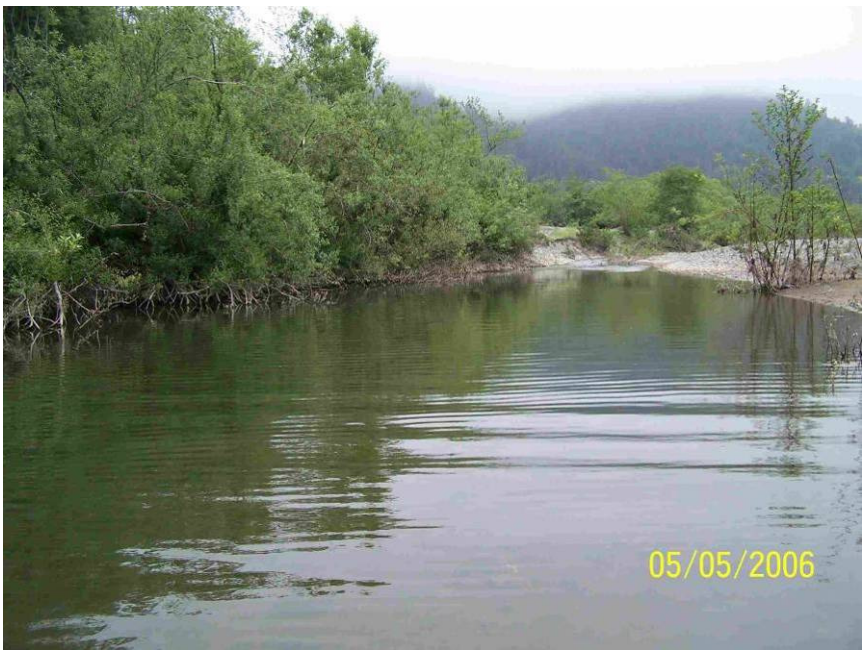


Figure 27. Tarup Creek floodplain channel and ponds: (a) aerial view of point bar and channel and pond locations; (b) lower pond at the time of spring runoff (May 5, 2006)—connection existed on the downstream end to the mainstem river but not on the upstream end (Klamath River flow at Klamath gauge at 36,700 cfs); ***continued to next page.***

Figure 27 continued – (c) middle pond within the Tarup Creek floodplain channel.

3.2.3.4 McGarvey Creek

McGarvey Creek (RM 6) is a small tributary to the lower section of the lower study area. While it supports natal coho production, it is also used by some non-natal juveniles originating from other spawning tributaries. Both coho smolts and spawners are annually enumerated in the stream by the Yurok Tribe. These data show a larger smolt yield than can reasonably be attributed to the number of spawners observed there, suggesting that some portion of the smolts are the result of non-natal juveniles moving into the stream for some part of their rearing prior to smolting.

McGarvey Creek is a low gradient stream (Figure 28a) that contains habitat elements consistent with good overwintering survival for juvenile coho (i.e., wood, pools, off-channel alcoves). Based on juvenile coho movements observed in other Pacific Northwest streams, it is certain that juveniles can access a substantial distance of channel in this stream during their fall redistribution to overwintering sites.

The confluence reach of this stream also supplies suitable overwintering habitat during periods of high flow in a similar fashion as that described for Roaches and Tectah creeks (Figure 28b and c). Water backed up into this reach by elevated flows in the mainstem river flood the creek's valley bottom and provide a velocity refuge area for coho in search of suitable habitat. The area that becomes flooded during high flow events is extensive. The dynamics of the McGarvey confluence with respect to ponding are not yet well described. Coho that use this area for some part of their overwintering would be subject to flow change, and therefore, the area may primarily serve for temporary overwintering refuge.

Figure 28. Lower McGarvey Creek: (a) stream upstream of the zone of inundation caused by the mainstem river; (b) lowest reach in the stream looking upstream from the mouth during summer low flow illustrating sediment deposits made due to flooding from the mainstem river in the previous spring or winter; ***continued to next page.***

Figure 28 continued – (c) flooding into lower McGarvey Creek from the mainstem river during high flow event on December 15, 2006 (Klamath River flow at Klamath gauge at 76,400 cfs).

3.2.3.5 Resighini Floodplain Channels and Ponds

The Resighini floodplain channel and ponds are located on the middle meander bend of the three meander bends described earlier (Figures 25a and 29a). This feature is comprised of two parallel floodplain channels located near the inside edge of a large point bar. These channels appear to combine into one channel at very high flows.

Connectivity of these channels at their upper end to the mainstem river occurs only at very high flows, the level of which has not been identified. It is not certain that connection occurred on the upper end in winter 2006-2007. Connectivity at the upper end did not occur in winter 2007-08. In general, the ponds associated with the channels potentially provide good overwintering habitat due to their slackwater characteristics (Figures 29b and 29c). The ponds are very extensive and remain watered to a considerable extent throughout all seasons of the year, though we are aware that summer temperatures within the ponds are high. Shallow hyporheic flow is the source of year-round water since no tributary inflow exists.

The ponds have more restricted connectivity to the mainstem river at their lower ends than does the Tarup Creek floodplain channel. The Resighini channel no. 1 (most upstream) has more prolonged connectivity than channel no. 2, though both channels currently would restrict smolt emigration through most of the period of normal outmigration timing (Figure 29c). Any improvements that could be made to maintain longer connectivity at the egress channels to the mainstem river during spring would be beneficial to the coho populations that use these ponds.

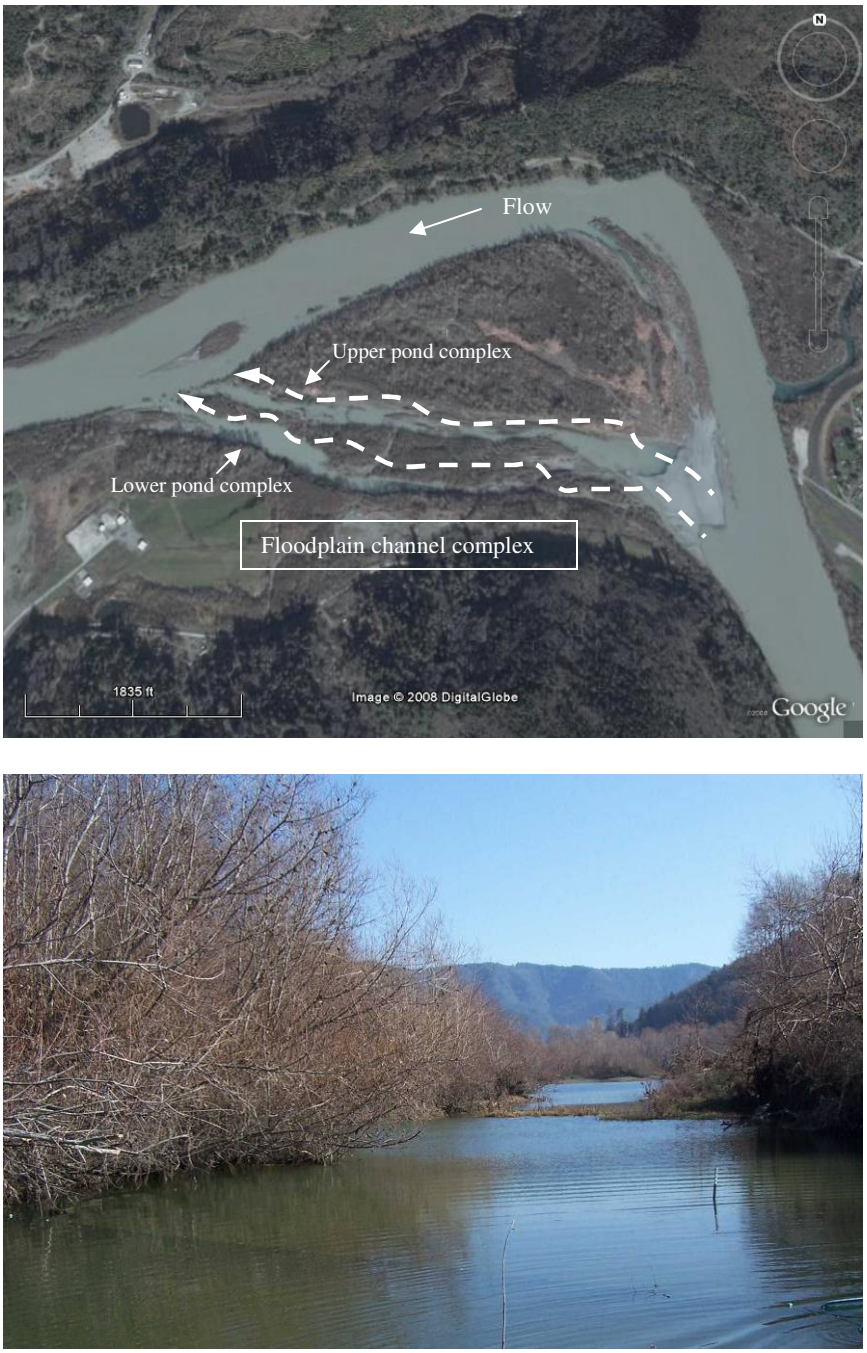


Figure 29. Resighini floodplain channels and ponds: (a) aerial view showing channel and pond locations; (b) lower end of Resighini channel no. 1 upstream of egress channel; ***continued to next page.***

Figure 29 continued – (c) lower end of Resighini channel no. 2 upstream of egress channel; (d) dry egress channel from channel no. 2. Photos shown in b, c, and d taken on January 26, 2007 (Klamath River flow at Klamath gauge at 10,300 cfs).

3.2.3.6 Waukell Creek and Junior Creek Pond

Waukell Creek is a small stream that enters the Klamath River at RM 3.19, near the upper end of the estuarine zone (Figure 23). The lower part of the Waukell subbasin sits within the Klamath River floodplain. Channel gradient of the stream in this area is very low and physical habitat is

generally suitable for coho rearing. Sections of the stream, however, have undergone extensive channelization in the past and are less suited for rearing due to channel simplification and lack of cover.

This stream, including its tributary called Junior Creek and an associated pond, became the focus of much of our fish trapping in the lower study area during Phase 1 activities. The stream has been selected for intensive monitoring as part of this project.

Due to the low gradient, Waukell Creek in its lower reaches has very low velocities and provides excellent overwintering habitat in many of its sections (Figure 30a). It also appears that certain areas of the stream provide good summer habitat for non-natal juveniles. The lower reaches of the stream are subject to being impounded by the flow of the mainstem river (Figure 30b) in similar fashion as described above for Roaches, Tectah and McGarvey creeks. This expansion and contraction of habitat associated with high flow events is quite extensive here and on a greater scale than occurs in the other tributaries described above. This is due to the widening of the river floodplain as the river mouth is approached and the presence of swales and relict channels that furrow the floodplain.

An example of this expansion and contraction within Waukell Creek associated with flow events is seen in Figure 31. The site shown is a relict channel of Waukell Creek, where it diverges from the existing active channel. Figure 31a shows the water level during a storm event in mid December 2006—the floodwater shown is the result of impounding by high flow and flooding from the mainstem river. Figure 31b shows the same site several weeks later. The photos illustrate the very extensive change in water level and habitat condition that occurs as a function of flow in the mainstem river. It bears noting that we trapped the connection between Waukell Creek with its relict channel during the receding hydrograph after the photo in Figure 31a was taken. Juvenile salmonids were trapped as they returned to the main Waukell Creek from the relict channel as flows receded.

Junior Creek, a tributary to Waukell Creek (Figure 23), forms a pond approximate 0.25 miles upstream of its confluence with Waukell Creek. The pond is approximately 0.6 acres in size. The egress channel flowing out of the pond is small, less than 3 ft in width (Figure 32a), and is the site of beaver damming. The pond is seasonal, filling during the fall with the onset of rain and recharging of Junior Creek, then slowly draining in the late spring when stream flow drops. Eventually the pond becomes completely dewatered and is dry during late summer (Figure 32b). The pond, while it seems to function in a completely natural manner, is actually man-made, dating to a past era when a mill operated in the vicinity. Junior Creek Pond, as seen in both Year 1 and Year 2 of this project, attracts relatively large numbers of juvenile coho that move into Waukell Creek out of the mainstem river for overwintering. Some of the fish that overwinter there originate in the Mid Klamath study area, from at least as far upstream as RM 117.

Figure 30. Lower Waukell Creek where the stream was trapped with fyke nets in winter 2006-07: (a) reach looking upstream from trapping site during a period of low flow; (b) looking upstream to the trapping site (trap is not installed) during a high flow event on December 15, 2006, showing flow impoundment due to high mainstem flow (Klamath River flow at Klamath gauge at 76,400 cfs).

Figure 31. Connection between existing channel in lower Waukell Creek with its former channel. Photographer is standing within the actively flowing Waukell Creek shooting into the relict channel: (a) high flow event on December 13, 2006 (Klamath River flow at Klamath gauge at 67,900 cfs); (b) same site on January 26, 2007 (Klamath River flow at Klamath gauge at 10,300 cfs).

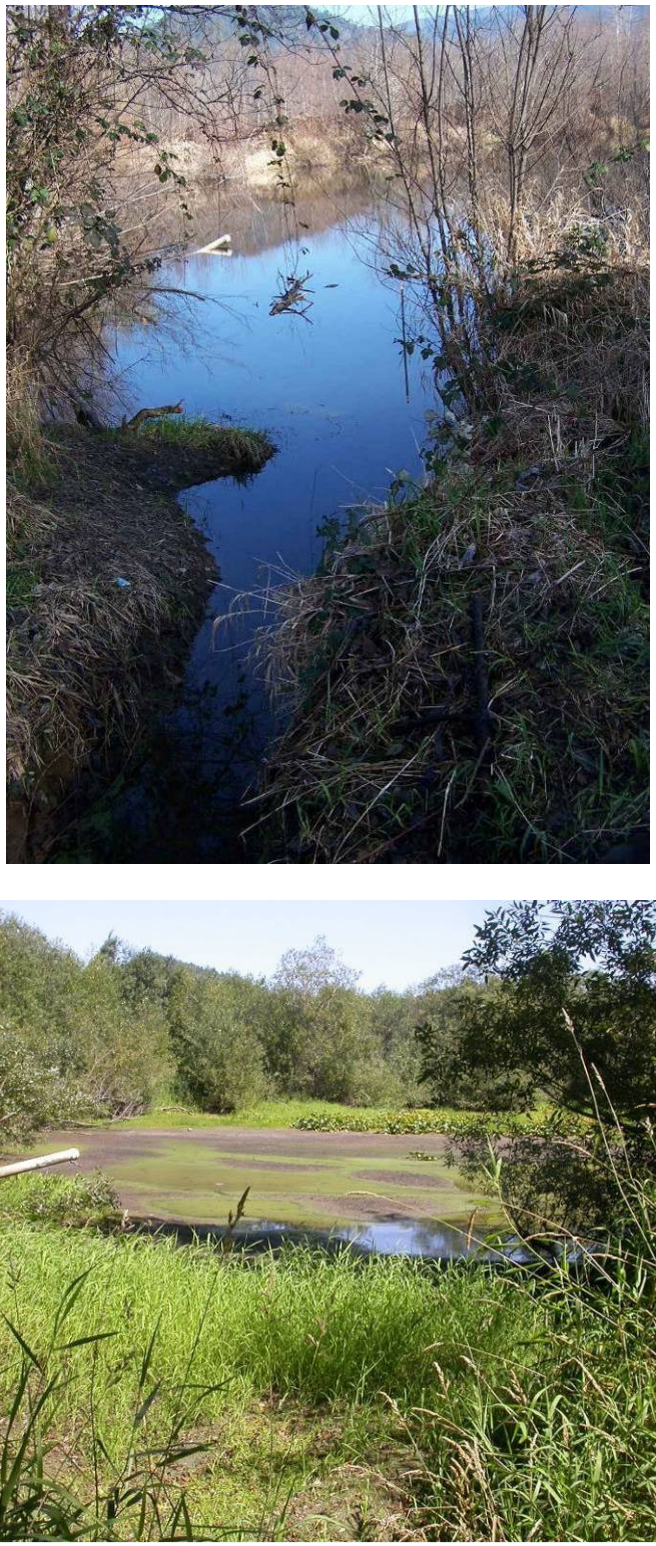


Figure 32. Junior Creek pond within the Waukell Creek system: (a) condition in mid January 2007, narrow egress channel is seen in the bottom of the photo; (b) pond in late summer 2007 with only small pockets of standing water.

Upstream of the confluence with Junior Creek, Waukell Creek flows through a large marsh that has the potential for providing a significant amount of good overwintering habitat. Virtually the entire marsh, however, is currently choked with dense canary reed grass, an invasive plant species. It appears likely that both juvenile and adult coho movement through the marsh is very difficult and it is uncertain to what extent that fish are able to either directly utilize or move through the area. Upstream of the marsh, the stream channel gradient steepens somewhat and a relatively substantial amount of spawning habitat exists. From all of the information available to us, we conclude that the Waukell Creek drainage is used by both natal and non-natal juvenile coho, though it appears to be most heavily used by non-natal juveniles. The current potential for coho production in the stream appears to be limited by the dense growth of canary reed grass in the marsh area. Restoration of this area through measures to reduce and control this invasive species appears to offer significant benefits for coho utilization.

3.2.3.7 Richardson Creek Ponds

Richardson Creek is a small stream that enters the Klamath River a short distance downstream of Waukell Creek at RM 2.82 (Figure 23). The creek forms two ponds (Figure 33a and b), which were created largely by past human activity (Hiner and Brown 2004). Both ponds are located within Redwood National Park. The upper pond, approximately 10 acres in size, is separated from the lower pond by a man-made berm that holds the upper pond at a somewhat higher elevation than the lower pond. It is uncertain how exactly flow passes from the upper upper pond to the lower pond.

Downstream of the lower pond, Richardson Creek flows under a road fill adjacent to the Klamath River, where the culvert is partly blocked by debris (Figure 33c), before joining the river (Figure 33d). The culvert has a partially rusted bottom, causing some amount of flow to drain into the fill before reaching the culvert outlet (RTA 2007). When flows are particularly low in Richardson Creek, all of the flow in the culvert drains through the rusted sections. The culvert is perched when river flows drops to a certain level, at which point it is uncertain how tidal fluctuations might facilitate passage through the culvert.

We determined that the lower pond is used by overwintering coho and we suspect the upper pond is utilized also. We are uncertain whether the fish are natal or non-natal to the stream, but we suspect that at least some are non-natal fish. RTA (2007) reported that some amount of spawning habitat exists in Richardson Creek upstream of the ponds. It is likely that invasive centrarchids (spiny-ray species) and bull frogs are abundant in the ponds.

Any restoration work that could be performed to improve access and utilization of the ponds would likely be highly beneficial to the coho.

Figure 33. Richardson Creek and associated ponds: (a) upper pond; (b) lower pond; ***continued to next page.***

Figure 33 continued – (c) lower stream reach entering the culvert under roadway fill, partially blocked by debris on upstream side; (d) same culvert on the downstream side slightly upstream of the stream's confluence with the Klamath River. Photos shown in a, b, and c taken on January 9, 2007. Photo shown in d taken on February 10, 2010 when the Klamath River flow was 17,800 cfs and tidal level was low.

3.2.3.8 Salt – Hunter Creek Complex

Salt Creek and Hunter Creek enter the Klamath River a short distance from one another within the estuarine zone (Figure 23 and Figure 34a). Both streams support natal coho production. Fish trapping during Year 2 of this project has confirmed that Salt Creek is also used by non-natal juvenile coho.

Although substantial channelization and other habitat loss has occurred to these streams (e.g., Figure 34b), large amounts of habitat well suited for coho overwintering remain. Major portions of both stream systems flow through low gradient valleys, having meandering channels interspersed with large beaver ponds and wetland habitats (Figure 34c)(Beesley and Fiori 2004; Beesley and Fiori 2007). The stream mouths have good connectivity to the middle part of the estuarine zone (Figure 34d). This entire stream complex appears to potentially provide a substantial amount and diversity of habitats for both natal and non-natal coho use. Habitat restoration work in both streams could potentially increase benefits significantly for both non-natal and natal populations using these streams.

The lower Salt Creek site has been selected for intensive monitoring. Panther Creek, a tributary to Hunter Creek, has also been selected for intensive monitoring. Both streams contain a substantial amount of pond habitat.

3.2.3.9 South Slough Complex

The South Slough and its many connecting channels dissect the expansive final meander bend on the river immediately upstream of the river mouth (Figure 25b). A major side channel of the river cuts through the middle of the area before joining with a large blind channel network on the southern edge of the meander bend. Numerous smaller channels and wetland ponds are connected within the area. Most of these channels are subject to tidal fluctuations, though saltwater intrusion is apparently slight or non-existent during winter flow conditions (Hiner and Brown 2004). Based on the sheer amount of low velocity habitat, and the extensive length of shorelines, this channel complex potentially represents the largest contiguous area of good overwintering habitat for juvenile coho in the Klamath River basin (Figure 35). Through the end of Year 2 of the project, limited amount of sampling has occurred within the South Slough due to logistical difficulties to regularly access the site. A more comprehensive sampling effort is planned.

Figure 34. Salt and Hunter creek complex: (a) aerial view of valleys containing Salt and Hunter creeks and their tributaries; (b) lower Spruce Creek, tributary to Hunter Creek, showing evidence of channel simplification due to land use activities; ***continued to next page.***

Figure 34 continued – (c) lower Hunter Creek immediately upstream of its confluence with the Klamath River; (d) mouth of Salt Creek as seen from the Klamath River.

Figure 35. South Slough complex: (a) looking upstream from the lower end of the large blind channel on the southern edge of the complex; (b) looking downstream from near the mid section of one of the large blind channels.

3.2.3.10 Mainstem River Edge Habitat

A large proportion of river edge habitat downstream of Trinity River is comprised of rocky bank edge (Figures 24a and 36a) and bar edge (Figure 36b). Interspersed are sections of bank edge habitat with lodged wood (Figure 36b and c) or cover provided by vegetation such as willows

and shrubs (Figure 36d). Edge width with slow velocities preferred by coho tend to be quite narrow in most places. These characteristics suggest that these edge habitats would generally not be used to a large extent by overwintering juvenile coho, except as stop-over sites while seeking more suitable habitats. Sampling of these sites using a boat electrofisher occurred during winter 2007-08 and appears to support these inferences.

Figure 36. Examples of bank edge habitats along the mainstem Klamath River downstream of Trinity River during a moderate winter flow. All four photos were taken between Tectah Creek and the Tarup Creek floodplain channel: (a) rocky bank edge; (b) lodged large wood pieces along a deep bank edge; ***continued to next page.***

Figure 36 continued—(c) stable redwood root mass along a deep bank edge; (d) vegetated bank edge with submerged branches and roots.

4.0 Assessment of Juvenile Movement Patterns

This section summarizes findings regarding patterns of movement by juvenile coho within the Klamath River corridor related to summer and winter habitat use. The results presented are preliminary and do not include all of the data that was collected during Year 2. Results of additional analyses for this period will be included in the Year 3 report. The findings presented

herein illustrate the general patterns that have been found and the extent to which movement occurred occurred during two years

4.1 Methods

Methods for assessing juvenile movement patterns were outlined in the Phase 1 report (Soto et al. 2008). The methods include systematic sampling with capture gear at frequent intervals at specific sampling sites during spring, summer, fall and winter, and the use of marks and PIT tags.

During Year 2, fish capture frequency at certain sites was increased significantly over what it was during the first year of study. Results for two streams in the Mid Klamath area, Independence Creek and Cade Creek, are reported here to illustrate patterns observed in this study area. In the Lower Klamath study area, sites within the Waukell subbasin were routinely monitored and are reported on here. In addition, movement patterns into and out of two other tributaries, Salt and Panther creeks, to the Lower Klamath study area are presented.

During May and June 2007, when age-0 coho were still too small to PIT tag, we employed freeze brand marking—though on a limited basis—to aid in assessing movements and habitat residency. In Phase 1, it became evident that the primary tool for marking and tagging would be with the use of PIT tag technology. Results presented herein focus on observations using PIT tags. Other information related to the freeze branding will be presented in the Year 3 report.

PIT tags were only applied to a very limited extent in Phase 1 for the purpose of field evaluation by the tribal crews. That evaluation resulted in a determination that PIT tags needed to play a central role in assessing movement patterns of juvenile coho in the basin. Consequently, a major emphasis of Year 2 activities was to capture and PIT tag significant numbers of age-0 coho in both study areas over a wide range of streams. The effort was aimed at tagging fish within mainstem corridor habitats to facilitate assessing their susequent movements. It was expected that the results of Year 2 would be used to guide the formulation of an improved tagging and tag detection plan for Year 3. The primary emphasis of PIT tagging in the Mid Klamath study area in Year 2 was on obtaining a very broad coverage across the area in tags released. Patterns of recpature—both in this study area and in the lower Klamath—would hopefully identify areas where juveniles are inclined to move from and areas where they move to. In contrast, the primary emphasis placed on PIT tagging in the Lower Klamath study area was to develop a better understanding of the extent that the Waukell subbasin is used by non-natal fish. Secondarily, tagging was applied across a number of streams in order to asess broader patterns of movement as was being done in the Mid Klamath area.

All PIT tag detection during Year 2 was to be done using hand-held wands in processing fish capatured at the various sampling sites.

4.2 Results

Results are presented first using catches made at sites where fish capture techniques were employed at frequent intervals over the period of interest, followed by results for PIT tagged fish.

4.2.1 Movement Patterns In and Out of Tributary Habitats in the Mid Klamath Study Area

Two streams routinely monitored for fish abundance during spring, summer, and fall were the Independence floodplain channel (RM 94) and Cade Creek (RM 112). Data for other streams, which were monitored less frequently, will be incorporated into the analysis as part of Year 3 activities.

The Independence Creek channel was sampled in its lower reach using a pole seine at various times between late May 2007 to near the end of January 2008 (Figure 37). While some of the age-0 fish captured early in the sampling period may have been natal fish produced in this stream, various observations made in the stream indicate that the large majority of captured fish were non-natal fish. The channel held a relatively large number of juvenile coho through summer. As will be seen with the PIT tagging results, residency appeared to be stable during this period, though immigration continued into the channel through mid summer. Following the advent of high flows, which occurred beginning in October, seine catches dropped and continued to decline through late January. The patterns displayed in Figure 37 suggests that increased flows in the channel during this period resulted in some fish emigrating from the site. This type of a pattern is expected due to the general lack of velocity refuge cover or sites in this stream to provide good overwintering.

Based on the arrival time of non-natal fish to the lower reaches of other tributary habitat in the Mid Klamath area, as seen at Cade Creek in 2007 and other streams in previous years, the primary factor affecting immigration timing into Independence Creek appears to be water temperature (Figure 38). The abundance of age-0 immigrant coho in Cade Creek was monitored using minnow traps in the lower reach of the stream. Immigrant coho began arriving to Cade Creek in early June, about the same time when sampling began in the Independence Creek floodplain channel. Water temperature in the mainstem Klamath River was hitting 19 ºC at the time when coho began arriving to Cade Creek. The number of juvenile coho moving into the stream increased as temperatures continued to rise. The decline in catches made in the minnow traps is likely due to the fish moving further upstream, away from the site where the traps were deployed, though Ron Sutton gave an alternative hypothesis (see below).

Ron Sutton with the USBOR made the following comments regarding Figure 38 in a technical memorandum on thermal refuge use in the Klamath River during 2006-2008: :

> "During a survey at Cade Creek on July 11, 2007, juvenile salmonids were observed attempting unsuccessfully to jump into the tributary from the mainstem, possibly trying to escape the warm main stem water temperatures. The main stem water temperature was 25.5ºC (77.9ºF) while the Cade Creek temperature was 21.5ºC

(70.7ºF) at 1300 hours. A minor stream restoration effort to create pocketwater habitat in lower Cade Creek would allow easier access for juvenile salmonids to enter Cade Creek.

Figure (38) illustrates when juvenile coho salmon and steelhead entered Cade Creek relative to mainstem Klamath River and Cade Creek water temperatures in 2007. Again, the horizontal red line represents the 22ºC level where we start to see stress on coho salmon. The vertical bars represent numbers of coho or steelhead captured by minnow traps in Cade Creek. It appears that coho salmon started entering Cade Creek when mainstem Klamath River temperatures exceeded about 19 ºC. Coho numbers peaked and declined before steelhead, possibly in response to a cold front in late July that allowed them to exit Cade Creek and move downstream towards overwintering areas. Steelhead numbers tended to follow mainstem temperatures with maximum numbers in Cade Creek occurring when mainstem temperatures were warmest. This suggests that steelhead can tolerate warmer mainstem temperatures than coho before they seek thermal relief."

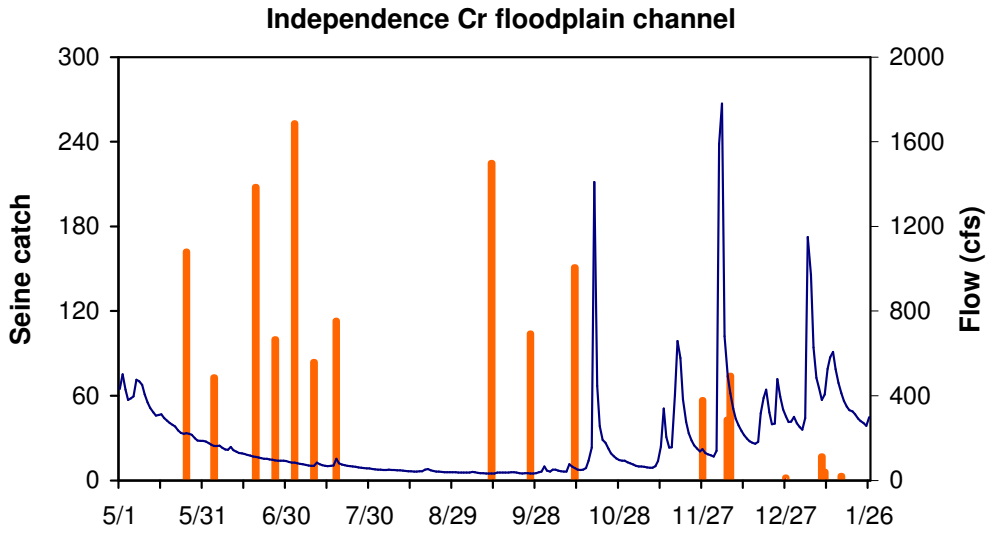


Figure 37. Seine catches of juvenile coho in the Independence Creek (RM 94) floodplain channel between May 2007-January 2008, showing apparent pattern of movement into and out of the stream reach. The daily flow in lower Indian Creek (RM 111) is also shown as an index of flow that occurred in Independence Creek. Flow contribution from the mainstem Klamath River to the floodplain channel during this period is not known.

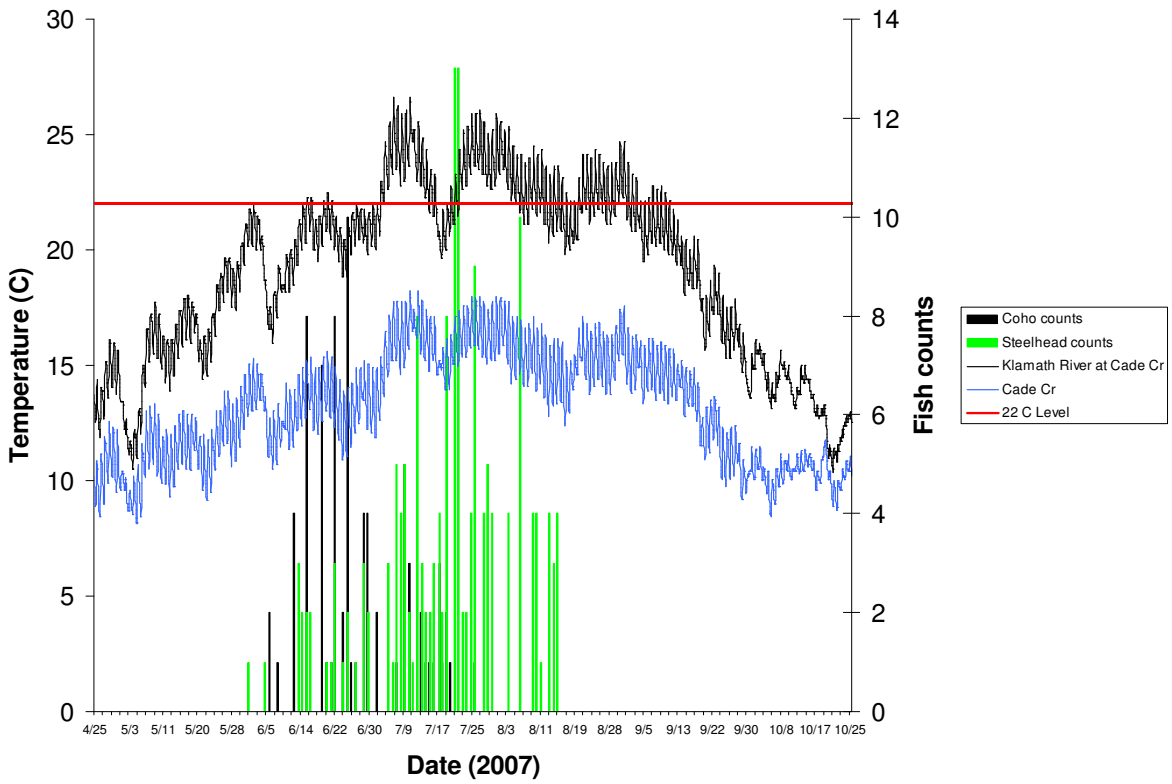


Figure 38. Timing of juvenile coho and steelhead movements into Cade Creek relative to mainstem Klamath and tributary temperatures during summer 2007. Black and green vertical bars are coho and steelhead catches, respectively. Fish numbers represent catches made by minnow traps in the lower reach of the stream. Graph is from Sutton (2009). The red horizontal line corresponds to 22 C.

The patterns seen in Figures 37-38 highlight the importance that cool water tributaries have to providing thermal refuge to juvenile coho that move away from natal streams and into the Klamath River corridor during late spring and summer. Similar patterns have been observed for many other tributaries that appear to provide this function in the Mid Klamath area (Karuk tribal unpublished data). Many of these streams, however, lack habitat features needed to provide velocity refuge during periods of high flow.

4.2.2 Movement Patterns In and Out of Tributary Habitats in the Lower Klamath Study Area

Movement patterns of juvenile into, within, and out of tributaries to the lower Klamath River were assessed through trapping at strategic sites within the streams using directional fyke nets. Three sets of traps were deployed in the Waukel subbasin: at the lower Waukell Creek site trapped in 2006-07, in Junior Pond Creek immediately downstream of Junior Pond, and in the lower end of the marsh in upper Waukell Creek, located upstream of the confluence of Junior Pond Creek and Waukell Creek. Trapping was also conducted in lower Salt Creek on the north side of the Klamath River estuary and in Panther Creek immediately downstream of a large pond complex in that stream. Movement patterns at these sites are reported below.

The pattern of upstream movement by juvenile coho into Junior Pond closely resembles the one documented in the winter of 2006-07 in lower Waukell Creek. Pulses of immigrants corresponded closely with freshet events until about mid January (Figure 39). At that time, the upstream migration appeared to largely be over followed by a few fish periodically being captured in the upstream directional trap. In 2006-07, the migration appeared to end in lower Waukell Creek on about January 1.

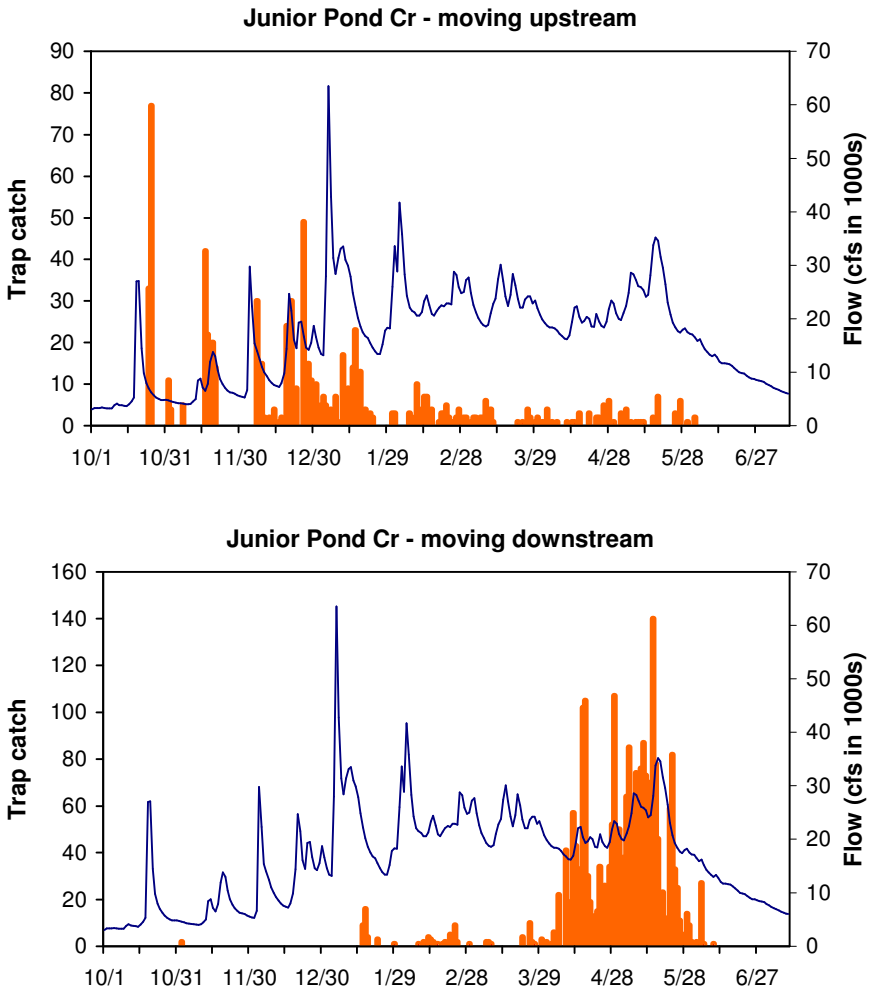


Figure 39. Daily catches (orange bars) of juvenile coho in the upstream (top) and downstream (bottom) directional fyke traps in Junior Pond Creek located a short distance downstream of Junior Pond between October 1, 2007 and July 15, 2008. Flow in the Klamath River is also shown (Terwer gauge near Highway 101).

Movement out of Junior Pond commenced in a significant manner in early April (Figure 39). Relatively few fish moved out of the pond prior to that time. The migration out of the pond continued into early June. However, it is noted that the egress channel from the pond had gone dry at this time and there was still a relatively large number of smolt-sized fish holding in the pond waiting to migrate. As discussed below, the coho smolt migration is known to have been exceptionally late in 2008 across a wide expanse of Northern California and the Pacific Northwest. In years such as this, some smolts are subjected to being stranded in streams with

sections going dry in early summer, or are trapped in ponds awaiting another opportunity to migrate in the next year.

Figure 40 displays the movement patterns recorded in lower Waukell Creek, the same site trapped in 2006-07. No distinct pattern of upstream migration was observed to have occurred in fall and winter, unlike the distinct upstream movement seen in 2006-07. It is evident, however, that trapping effort at this site was marginal at best because juveniles had to migrate past this site to move upstream into Junior Pond. Therefore, the data cannot be used to illustrate upstream fall and winter movement. The patterns are also puzzling for the spring period because relatively large numbers of fish were moving upstream while the downstream movement was occurring. Many of the fish moving upstream in spring were not age-0 fish, as seen in the length frequency data for the site (Figures 41-42). The length frequency data show that while many of the upstream migrants were large (easily large enough to be smolts), they were somewhat smaller than the yearling fish moving seaward.

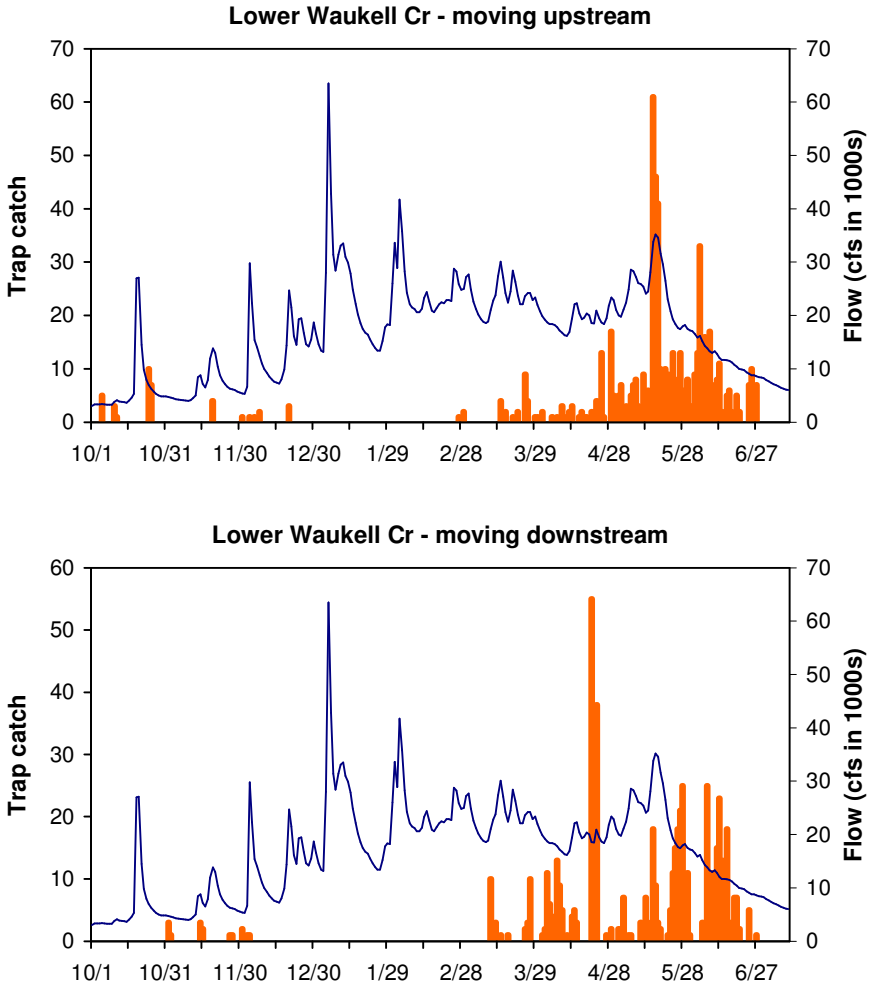


Figure 40. Daily catches (orange bars) of juvenile coho in the upstream (top) and downstream (bottom) directional fyke traps in lower Waukell Creek between early November, 2007 and the end of July, 2008. Flow in the Klamath River is also shown (Terwer gauge near Highway 101). See Figures 41-42 for information related to the age structure of migrants.

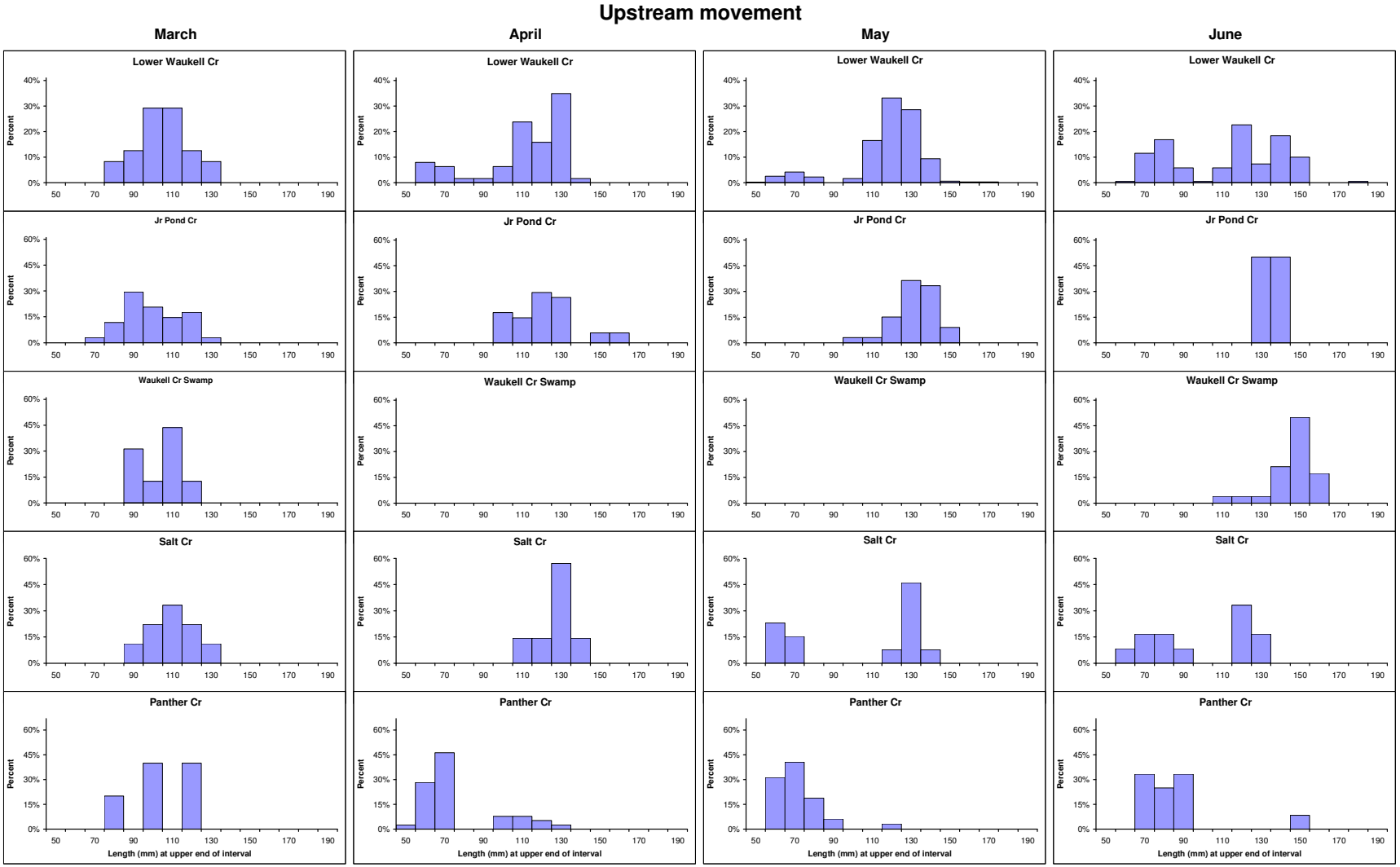


Figure 41. Length frequency charts for juvenile coho captured in upstream directional fyke traps during fall, winter, spring, and early summer of 2007-2008 in lower Waukell Creek, Junior Pond Creek, upper Waukell Creek swamp, Salt Creek, and Panther Creek.

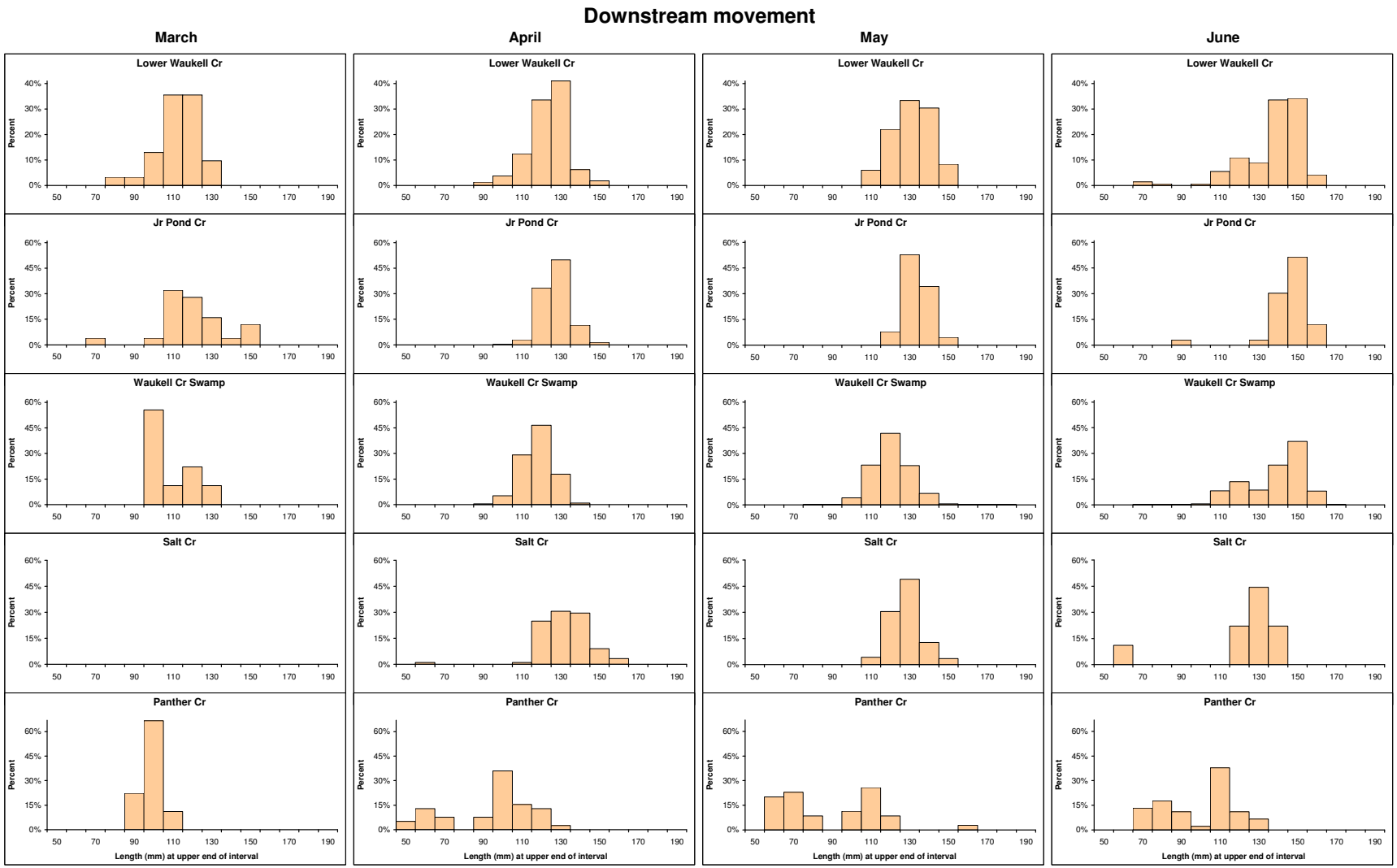


Figure 42. Length frequency charts for juvenile coho captured in downstream directional fyke traps during fall, winter, spring, and early summer of 2007-2008 in lower Waukell Creek, Junior Pond Creek, upper Waukell Creek swamp, Salt Creek, and Panther Creek.

Movement patterns recorded at the upper Waukell Creek marsh site are seen in Figure 43. The reader should note that only one trap was used between the time when trapping began in mid November 2007 and the end of June 2008. The trap was deployed to catch upstream migrants until mid March, then reversed to catch downstream migrants between mid March and the end of June. A second trap was installed at the end of June, thereby catching both upstream and downstream migrants.

The patterns seen in Figure 43 raise additional questions about the nature of the smolt migration in Waukell Creek in 2008. The number of upstream migrants appears to have increased after mid January instead of declining as it did at Junior Pond Creek (as it also did in Lower Waukell in 2007). While this small amount of data anomaly might be due to trapping inconsistencies, it is uncertain whether the movement patterns into Junior Creek and upper Waukell Creek at the marsh site are the same. Data collected after May 2008 are expected to help resolve this uncertainty. Also, the surge in upstream movement recorded at the Waukell marsh site is also striking. Not shown in the chart is that trapping continued through July into early August and the same pattern persisted. The fish being caught were very large (most ranging between approximately 130-170 mm). Near mid summer, we discovered that a beaver dam existed in Waukell Creek between the confluence of Junior Creek and the lower Waukell trap site. Passage of juveniles at site appeared to be impossible at this time (mid July). We conclude, therefore, that yearling coho that had not yet left the stream by late June were unable to emigrate at that point. The trap data suggests that fish were wandering within the reach, perhaps seeking some way downstream or moving to find more suitable habitat for continued residency.

In contrast to the large sizes of fish caught at the upper Waukell marsh site, upstream migrants at the lower Waukell Creek site at the same time (June) were somewhat smaller and consisted of both age-0 fish and smolt sized immigrants. It is also noteworthy that a fyke trap set in the Panther Creek pond in July also captured a significant number of large smolt sized coho juveniles (mostly 130-145 mm). The length frequencies in Figure 42 do not show any catches of fish of this size at the trapping sites downstream of the pond. These patterns suggest two hypotheses: (1) migration blockages existed in these streams that were not apparent to the biologists; or (2) smolt sized juveniles de-smolted as the smolt window passed and moved to the upper reaches of these streams seeking cool water refuge and forage. As noted earlier, the coho smolt migration was exceptionally late across much of the west coast, which may have resulted in the latest segment of the migration to desmolt. Moreover, elevated water temperatures in the lower Klamath River and estuary may have exacerbated difficulties in smoltification due to the lateness of the migration. We believe that the unusual patterns in movement seen at the various sites by mid June were caused by a combination of blockages and desmolting.

Movement patterns seen in trap catch data for Salt Creek and Panther Creek are provided in Figures 44-45. Both traps produced much smaller catches than those found in Waukell Creek. Also, while Panther Creek contains abundant marsh and pond habitat, and is not located far from the mainstem Klamath River, the catches were dominated by much smaller fish than found at the other sites. Further investigation is needed to learn the nature of smolt production and use by natal and non-natal fish in this stream.

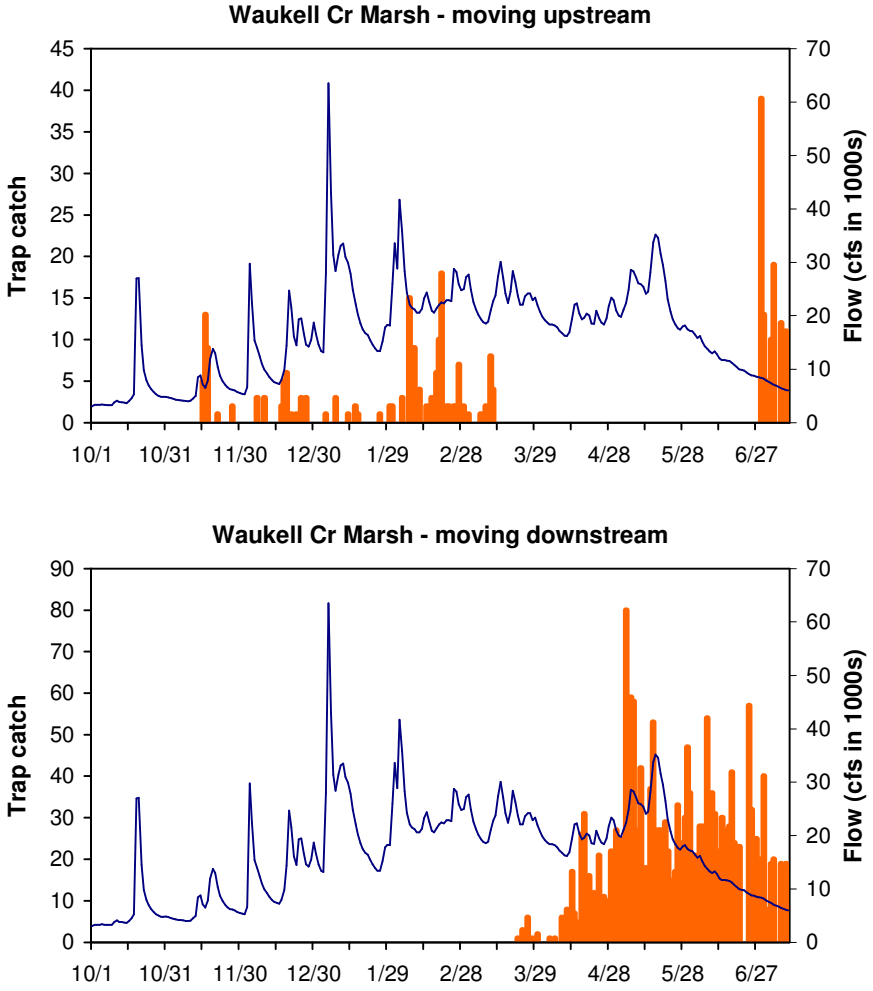


Figure 43. Daily catches (orange bars) of juvenile coho in the upstream (top) and downstream (bottom) directional fyke traps in the upper Waukell Creek marsh site between early November, 2007 and mid July, 2008. Flow in the Klamath River is also shown (Terwer gauge near Highway 101). See Figures 41-42 for information related to the age structure of migrants.

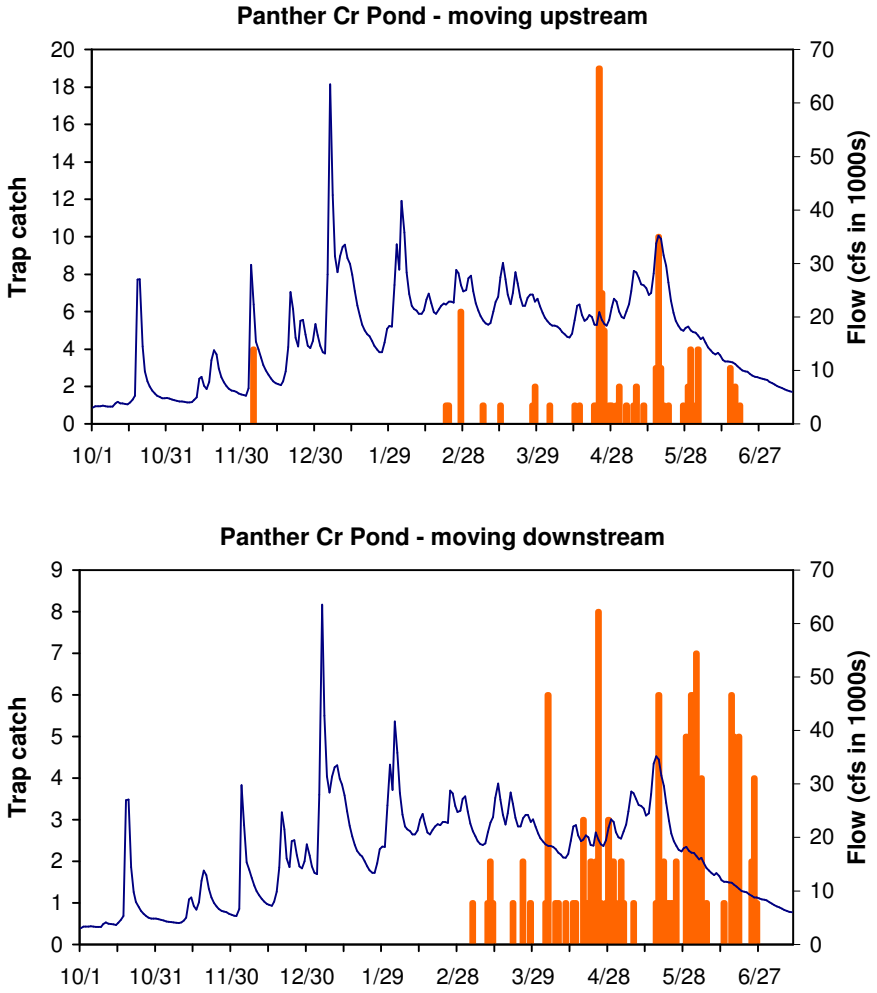


Figure 44. Daily catches (orange bars) of juvenile coho in the upstream (top) and downstream (bottom) directional fyke traps in Panther Creek between early December, 2007 and the end of June, 2008. Flow in the Klamath River is also shown (Terwer gauge near Highway 101). See Figures 41-42 for information related to the age structure of migrants.

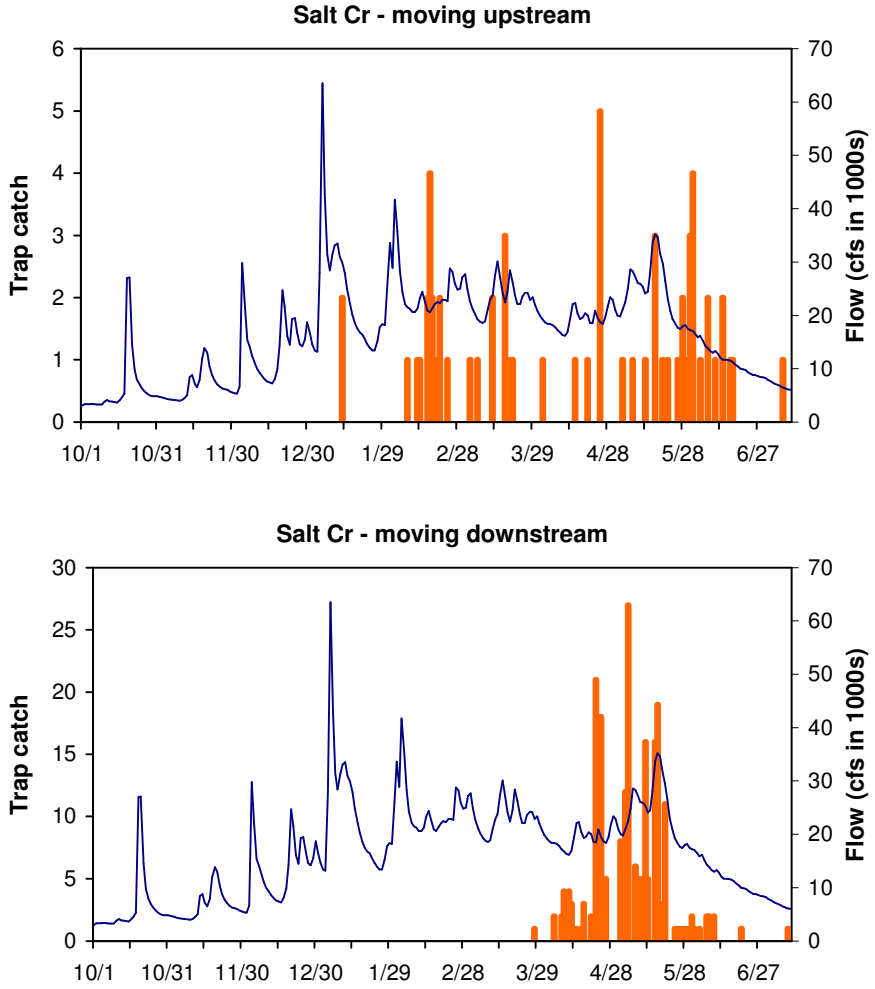


Figure 45. Daily catches (orange bars) of juvenile coho in the upstream (top) and downstream (bottom) directional fyke traps in Salt Creek between mid January, 2008 and the end of June, 2008. Flow in the Klamath River is also shown (Terwer gauge near Highway 101). See Figures 41-42 for information related to the age structure of migrants.

4.2.3 Movements Assessed through PIT Tag Tagging

The use of PIT tag technology provided the means to assess movements of individually identified fish in conjunction with the extensive trapping and seining activities conducted during the study period. No stationary detection stations were in place to aid in monitoring, but the various traps and seining sites gave a reasonably effective way of recapturing tagged fish at the many sampling sites between the two study areas.

Between May 2007 and May 2008, more than 2,700 juvenile coho were successfully PIT tagged and released between the two study areas (Table 3). A total of 1,959 tagged fish were released in the Mid Klamath study area and the remainder in the lower study area. The large majority of these tagged fish were released prior to December 2008.

Table 3. The numbers of juvenile coho tagged with PIT tags and successfully released in the middle and lower Klamath study areas between May 2007 and May 2008 .

Month	Number tagged	
	Mid Klamath	Lower Klamath
May	-	7
June	48	31
July	232	2
August	479	16
September	613	108
October	191	159
November	58	247
December	183	67
January	108	35
February	12	30
March	26	43
April	7	20
May	2	-
Total	1,959	765

In the Mid Klamath study area, tagged fish were released at 16 different stream sites over a distance of about 110 miles as measured by the stream mouth or site location along the Klamath River (Table 4). The three sites where the most juvenile coho were tagged were Aikens Creek (RM 50 – 10.3% of the total), Independence Creek (RM 94 – 39% of the total, and China Creek (RM 118 – 15% of the total). The most upstream site where a fish was tagged was Beaver Creek at RM 161.

Of the total number (1,959) of fish tagged in the Mid Klamath study area, 289 (15%) were recaptured at least once within the same study area (Table 5). One fish was recaptured a total of twelve times over a period of seven months. That fish was tagged in the Independence Creek floodplain channel and then recaptured multiple times in the Sandy Bar floodplain channel. A total of eleven tagged fish (0.6%) were recaptured at least once at one of the other sampling sites than where they were originally tagged and released.

It bears noting the journey of one of these eleven fish that relocated within the Mid Klamath study area. The fish was tagged in Tom Martin Creek, a thermal refuge site, on August 16, 2007. Water temperature in the Klamath River near the site at the time was approximately 22-24ºC. The fish was recaptured on September 18, 2007 approximately 15 miles downstream in Fort Goff Creek—water temperature in the main river at the time was about 17ºC, demonstrating that some fish that seek relief in a thermal refuge site leave the site and find habitat elsewhere when water temperatures subside.

In contrast to the 0.6% of the tagged fish recaptured at a different site within the Mid Klamath study area, 2.5% of the tagged fish were recovered by Yurok tribal staff within the Lower Klamath study area (Table 6). Of the total number tagged (1,959), 48 were recaptured at least once within the Lower Klamath study area. Table 7 lists the recapture incidents for each of these 48 fish—giving date of tagging, location tagged, and fish length followed by recapture date, location of recapature, and size at recapture.

The longest distance traveled of a fish that re-entered one of the tributaries in the lower Klamath study area—and was recaptured—was 125 miles. That fish was tagged on September 18, 2007 in Fort Goff Creek, then was recaptured in Salt Creek on May 10, 2008. It is not known for certain, however, where this fish overwintered, though we think it likely that it was in Salt Creek. The longest redistribution of a fish known to overwinter in the lower Klamath study area was 114 miles. That fish was tagged on August 14, 2007 in China Creek, then was recaptured moving upstream in Junior Pond Creek on January 2, 2008.

Table 4. The numbers of juvenile coho tagged with PIT tags and successfully released in the Mid Klamath study area by stream site between May 2007 and May 2008 .

Stream	RM	No. tagged	Percent
Aikens Creek	49.6	201	10.3%
Big Bar (Klamath R)	50.0	50	2.6%
Camp Creek	57.1	96	4.9%
Stanshaw Creek	76.9	72	3.7%
Sandy Bar Creek	77.6	116	5.9%
Dillon Creek	84.1	44	2.2%
Independence Creek	94.0	756	38.6%
Titus Creek	96.7	49	2.5%
Bulk Plant (Klamath R)	111.5	37	1.9%
Cade Creek	112.5	32	1.6%
China Creek	117.9	302	15.4%
(Little) Horse Creek	118.1	25	1.3%
Thompson Creek	123.0	51	2.6%
Fort Goff Creek	128.0	72	3.7%
Tom Martin Creek	144.2	55	2.8%
Beaver Creek	161.0	1	0.1%
Total		1,959	100.0%

Table 5. The number of tagged fish by tagging site that were recaptured one or more times within the Mid Klamath study area between May 2007 and May 2008 . The number of tagged fish that moved to a different site within the same study area—and were recaptured—is also shown.

Area	RM	No. tagged	No. tags recaptured at least the no. shown in Mid Klamath												No. moved
			1	2	3	4	5	6	7	8	9	10	11	12	
Aikens Cr	49.6	201	24	1											
Big Bar	50.0	50													
Camp Cr	57.1	96													
Stanshaw Cr	76.9	72	30	18	13	6	3	1	1	1					
Sandy Bar Cr	77.6	116	67	49	31	20	9	6	3						
Dillon Cr	84.1	44													
Indepen. Cr	94.0	756	149	36	6	2	1	1	1	1	1	1	1	1	11
Titus Cr	96.7	49													
Bulk Plant	111.5	37	1												
Cade Cr	112.5	32	10	3	2										
China Cr	117.9	302	6												1
(L) Horse Cr	118.1	25													
Thomp. Cr	123.0	51													
Fort Goff Cr	128.0	72	1												
Tom Martin Cr	144.2	55	1												1
Beaver Cr	161.0	1													
Total		1959	289	107	52	28	13	8	5	2	1	1	1	1	13

Table 6. The number of tagged fish by tagging site that were recaptured one or more times within the Lower Klamath study area between May 2007 and May 2008.

Stream	RM	No. tagged	No. recap in lower Klamath	% recap in lower Klamath
Aikens Creek	49.6	201	4	2.0%
Big Bar (Klamath R)	50.0	50	4	8.0%
Camp Creek	57.1	96	3	3.1%
Stanshaw Creek	76.9	72	3	4.2%
Sandy Bar Creek	77.6	116	3	2.6%
Dillon Creek	84.1	44	3	6.8%
Independence Creek	94.0	756	23	3.0%
Titus Creek	96.7	49	0	0.0%
Bulk Plant (Klamath R)	111.5	37	0	0.0%
Cade Creek	112.5	32	0	0.0%
China Creek	117.9	302	3	1.0%
(Little) Horse Creek	118.1	25	0	0.0%
Thompson Creek	123.0	51	1	2.0%
Fort Goff Creek	128.0	72	1	1.4%
Tom Martin Creek	144.2	55	0	0.0%
Beaver Creek	161.0	1	0	0.0%
Total		1959	48	2.5%

Table 7. Listing of the recapture incidents for the 48 fish tagged in the Mid Klamath study area and subsequently recaptured at sites within the Lower Klamath study area between May 2007 and May 2008. Table is continued onto multiple pages.

Tagging site	Date tagged	Tag code	Tagging length (mm)	Recap incident	Date recap	Recap site	Recap length (mm)
Aikens Cr	10-Sep-07	487770564A	81	1	29-May-08	Panther Cr	115
Aikens Cr	10-Sep-07	487770564A	81	2	30-May-08	Panther Cr	116
Aikens Cr	17-Sep-07	48762E4358	75	1	07-Dec-07	Jr Pond Cr	83
Aikens Cr	17-Sep-07	48762E4358	75	2	04-Apr-08	Jr Pond	105
Aikens Cr	17-Sep-07	48762E4358	75	3	11-May-08	Jr Pond Cr	128
Aikens Cr	17-Sep-07	48762E4358	75	4	20-May-08	Jr Pond Cr	130
Aikens Cr	17-Sep-07	48762E4358	75	5	27-May-08	Waukell Cr	130
Aikens Cr	17-Sep-07	48780F6C32	68	1	10-May-08	Jr Pond Cr	127
Aikens Cr	17-Sep-07	48780F6C32	68	2	04-Jun-08	Jr Pond	145
Aikens Cr	05-Dec-07	486A646E05	89	1	16-Jan-08	Jr Pond Cr	92
Big Bar (KR)	08-Nov-07	486A37282C	82	1	04-Jun-08	Jr Pond	141
Big Bar (KR)	05-Dec-07	48767C3F6A	90	1	20-Jun-08	Salt Cr	131
Big Bar (KR)	11-Dec-07	4877063829	94	1	21-Dec-07	Jr Pond Cr	93
Big Bar (KR)	18-Dec-07	486A7A5274	99	1	04-May-08	McGarvey Cr	106

Tagging site	Date tagged	Tag code	Tagging length (mm)	Recap incident	Date recap	Recap site	Recap length (mm)
Camp Cr	21-Aug-07	4875204C3C	85	1	16-Apr-08	Jr Pond Cr	125
Camp Cr	21-Aug-07	4875204C3C	85	2	17-Apr-08	Jr Pond Cr	124
Camp Cr	21-Aug-07	4875377620	69	1	22-May-08	Salt Cr	131
Camp Cr	28-Aug-07	470457056D	73	1	02-Apr-08	Waukell Cr	97
Camp Cr	28-Aug-07	470457056D	73	2	03-Apr-08	Waukell Cr	98
China Cr	14-Aug-07	134427450A	68	1	02-Jan-08	Jr Pond Cr	92
China Cr	14-Aug-07	134427450A	68	2	10-Jun-08	Jr Pond	145
China Cr	14-Aug-07	134427450A	68	3	12-Jun-08	Waukell Cr	145
China Cr	14-Aug-07	134427450A	68	4	13-Jun-08	Waukell Cr	145
China Cr	14-Aug-07	134427450A	68	5	25-Jun-08	Waukell Cr	146
China Cr	27-Aug-07	48757D7671	73	1	30-Mar-08	Jr Pond Cr	118
China Cr	27-Aug-07	48780A712B	65	1	20-May-08	Salt Cr	105
Dillon Cr	05-Oct-07	486B121919	75	1	29-Apr-08	Waukell Cr	117
Dillon Cr	05-Oct-07	487674454B	85	1	08-May-08	Jr Pond Cr	125
Dillon Cr	05-Oct-07	487674454B	85	2	24-May-08	Waukell Cr	125
Dillon Cr	05-Oct-07	48777D6B07	81	1	18-Apr-08	Jr Pond Cr	118
Fort Goff Cr	18-Sep-07	4708010373	82	1	10-May-08	Salt Cr	140
Indepen. Cr	03-Jul-07	133531393A	68	1	25-May-08	Jr Pond Cr	135
Indepen. Cr	03-Jul-07	133531393A	68	2	27-May-08	Jr Pond Cr	134
Indepen. Cr	03-Jul-07	133531393A	68	3	05-Jun-08	Waukell Cr	136
Indepen. Cr	10-Jul-07	134659450A	71	1	04-Jun-08	Jr Pond	158
Indepen. Cr	18-Jul-07	133568477A	66	1	21-Apr-08	Waukell Cr	120
Indepen. Cr	18-Jul-07	133636144A	77	1	06-May-08	Jr Pond Cr	126
Indepen. Cr	18-Jul-07	133636144A	77	2	05-Jun-08	Jr Pond	142
Indepen. Cr	12-Sep-07	486A404241	83	1	27-May-08	McGarvey Cr	130
Indepen. Cr	12-Sep-07	486A687452	73	1	08-May-08	Jr Pond Cr	125
Indepen. Cr	12-Sep-07	486B111A7D	74	1	15-Jun-08	Waukell Cr	139
Indepen. Cr	12-Sep-07	4875192A50	80	1	17-Apr-08	Salt Cr	110
Indepen. Cr	12-Sep-07	48752E134C	88	1	08-Nov-07	McGarvey Cr	90
Indepen. Cr	12-Sep-07	4875341841	86	1	16-May-08	Waukell Cr	106
Indepen. Cr	12-Sep-07	487545123D	78	1	18-Apr-08	Jr Pond Cr	118
Indepen. Cr	12-Sep-07	487545123D	78	2	01-May-08	Jr Pond	118
Indepen. Cr	12-Sep-07	487545123D	78	3	03-Jun-08	Jr Pond	138
Indepen. Cr	12-Sep-07	4876751827	78	1	16-May-08	Waukell Cr	112
Indepen. Cr	12-Sep-07	48770C3752	69	1	26-Dec-07	Jr Pond Cr	80
Indepen. Cr	12-Sep-07	48770C3752	69	2	19-Feb-08	Jr Pond Cr	78
Indepen. Cr	26-Sep-07	487629780B	73	1	07-Jun-08	Waukell Cr	114
Indepen. Cr	26-Sep-07	487629780B	73	2	08-Jun-08	Waukell Cr	114
Indepen. Cr	26-Sep-07	487629780B	73	3	16-Jun-08	Waukell Cr	114
Indepen. Cr	26-Sep-07	487629780B	73	4	24-Jun-08	Waukell Cr	114

Tagging site	Date tagged	Tag code	Tagging length (mm)	Recap incident	Date recap	Recap site	Recap length (mm)
Indepen. Cr	26-Sep-07	487629780B	73	5	25-Jun-08	Waukell Cr	114
Indepen. Cr	26-Sep-07	4878062F1F	73	1	09-Jun-08	Waukell Cr	119
Indepen. Cr	26-Sep-07	4878062F1F	73	2	10-Jun-08	Waukell Cr	121
Indepen. Cr	26-Sep-07	4878062F1F	73	3	24-Jun-08	Waukell Cr	121
Indepen. Cr	12-Oct-07	486A2F6511	77	1	16-Jan-08	Jr Pond Cr	88
Indepen. Cr	12-Oct-07	486A2F6511	77	2	16-Apr-08	Jr Pond Cr	127
Indepen. Cr	12-Oct-07	486A2F6511	77	3	17-Apr-08	Jr Pond Cr	125
Indepen. Cr	12-Oct-07	486B0A674E	78	1	11-Jan-08	Jr Pond Cr	83
Indepen. Cr	12-Oct-07	486B0A674E	78	2	24-May-08	Jr Pond Cr	139
Indepen. Cr	12-Oct-07	486B12741C	78	1	17-Jan-08	Jr Pond Cr	95
Indepen. Cr	12-Oct-07	486B12741C	78	2	04-Apr-08	Jr Pond	108
Indepen. Cr	12-Oct-07	486B12741C	78	3	06-May-08	Jr Pond Cr	124
Indepen. Cr	12-Oct-07	486B12741C	78	4	08-May-08	Jr Pond Cr	122
Indepen. Cr	12-Oct-07	4876335408	74	1	05-May-08	Jr Pond Cr	128
Indepen. Cr	27-Nov-07	4875305F39	77	1	13-Apr-08	Jr Pond Cr	125
Indepen. Cr	27-Nov-07	48762F4B0A	87	1	21-May-08	Jr Pond Cr	143
Indepen. Cr	27-Nov-07	48762F4B0A	87	2	27-May-08	Waukell Cr	143
Indepen. Cr	27-Nov-07	487744063A	72	1	29-Dec-07	Jr Pond Cr	78
Sandy Bar Cr	27-Dec-07	486A694102	102	1	23-May-08	Jr Pond Cr	141
Sandy Bar Cr	29-Dec-07	4877257834	93	1	07-May-08	Waukell Cr	108
Sandy Bar Cr	02-Jan-08	48765C4F79	113	1	20-Apr-08	Waukell Cr	117
Stanshaw Cr	18-Dec-07	486A652E68	102	1	07-May-08	Jr Pond Cr	123
Stanshaw Cr	18-Dec-07	486A652E68	102	2	19-May-08	Jr Pond Cr	122
Stanshaw Cr	18-Dec-07	486A652E68	102	3	24-May-08	Waukell Cr	121
Stanshaw Cr	18-Dec-07	4876316C54	100	1	14-Apr-08	Jr Pond Cr	115
Stanshaw Cr	04-Jan-08	48746D1D52	96	1	16-May-08	Waukell Cr	127
Thomp. Cr	04-Sep-07	4877797862	70	1	21-May-08	Waukell Cr	110

The percent recaptures of Mid Klamath tagged fish in the Lower Klamath study area demonstrates that not all groups of tagged fish were equally likely to be recovered in the downstream area (Figure 46). To further examine the potential importance of the relationship shown in Figure 46, we grouped the release data into 20 mile intervals to increase group size, then plotted them against the midpoint of the location (Figure 47 top). Computing the corresponding percent recaptures that occurred in the Lower Klamath study area for these groupings suggest the relationship seen in Figure 47 middle. When the high flow to low ratio for each of the sites where flow is measured (Table 2) is added to the chart, it suggests that a key factor in affecting the likelihood for fall-winter redistribution is the flow regime. It must noted, however, that Water Year 2008 was exceptionally dry and fall and winter runoff was low. These same types of data are needed for higher flow years to better understand the effect of the flow regime.

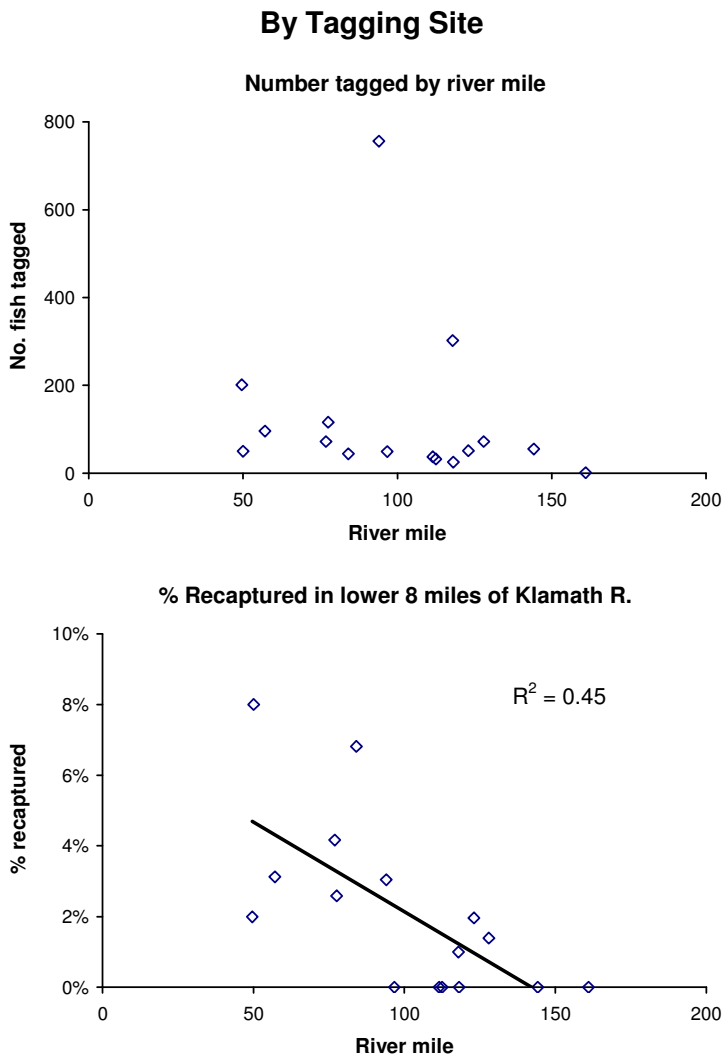


Figure 46. (Top) The number of juvenile coho tagged and released by river mile along the mainstem Klamath River within the Mid Klamath study area. Happy Camp is located at approximately RM 110. (Bottom) Relationship between the percent recapture of each tag group and the location of the tag release site along the mainstem river. Percent recaptures dropped sharply at approximately Happy Camp.

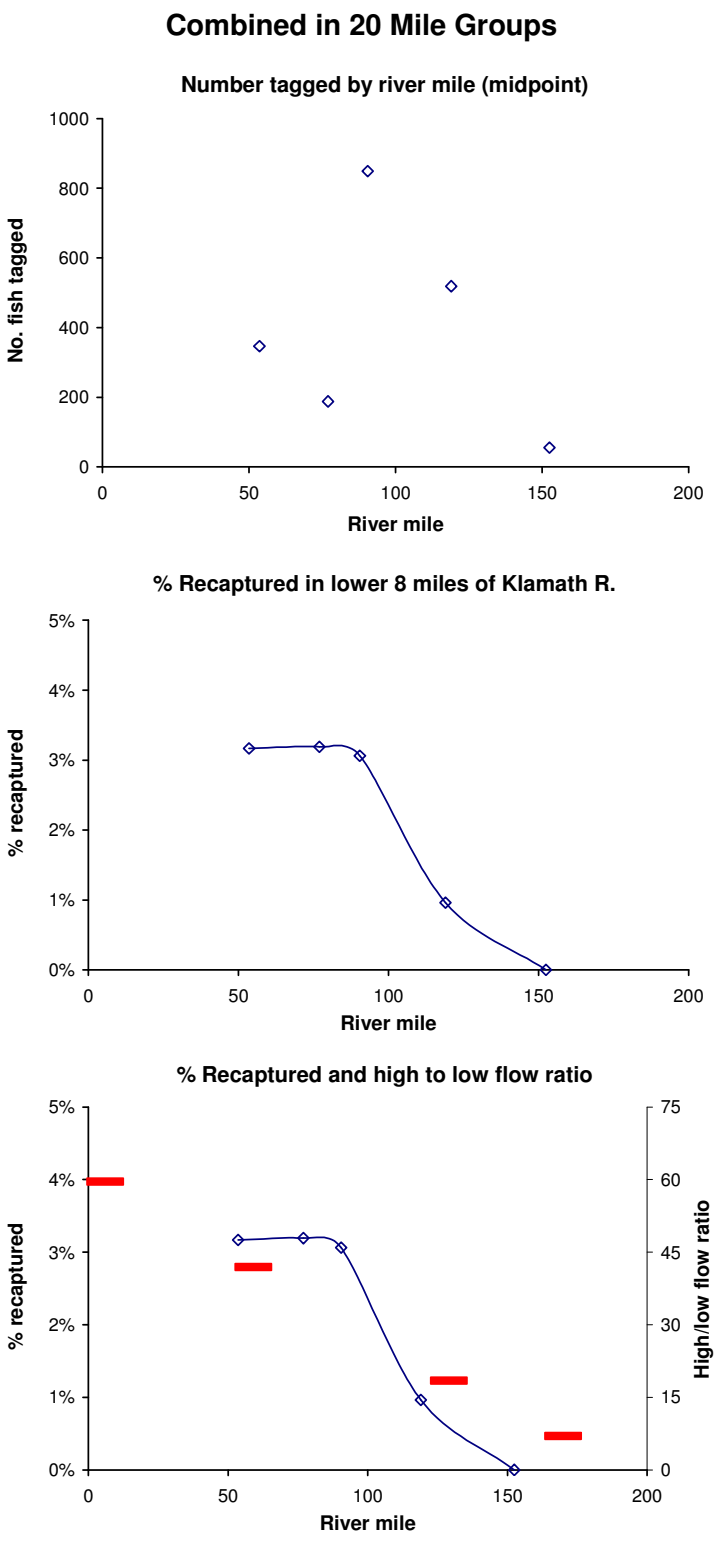


Figure 47. (Top) Release groups shown in Figure 46 grouped by 20 mi intervals and plotted against the mid point for each interval. (Middle) Corresponding percent recaptures in the Lower Klamath study area are plotted for each grouped release with fitted curve. (Bottom) The high flow to low flow ratio is plotted on the chart at flow measured sites (Table 2), which suggests that the changing flow regime along the river may be an important factor affecting redistribution likelihood during fall and winter.

In the Lower Klamath study area, tagged fish were released at 13 different stream sites between May 2007-May 2008 (Table 8). Nearly all of the releases were made at sites near or along the mainstem river between McGarvey Creek and the river mouth. The large majority of fish were tagged and released within the Waukell Creek subbasin.

Of the total number (765) of fish tagged in the Lower Klamath study area, 228 (30%) were recaptured at least once during the period of study (Table 8). The large majority of these were tagged in either Junior Pond Creek or Junior Pond itself.

Table 8. The numbers of juvenile coho tagged with PIT tags and successfully released in the lower Klamath study area by stream site between May 2007 and May 2008 , and the numbers of tagged fish recaptured at least once at these same sites during the same period.

Tagging area	No. tagged	Percent	Recap once or more	Percent recap
Above Blue Cr Klamath R	5	0.7%		
Below Blue Cr Klamath R	7	0.9%		
McGarvey Cr	62	8.1%	4	6.5%
Terwer Klamath R	1	0.1%		
Kamp Klamath	1	0.1%		
Waukell Cr	172	22.5%	44	25.6%
Jr Pond & Cr	436	57.0%	177	40.6%
Saugep Cr	8	1.0%		
Spruce Cr	1	0.1%		
Mynot Cr	10	1.3%		
Panther Cr	29	3.8%	3	10.3%
Salt Cr	16	2.1%		
South Slough	17	2.2%		
Total	765	100.0%	228	29.8%

5.0 Assessment of Habitat Utilization Rates

The assessment of habitat utilization rates aims to determine the relative rates that different habitat types are seasonally used. Because the characteristics of habitat types differ so much between them—and between seasons—a variety of sampling gears and analyses are required. Results of the assessment work through the third year of study will be presented together in the Year 3 report. Only a brief summary of some of aspects of the work is provided herein.

5.1 Methods

Two groups of methods are being used to assess relative utilization rates. The first involves the use of various sampling gears to measure catch per unit effort within the various types of habitat. The second derives estimates of the abundance within selected sites based on mark-recapture

techniques, ratios of tag detection, or total enumeration. Work is still continuing on how to effectively estimate abundance in some of the habitats and results presented here are highly preliminary and are likely to be modified.

5.2 Results

Results are presented for each of the study areas separately.

5.2.1 Middle Klamath Study Area

Table 9 summarizes results of all of the efforts to capture juvenile coho within the Mid Klamath study area between May 2007-May 2008. The results are presented by combining data within several months corresponding to life stages of interest and how fish behavior is affected by dominant environmental factors within those months. The month combinations are May-July of 2007, August-October of 2007, November-March of 2007-08, and April-May of 2008. Results are separated by capture or observation method. Units of fishing or observation effort are the same as those employed in the Year 1 report where a one-day's typical effort defines 1 unit of effort. Table 9 is presented to simply summarize the range of capture methods employed during this reporting period and to provide crude measures of gear effectiveness by habitat types and monthly period.

Table 9. Summary of capture or observation effort by method, associated catch (or count), CPUE, and average length for juvenile coho by monthly grouping and habitat or site type within the Mid Klamath study area between May 2007-May 2008. Results are shown separately for sites downstream (Blw) of RM 110 and those upstream (Abv). Site types are Klamath River floodplain channel, the Klamath River mainstem, Klamath River side channel, Klamath River backwater pool, and tributary. Effort represents a typical day's effort to count or catch fish at a site. Table is continued to the next page.

Months	Site type	Method	Effort		Catch		CPUE		Ave length mm	
			Blw RM 110	Abv RM 110	Blw RM 110	Abv RM 110	Blw RM 110	Abv RM 110	Blw RM 110	Abv RM 110
May-Jul	KR floodplain chan	Seine	8		995		124.4		62.7	
		Fyke	20		115		5.8		63.7	
		Upstream	10		20		2.0		68.1	
		Visual	4		95		23.8			
	KR mainstem	Screw trap	4		15		3.8		83.3	
		Minnow		3		1		0.3		55.0
	Tributary	Dnstream		4		5		1.4		64.4
		Upstream		7		9		1.3		66.2
		Minnow		45		90		2.0		67.1
Aug-Oct	KR floodplain chan	Seine	4		486		121.5		74.8	
		Fyke	2		2		1.0		80.0	
		Upstream	1		1		1.0		82.0	
		Minnow	8		11		1.4		68.5	
	KR mainstem	Screw trap	1		3		3.0			

Months	Site type	Method	Effort		Catch		CPUE		Ave length mm	
			Blw RM 110	Abv RM 110	Blw RM 110	Abv RM 110	Blw RM 110	Abv RM 110	Blw RM 110	Abv RM 110
	KR sidechannel	Seine		1		58		58.0		74.1
	Tributary	Seine	11	10	732	793	66.5	79.3		70.2
Nov-Mar	KR backwater pool	Fyke	2	10	2	27	1.0	2.7	87.5	93.5
	KR floodplain chan	Seine	7		202		28.9		78.5	
		Fyke	57		294		5.2		95.4	
		Dnstream	4		4		1.0		96.7	
		Upstream	28		97		3.5		98.7	
		H & L	7		40		5.7		104.5	
	KR mainstem	Seine	1		5		5.0		85.6	
		Fyke	1		1		1.0		91.0	
		Dnstream		1		9		9.0		96.4
		Upstream		1		2		2.0		92.0
		Screw trap	14		45		3.2		88.6	
	Tributary	Seine	3	1	32	1	10.7	1.0		75.0
		Fyke	3		3		1.0			
Apr-May	KR backwater pool	Fyke	1	2	1	4	1.0	2.0	49.0	98.3
	KR floodplain chan	Seine	1		3		3.0		42.3	
		Fyke	5		12		2.4		110.8	
		Dnstream	4		5		1.3		117.0	
		Upstream	6		10		1.7		108.4	
		H & L	7		12		1.7		116.8	
	KR mainstem	Seine								
		Fyke	1		1		1.0		129.0	
		Dnstream		1		1		1.0		115.0
		Upstream		1		1		1.0		108.0

The site within the Mid Klamath study area that was most intensely monitored in Year 2 was the Independence Creek floodplain channel. The site was routinely assessed using pole-seine. Fish were marked or tagged at each of the sampling dates. Estimates of abundance were made using a modified simple Peterson estimator by grouping data (Figure 48). The estimator, however, does not take into account that the population during at least part of the period would necessarily be considered open, i.e., abundance would be affected by both immigration and emigration. The Peterson estimate should only be applied to closed populations to be completely valid. Still the Peterson estimator may provide a reasonable estimate for some time periods when movement in and out of the site is relatively minor. A more appropriate method of assessment might be to utilize the Jolly-Seber method for multiple mark and recapture periods (i.e., Pollock et al. 1990); this is under consideration.

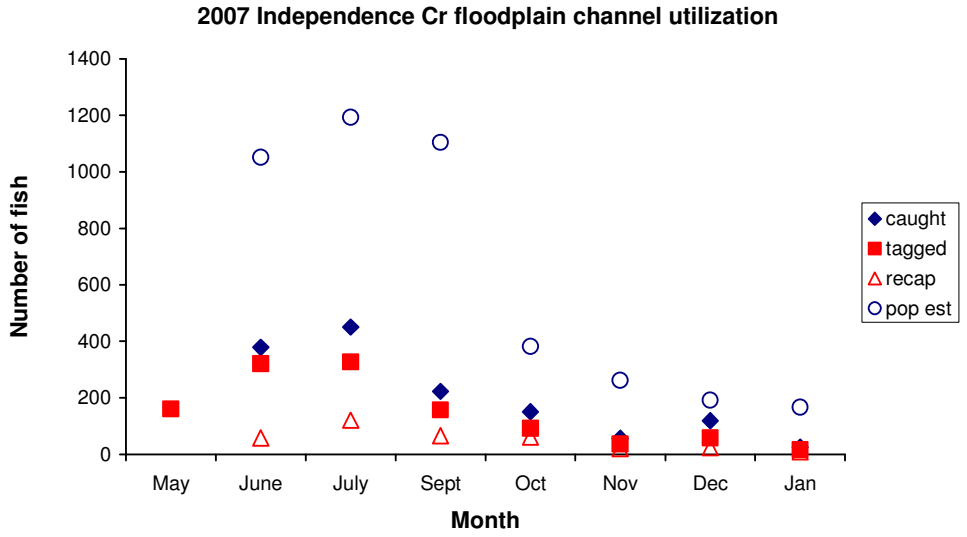


Figure 48. Preliminary results of applying an approach of grouping data to estimate abundance (pop est) of juvenile coho in the Independence Creek floodplain channel using a simplified Peterson estimator.

5.2.2 Lower Klamath Study Area

Two sets of results are presented here for all or part of the Waukell Creek system to assess abundance. The first set of results estimates the total abundance of immigrant coho moving into the Waukell system (i.e., passing the lower Waukell trap site) in fall and winter, as well as the total abundance of emigrants leaving the system as smolts in the spring. The second set of results uses a stratified sampling method to estimate the number of emigrants leaving Junior Pond during the smolt outmigration.

The estimates of total immigrants and emigrants in Waukell Creek are made using the simple Peterson estimator where PIT tagged fish serve as the marked fish (Table 10). The estimate of immigrants is made for the period when fish are entering the system with only minor emigration occurring at the same time—thus the population is operating essentially as closed. The total number of PIT tagged coho passed upstream of the Junior Pond upstream trap provides the number of marks released into the population. Only tagged fish passed upstream during the period of most active immigration are used, i.e., those migrating during October through mid January. The sample of the population to obtain the mark ratio is then obtained by using downstream catches made at the lower Waukell site during the smolt emigration, i.e., March 15 to June 30. The number of PIT tagged fish of those passed upstream into Junior Pond, then caught emigrating at the lower Waukell site serves at the recapture of marks. The ratio of marks to the total catch at the site should reasonably represent the ratio of marked fish to the total population that moved into Waukell Creek during the fall and winter. Table 10 summarizes the data applied and the estimate of immigrant abundance. The estimated number of total immigrants moving into Waukell Creek in 2007-08 is 6,990 fish.

A similar procedure is used to estimate the number of emigrants leaving the system in the spring. In this case, the number of PIT tagged fish caught at the downstream trap in Junior Pond Creek

in the spring provides the number of marks. The population sample size is the same number used for the estimating immigrants. The number of recaptured marks is simply the number of PIT tagged fish caught again in the lower Waukell trap that had been passed downstream in the Junior Pond Creek trap. The estimated number of total emigrants leaving Waukell Creek in 2008 is 5,002 fish.

Table 10. Summary of input variables and abundance estimates for the projecting the number of age-0 immigrants and age 1+ emigrants of juvenile coho in the Waukell Creek subbasin in 2007-08.

Upstream age-0 immigrants

Variable	Period	No.
No. PIT tagged fish passed upstream in Jr. Pond Cr. (M)	Oct - Jan	411
Trap catch of age-1+ fish moving down at Waukell site (C)	Mar 15 - Jun 30	491
No. PIT tagged fish recaptured (R)	Mar 15 - Jun 30	28
Estimated number of immigrants	Oct - Jan	6,990

Downstream age-1+ emigrants

Variable	Period	No.
No. PIT tagged fish passed downstream in Jr. Pond Cr. (M)	Mar 15 - Jun 30	121
Trap catch of age-1+ fish moving down at Waukell site (C)	Mar 15 - Jun 30	491
No. PIT tagged fish recaptured (R)	Mar 15 - Jun 30	11
Estimated number of emigrants	Mar 15 - Jun 30	5,002

A different approach was used to estimate the number of emigrants leaving just Junior Pond in spring 2008.[7] The approach uses a temporally-stratified mark-recapture procedure as described by Bjorkstedt (2000), referred to as Darroch Analysis with Rank Reduction. To apply the method, fish emigrating from Junior Pond were caught immediately below the pond as they were moving down the egress channel. The fish were given a fin mark then released just upstream of the trap. Marks were changed weekly. Recaptured marks were then incorporated into the estimator. The stratifed mark-recapture method produced the results given in Table 11. The estimated number of outmigrants was 3,570 fish. Timing of the outmigrants is shown in Figure 49.

Of concern with the estimate of Junior Pond emigrants is the reported trap efficiencies (Table 11). The overall value of trap efficiency for the season was estimated to be 0.55. One of the authors of this report (Scott Silloway), who supervised the field work, believes that the efficiency estimates seem much too low, given that the fyke traps were able to cover the entirety of the flow for most of the season. The egress channel is very small. It is notable that at the end of the migration period, when the egress channel had essentially gone dry, an effort was made to rescue stranded fish in the pond. Approximately 400 fish were rescued and many had the fin marks

[7] / This estimate was derived by Dan Gale, former biologist with the Yurok Tribe and now with the U.S. Fish and Wildlife Service.

being used as part of the estimator. It appears likely that the procedure of marking all fish caught at the trap may have caused some marked fish to be trap wary, keeping them again from moving into the trap, thereby reducing trap efficiency and biasing the estimate high. It is believed, therefore, that the estimate of 3,570 represents a high end for the number of pond outmigrants.

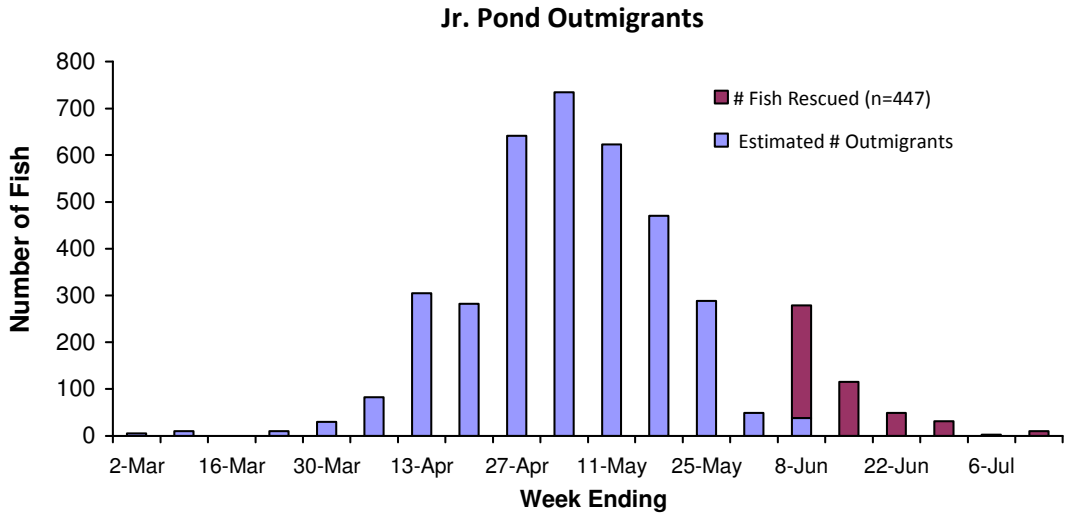


Figure 49. Estimated number of juvenile coho emigrants leaving Junior Creek Pond in spring 2008 based on application of a temporally-stratified mark-recapture method. The estimate is based on a method described by Bjorkstedt (2000).

Table 11. Summary of results for estimating the number of coho outmigrants leaving Junior Creek Pond in spring 2008. The method is based on Bjorkstedt (2000).

Mark period	Week ending	No. of days marked	No. captured	No. marked	No. recaptured	Trap efficiency (%)	Estimated outmigrants	Variance	Standard deviation
1	2-Mar-08	7	2	1	0	0.40[1]	5	2218.1p	47.1.5[p]
2	9-Mar-08	7	4	4	0	0.40[1]	10	2218.1p	47.1.5[p]
3	16-Mar-08	3	0	0	0	0.40[1]	0	2218.1p	47.1.5[p]
4	23-Mar-08	1	4	4	0	0.40[1]	10	2218.1p	47.1.5[p]
5	30-Mar-08	7	13	12	0	0.40[1]	30	2218.1p	47.1.5[p]
6	6-Apr-08	7	33	30	6	0.40[1]	83	2218.1p	47.1.5[p]
7	13-Apr-08	7	122	122	67	0.40[1]	305	2218.1p	47.1.5[p]
8	20-Apr-08	7	204	204	137	0.72	282	265.4	16.3
9	27-Apr-08	7	270	72	34	0.42	641	17,409.1	131.9
10	4-May-08	7	270	254	114	0.37	734	6,096.5	78.1
11	11-May-08	7	345	338	198	0.55	623	1,462.1	38.2
12	18-May-08	7	318	108	73	0.68[2]	470	2,904.9[p]	53.9[p]
13	25-May-08	7	195	0	0	0.68[2]	288	2,904.9[p]	53.9[p]
14	1-Jun-08	7	33	0	0	0.68[2]	49	2,904.9[p]	53.9[p]
15	8-Jun-08	4	26	0	0	0.68[2]	38	2,904.9[p]	53.9[p]
	Trap pulled on 09-June due to low fish capture								
	Totals	92	1,839	1,149	629	0.55	3,570	30,356.2	174.2

- Estimated trap efficiency for pooled marking periods
p - Estimated variance and standard deviation for pooled marking periods

6.0 Assessment of Seasonal Performance

The relative importance of habitats within the Klamath River corridor must ultimately be measured either directly or indirectly by the performance of fish that use the corridor to complete their life cycles. Performance is most directly measured as survival, or if possible, as productivity that includes consideration for size of adults as it affects fecundity—along with survival (i.e., recruits per spawner). For our purpose, survival is the best measure as it would reflect the survival that occurs during specific seasons or life stages. Often, however, survival is extremely difficult to estimate for riverine populations with spatial-temporal complexity in habitat use. In these cases, growth or body size can serve as a good surrogate. Also, length or stability in habitat residency can also be informative about how animals perceive their enviroment with respect to its survival likelihood.

Work is proceeding to determine useful measures of performance as part of this project. The issue is to be addressed more completely as part of the Year 3 report.

For this report, two measures of performance are presented. Both are considered as preliminary findings—and both pertain to the Waukell Creek system.

An estimate of overwintering survival is made based on the estimates presented above for the number of fall-winter immigrants and the number of spring emigrants. The number of spring emigrants divided by fall-winter immigrants is equal to the overwinter survival, as shown below:

Overwintering survival in Waukel Creek subbasin

Estimated overwintering survival	71.6%

This estimate of overwintering survival is on the high side of the range reported in the scientific literature for coho overwintering (Lestelle 2007). If real, it would mean that overwintering habitat within the Waukell system is of excellent quality, providing a significant boost to life cycle productivity of fish that overwinter there. Fish that overwinter there not only are given a survival boost, but they are also on the doorstep of entering the ocean upon departing as smolts.

Uncertainties remain, however, about certain aspects of life history for fish that use the Waukell system and other off-channel habitats in the lower river. The number of fish that needed to be rescued from Junior Pond in spring 2008 prior to it going dry is one uncertainty to performance (Figure 50). The high number that required to be rescued may have been exacerbated by the procedure to mark and place back upstream fish that were inclined to emigrate. Also, the odd situation that occurred in spring 2008 with large smolt sized fish continuing to reside in Waukell Creek and Panther Pond after the period of smoltification needs further investigation. These matters will be further addressed as part of the Year 3 report.

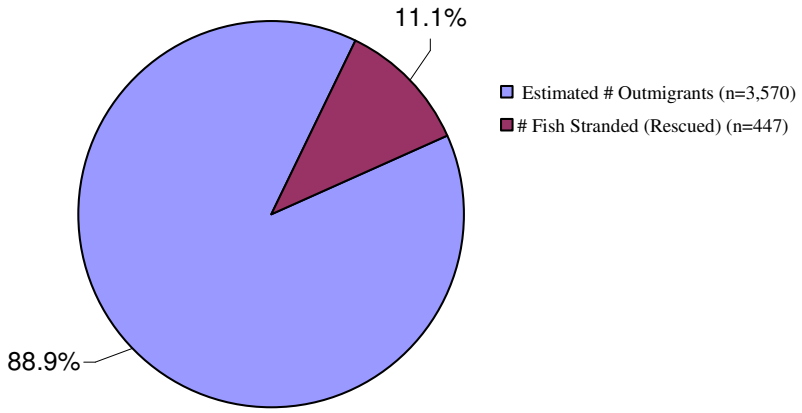


Figure 50. Estimated numbers of outmigrants and yearling coho requiring rescue in Junior Pond in spring 2008.

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