Shasta River

Brood Year 2012 Juvenile Coho Salmon

PIT Tagging Study

California Department of Fish and Wildlife

Yreka Fisheries

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Executive Summary

This report summarizes PIT tag data collected on brood year 2012 coho in the Shasta River (the progeny of adult coho that spawned in 2012). The key findings of this study were:

1. Overall known survival of PIT tagged BY2012 coho, from the time they were tagged in upper Shasta River in 2013 to outmigration into the Klamath River in the spring of 2014, was 33%.
2. Over 70% of the coho fry tagged in the upper Shasta River downstream of Big Springs Creek migrated upstream in May and June 2013 when stream temperatures increased to ~20 C.
3. Coho utilized a small spring complex adjacent to the Shasta River downstream of Parks Creek as short term thermal refugia during May and June 2013.
4. Successful summer rearing occurred in areas with cold spring inflows, including Little Springs Creek.
5. Overall, known survival was lowest during winter with the poorest winter survival occurring in Big Springs Creek.
6. Outmigrating coho smolts that were known to be alive in the upper Shasta River in March 2014 survived to reach the Klamath River at a rate of 90%, which is higher than documented in the BY2010 study (77%).

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I. INTRODUCTION

The California Department of Fish and Wildlife (CDFW) has been using passive integrated transponder (PIT) tags to monitor juvenile coho salmon (*Oncorhynchus kisutch*) movements and survival in the Shasta River since 2008. Individually marking fish and tracking their movements using stationary PIT tag antenna stations has proven to be a useful tool for gathering data that can inform fisheries managers. This report presents data collected on 440 PIT tagged brood year 2012 (BY2012) juvenile coho, which is a sample of the progeny of an estimated 115 returning adults and jacks that spawned in the Shasta River in the fall of 2012. BY2012 coho emerged from redds in the spring of 2013 and out-migrated as age-1 smolts in the spring of 2014.

In this report, a balance was sought to represent the data with enough resolution to detect patterns and trends, yet simple enough that the findings could be used to reasonably identify potential management actions and future monitoring needs. Some basic analyses were conducted so that the results of this study might easily be compared with results of other brood year studies. In addition to general findings on fish movement and survival throughout the watershed, four specific topics were evaluated (each described more thoroughly below):

1. Movement and survival of juvenile coho that initially reared in the mainstem Shasta River downstream of the confluence with Big Springs Creek.
2. Juvenile coho use of a small spring located downstream of the Shasta River's confluence with Parks creek (RKM 55 Spring).
3. Movement and survival of juvenile coho in Big Springs Creek.
4. Age-1 smolt outmigration timing and survival.

We have placed all the photos referenced to in this document in Appendix D.

1. Spring/Summer Fry Migrations

In previous studies, coho fry have been observed in the mainstem Shasta River within a kilometer downstream of the Big Springs Creek confluence during April and May (Chesney et al 2009, Adams 2013). Physical aquatic habitat in this location is favorable for juvenile coho and includes areas with low velocities and structural complexity provided by cut banks, aquatic macrophytes, and submerged large wood along the river banks (Photos 1-2). Based on dive surveys, coho fry vacate this site between mid-May and end of June. This is most likely due to increasing water temperatures. Elevated water temperatures often occur in the Shasta River during this time; irrigation withdraws have begun and emergent aquatic vegetation has not yet grown enough to provide substantial shading. Based on CDFW monitoring efforts, water temperatures in the mainstem Shasta River downstream of Big Springs Creek generally become detrimental for juvenile coho (>20.3° C, Stenhouse et al 2011) in May or June. This is the mixing zone of the mainstem Shasta River and Big Springs Creek which can be inputting substantially different water quality and quantity at any given time during the irrigation season depending on water management practices upstream. Previous tagging studies have shown that most of the surviving coho fry tagged in this location migrate several kilometers in an upstream direction and over-summer near cold spring inflows in Big Springs Creek, the upper Shasta River and Parks Creek (Chesney et al 2009, Adams 2013). Additional information regarding this segment of coho life history in the Shasta River is necessary to inform ongoing coho recovery efforts. In this study, we investigate the timing and locations of juvenile coho movements and how they might be correlated with water temperatures of Big Springs Creek and the Shasta River.

2. RKM 55 Spring

A small complex of springs emerges adjacent to the Shasta River approximately 250 meters downstream from the Parks Creek confluence (Photos 3-5). These are unnamed springs. For the purpose of this report they will be referred to collectively as RKM 55 Spring. Juvenile coho were observed rearing in RKM 55 Spring in May during a previous study (Adams 2013). No spawning activity has been documented in RKM 55 Spring, and the substrate is mostly sandy, so these young of the year coho likely moved into this area from other locations. The total discharge of the RKM 55 Spring was measured by CDFW in the summer of 2013 at approximately 3 cubic feet per second (cfs). It is unknown if the discharge varies from season to season or year to year. Depending on irrigation practices, the cold water habitat at RKM 55 spring can be seriously compromised by tailwater inflows from Hole in the Ground Creek that exceed 20 C°. Considering the limited quantity of cold spring habitat available for juvenile coho rearing in the Shasta River, we investigated coho habitat use at this site.

3. Big Springs Creek

The springs feeding Big Springs Creek are the largest source of spring water (>80 cfs) in the Shasta River watershed. Big Springs Creek itself has the potential to provide approximately three kilometers of cold water summer rearing habitat for juvenile coho, and its favorable thermal input could extend down the Shasta River past its confluence. However, irrigation withdraws, tailwater inputs, and cattle grazing in the stream have compromised the salmonid habitat in Big Springs Creek. Recent cattle exclusion fencing and alternative water management practices have improved conditions in Big Springs Creek for salmonids. Despite favorable summer stream temperature conditions existing throughout much of Big Springs Creek, previous studies suggest that juvenile coho primarily utilize two discrete locations for summer rearing; the outfall pool directly downstream of Big Springs Lake and the reach immediately downstream of the water wheel structure (located at RKM 2).

Little Springs Creek is a tributary of Big Springs Creek. It is approximately 2.4 kilometers long and is fed by a spring complex that discharges at a rate of approximately 7cfs (Photos 6-10). The entire flow of this spring creek has historically been used for irrigation between April 1 and September 30. However, in 2013 juvenile coho were documented utilizing the creek and diversion from Little Springs Creek was forgone. In order to maximize coho production in Big Springs Creek and Little Springs Creek, an understanding of how coho currently utilize habitat there is necessary. In this study, we investigate juvenile coho movements and survival within Big Springs Creek and Little Springs Creek.

4. Smolt Outmigration

Smolt outmigration is an important segment of coho life history since fish must pass through the entire river system downstream of their rearing locations. PIT tag detection data has shown that the timing of age-1 coho smolt outmigration in the Shasta River coincides with the onset of the irrigation season. For the mainstem Shasta River and Big Springs Creek the irrigation season is from April 1 to September 30 with the exception of riparian water right holders which are not regulated. For the two main tributaries of the Shasta River, Parks Creek and Little Shasta River, the irrigation period is March 1 to November 1 (Shasta River Adjudication 1932). It is important to understand smolt migration timing and identify potential impacts of water management so that survival of outmigrating cohos molts may be maximized during this critical period.

II. STUDY SITE

The Shasta River is located in Siskiyou County in northern California, and flows approximately 100 kilometers from its headwaters to the Klamath River (Figure 1). Tributaries fed by springs, precipitation, and snow melt flow from the western slopes of the Cascade Range and eastern slopes of the Eddy Mountains flow into the Shasta River. Cold water springs provide most of the summer base flow in the main stem Shasta River. These springs, located in the upper Shasta River watershed, are charged by glacial melt from Mount Shasta. The spring flow becomes nutrient rich as the water flows through porous volcanic and sedimentary rock. Water from the springs enters the river at a constant temperature of approximately 13 C°. As a result of these attributes, primary productivity in the Shasta River is very high and in turn salmonid prey abundance is high and rearing juvenile salmonids experience rapid growth rates.

The gradient is relatively low throughout the Shasta Valley, but increases through the lowest ten kilometers, where the river flows through a canyon before converging with the Klamath River approximately 350 river kilometers from the Pacific Ocean. Dwinnell Dam was constructed in 1928 at Shasta RKM 65 (65 kilometers upstream from the Klamath River), impounding Lake Shastina and blocking migration of anadromous fish. The climate is semi-arid with annual precipitation ranging from about 25-45 cm, the majority of which falls as snow at the higher elevations in winter. Flows are severely impacted by irrigation withdraws, particularly during the summer months. USGS streamflow data from October 2012 to July 2014, measured near the Shasta River's confluence with the Klamath River is shown in Figure 2.

Based on previous radio tagging efforts and redd survey data collected by CDFW, coho spawning currently occurs in two general areas of the Shasta River. These areas are the "canyon" reach located between RKM 0 and RKM 12, and the "upper" Shasta River, located between the confluence of Big Springs Creek (RKM 53) and the first kilometer upstream of Parks Creek (RKM 57), Big Springs Creek, and the valley portion of Parks Creek (Figure 1).

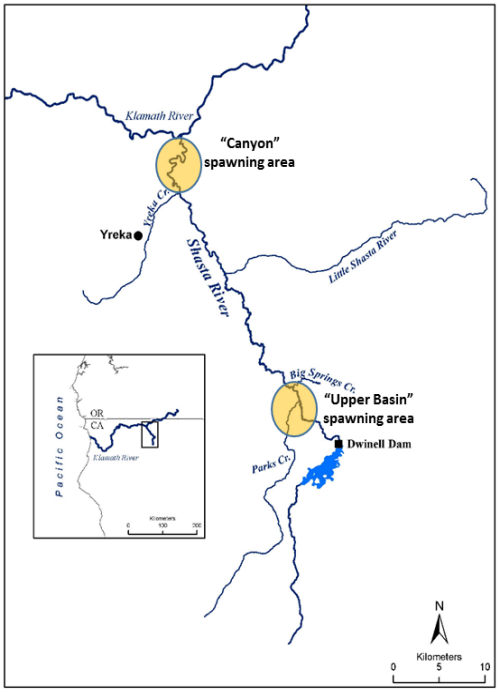

Figure 1. Map of Shasta River showing coho spawning locations.

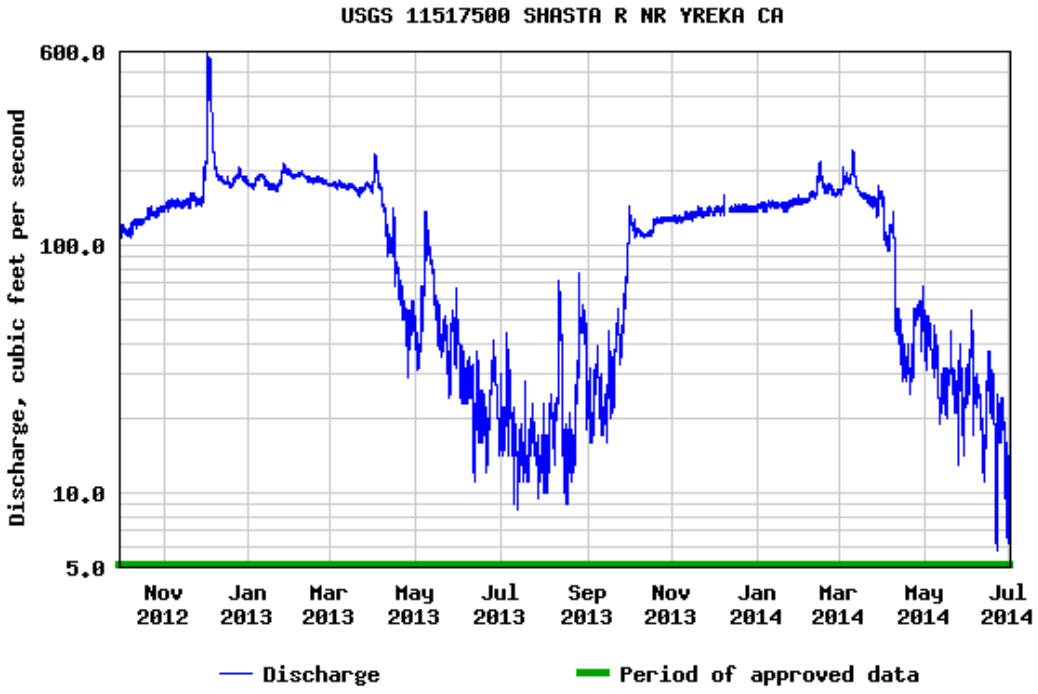

Figure 2. USGS hydrograph data from the gage station located at Shasta River RKM 0 from October 2012 to July 2014.

III. METHODS

1. Capture/Tagging

Reconnaissance level snorkel surveys were conducted throughout Big Springs Creek and the Shasta River from RKM 51 (Nelson Ranch) to RKM 62 (near Dwinnell Dam). Capture efforts were carried out where substantial numbers of coho were observed during the dive surveys. Trapping methods included hand nets used while snorkeling, seine nets, and overnight sets with un-baited minnow traps and fyke nets. Most of the capture efforts in the upper Shasta River were undertaken during May and June 2013. In addition to upper Shasta River tagging efforts, some BY2012 coho were tagged at an outmigrant rotary screw trap that CDFW operates near the confluence of the Shasta River and the Klamath River (RKM 0) from February through June. Coho captured at this site were scanned for PIT tags and a sample of untagged fish were implanted with PIT tags during their migration out of the Shasta River.

Captured juvenile coho were anesthetized with CO_2 and scanned with a hand-held PIT tag reader to identify previously tagged individuals. PIT tags and a 14 gage needle were disinfected with isopropyl alcohol prior to use. An incision was made approximately 10 mm anterior to the base of the left pelvic fin with the needle and the PIT tag was then inserted by hand. Coho 50-59 mm fork length were implanted with 9mm PIT tags while those 60mm or larger were implanted with 12 mm tags. Fish were measured for fork length, tagged, and held in aerated recovery containers before releasing them at their capture location.

2. PIT Tag Detection

Seventeen PIT tag detection stations were operated in the Shasta River and tributaries during this study (Figure 3, Photos 11-25). These antenna systems were custom built in collaboration with Mauro Engineering. Antennas were made of a wire conductor threaded through PVC pipe for structure and secured to t-posts driven into the river bed. A variety of antenna dimensions were used depending on channel characteristics at a given site. A data logger powered by a solar panel and batteries recorded PIT tag detections onto an SD card along with a date and time stamp. Data was uploaded to a Microsoft Access database for analysis.

Most PIT tag antenna stations were checked on a weekly basis to verify operation, perform any needed maintenance, and assess detection capability. During each visit, antenna station performance was rated on a 0-3 scale based on each antennas read range and total portion of the rivers transect over which detection was possible (Appendix A). This served to qualitatively track daily detection efficiency at each site throughout the study. All stations operated fairly consistently throughout the study, but did experience short periods (days) of compromised performance due to high water, damage from rodents, or equipment malfunction. Antenna stations were in operation downstream of the upper Shasta River tagging locations throughout the entirety of the study (Figure 4).

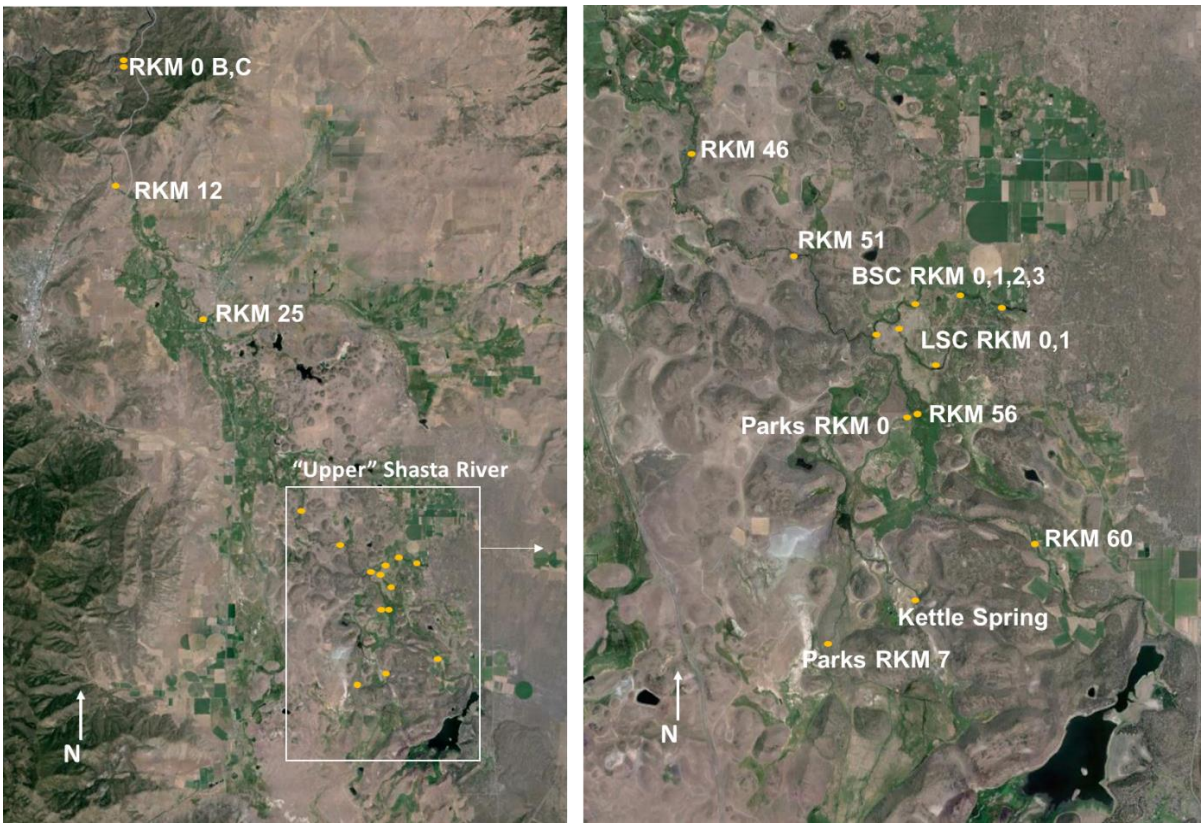

Figure 3. Locations of PIT Tag detection stations in the Shasta River during the BY2012 coho study.

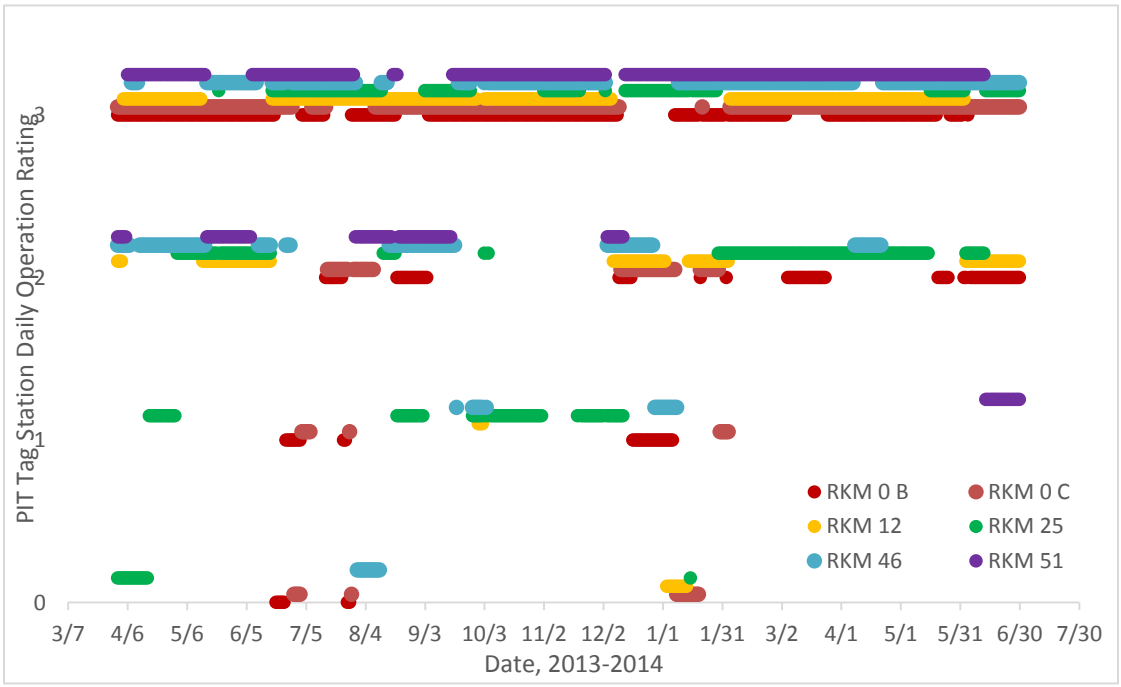

Figure 4. Daily PIT tag antenna station effectiveness for the six locations downstream of the upper Shasta basin tagging locations. Rating scheme based on estimated percentage of river transect covered by a PIT tag detection field: 3=67-100% 2=34-66% 1=1-33 0=0%.

3. Temperature Monitoring

Temperature loggers (HOBO by Onset) were deployed at most PIT tag antenna stations. Temperature loggers were housed in a section of steel or PVC pipe and attached to rebar or t-post anchors with steel cable. Most temperature loggers were cleaned and downloaded on a monthly basis. Stream temperature was recorded at hourly intervals. Temperature plots for each station are located in Appendix C.

4. Data Analysis

Temporal and spatial categorical schemes were developed to evaluate juvenile coho movement and survival at the watershed scale, similar to that developed in the BY2010 Shasta River coho study (Adams 2011). The spatial categories are defined by dividing the Shasta River into five reaches (Table 1, Figure 5). These reaches are each coded by an individual letter and specific color in this report as: L (green)=Lower section of the upper Shasta River (Nelson Ranch to Big Springs Creek; RKM 51-53), U (orange)=Upper section of the upper Shasta River (Big Springs Creek to Dwinnell Dam; RKM 54-60), B (blue)=Big Springs Creek including Little Springs Creek, P (pink)=Parks Creek (Parks RKM 0-7 including Kettle Spring), and M (red)=the Shasta River from the confluence with the Klamath River upstream to RKM 50 (downstream of L). Each reach includes tagging locations and PIT tag stations.

The temporal categories are defined by five encounter periods (Figure 6). An “encounter” of an individual can mean either detection at an antenna station or a physical recapture during a trapping effort. The first encounter occasion is the initial tagging effort during which individuals are assigned to the location where they were tagged (April-July 2013). The second encounter occasion is summer rearing period during which individuals are assigned the location they were last encountered from April-September 2013 (excluding the spring tagging location). Individuals tagged after July are included in the summer rearing encounter period. The third encounter occasion is the winter rearing period during which individuals are assigned the location they were last encountered from October 2013-February 2014. The fourth encounter occasion is smolt departure from the upper Shasta River during which individuals are identified as alive and present in the upper Shasta River at the start of the smolt outmigration period based on their encounter upstream of RKM 12 from March-May 2014. The fifth and final encounter occasion is smolt outmigration from the Shasta River, in which individuals are identified as successfully reaching the Klamath River based on their encounter at RKM 0 or RKM 12 from March-May 2014.

An individual tagged fish is determined to have survived a given temporal category if it was encountered on any proceeding occasion in any location (known survivor). To calculate the total known survival rate from a given encounter occasion to the next, the number of known survivors was divided by the total number of individuals known to be alive and present. This calculation is performed for all upper Shasta River tagged coho combined, as well as for each location category individually. The result of these “known survival” calculations is actually a minimum survival estimate, since fish that outmigrated without being encountered are assumed to be mortalities. Given that only two upper Shasta River tagged BY2012 coho were encountered downstream of the upper Shasta River prior to the smolt outmigration period, and the operation of the multiple antenna stations downstream of the upper Shasta River (Figure 4), it is assumed that this “known survival” calculation is close to the true survival rate. It is not likely that many coho outmigrated from the upper Shasta River without being encountered at least once.

Table 1. Spatial categories defined for movement and survival analyses.

Location Code	Description	Capture Locations		Detection Locations	
L	Upper Shasta River Downstream of Big Springs Creek (RKM 51-53)	RKM 53		RKM 51	
U	Upper Shasta River Upstream of Big Springs Creek (RKM 54-60)	RKM 55 Spring	RKM 57	RKM 56	
		RKM 55	RKM 58	RKM 60	
		RKM 56	RKM 59		
B	Big Springs Creek and Little Spring Creek	BSC RKM 2		BSC RKM 0	BSC RKM 3
		LSC RKM 0		BSC RKM 1	LSC RKM 0
				BSC RKM 2	LSC RKM 1
P	Parks Creek RKM 0-7 including Kettle Spring	Kettle Spring		Parks RKM 0	Kettle Spring
				Parks RKM 7	
M	Downstream of upper Shasta (RKM 0-50)	RKM 0		RKM 0 B	RKM 25
				RKM 0 C	RKM 48
				RKM 12	

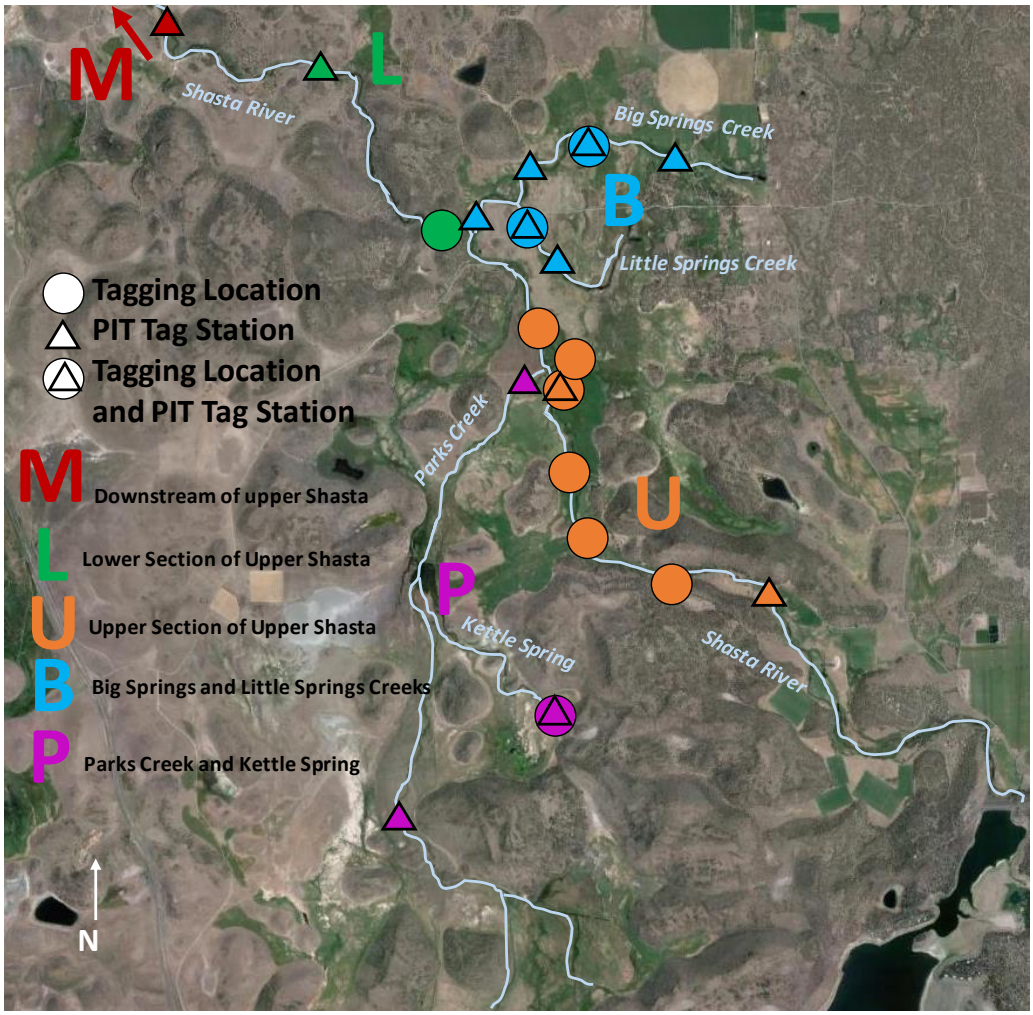

Figure 5. Map of Shasta River spatial categories defined for BY2012 coho survival and movement analyses.

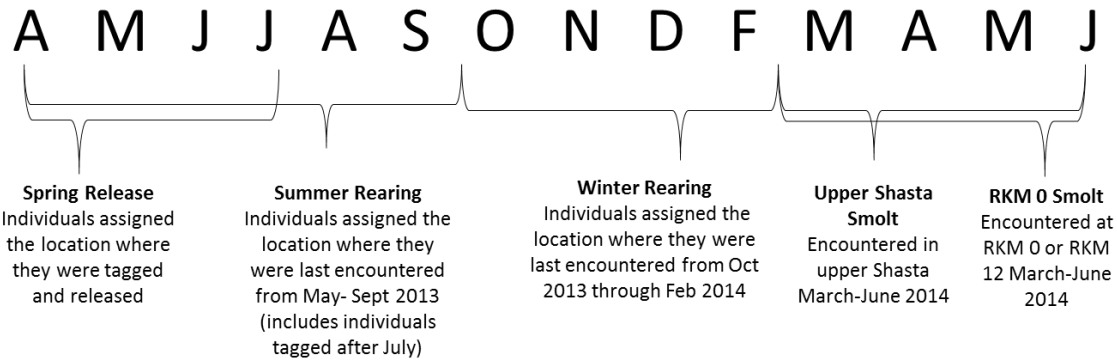

Figure 6. Temporal categories defined by five encounter occasions from April 2013 to June 2014.

IV.RESULTS

1. Capture/Tagging

A total of 441 age-0 BY2012 coho were tagged in the upper Shasta River (Table 2, Figure 7). During April and early May 2013, coho fry were observed in the mainstem Shasta River within the first kilometer downstream of Big Springs Creek (RKM 53, Photo 26) where 166 individuals were captured with hand nets and subsequently PIT tagged. Direct observations of BY2012 coho at this location ceased by late May, except for one individual that was captured in a fyke net and tagged in August. During late May and June, 58 individuals were tagged in the Shasta River within a kilometer upstream and downstream of Parks Creek (RKM 55, 56, 57) and 89 individuals were tagged in RKM 55 Spring which enters the Shasta River approximately 250 meters downstream of Parks Creek (Photo 27, 28). Juvenile coho were no longer observed in these locations by late June. From July through September 2013, 75 coho were tagged in the Shasta River within a kilometer downstream of Clear Spring (RKM 58, 59).

The number of juvenile coho observed in Big Springs Creek just downstream of the water wheel structure increased during late May and June (BSC RKM 2, Photo 29), likely because individuals continued to migrate there from downstream locations. Coho were observed at this location throughout the duration of the study and a total 33 individuals were captured and tagged there between May and September. Coho were first observed in Little Springs Creek, between Big Springs Creek and Louie Road, in May where one was captured and tagged, and then, in the reach just upstream of Louie Road, in July where five were captured and tagged (Photo 30, 31). Capture and tagging in Parks Creek was limited to one occasion at the outfall of the Kettle Spring impoundment where 10 coho were tagged in July.

The fork length of captured coho increased rapidly from the minimum of 50mm in April to some over 90mm by late June (Figure 8). Coho captured in September were not much larger than those captured in June, suggesting that growth rates are fast in the spring and early summer but slow down through the summer and into fall.

A total of 376 untagged BY2012 coho were captured at the rotary screw trap (RKM 0) as age-0 fish between March 19 and June 22, 2013 and of those 79 were measured (Figure 9). Fifty seven outmigrating age-0 coho salmon were implanted with PIT tags in 2013. None of the BY2012 coho captured at RKM 0 in 2013 were identified as having been previously tagged in the upper Shasta River. A total of 490 BY2012 were captured at the RKM 0 rotary screw trap as age-1 fish between March 12, 2014 and May 16, 2014, including 33 that were

identified as being previously tagged in the upper Shasta River. PIT tags were implanted into 212 of those coho smolts that were not previously tagged.

Table 2.PIT tagged BY2012 coho by location and date range.

Reach	Location	Total Tagged	Date Range		Gear
L	RKM 53	167	4/25/2013	8/6/2013	Hand Net
U	RKM 55	9	6/21/2013	6/25/2013	Hand Net
U	RKM 55 Spring	89	5/16/2013	6/20/2013	Minnow Trap, Hand Net
U	RKM 56	44	5/28/2013	6/25/2013	Hand Net
U	RKM 57	8	5/7/2013		Hand Net
U	RKM 58	13	7/2/2014		Hand Net
U	RKM 59	62	7/2/2013	10/2/2013	Fyke, Hand Net
B	BSC RKM 2	33	5/22/2013	9/9/2013	Minnow Trap, Fyke, Hand Net
B	LSC RKM 0	6	5/14/2013	7/8/2013	Hand Net
P	Kettle Spring	10	7/22/2013		Hand Net
	Total Upper	441			
M	RKM 0 (2013)	57	6/4/2013	6/22/2013	Rotary Screw Trap
M	RKM 0 (2014)	212	4/4/2014	7/1/2014	Rotary Screw Trap

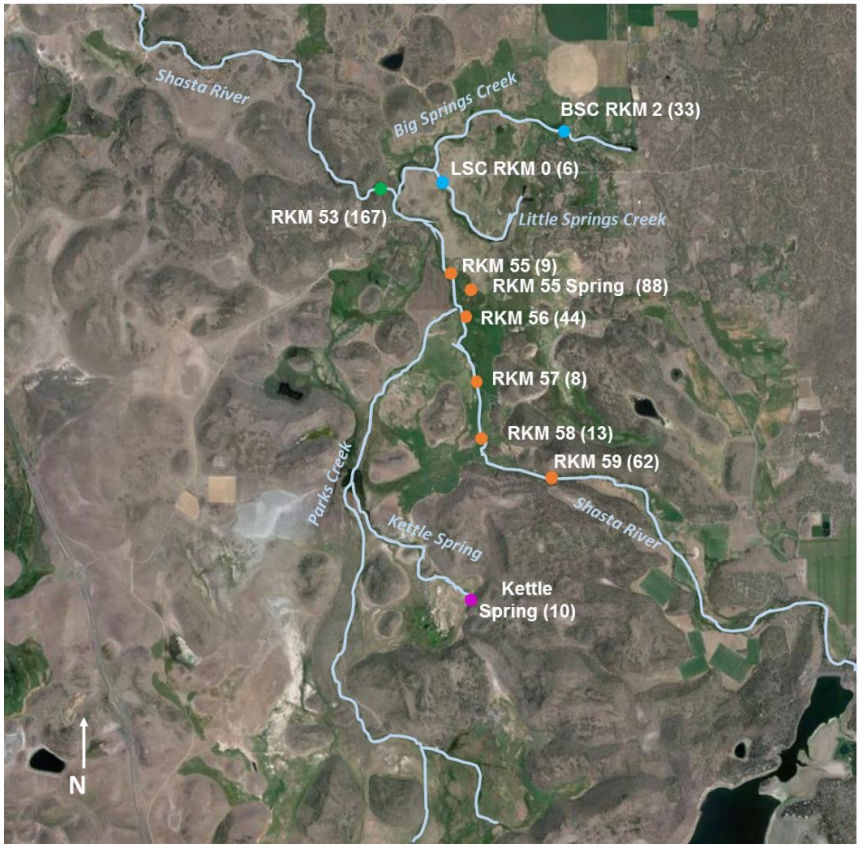

Figure 7. Upper Shasta River tagging locations for BY2012 coho. Total tagged at each site shown in parentheses.

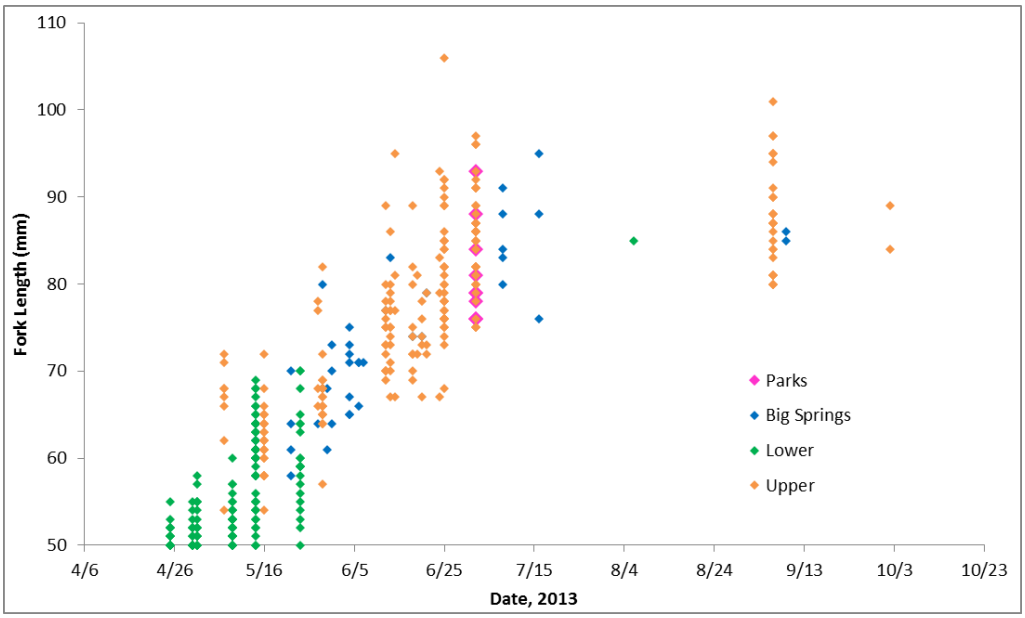

Figure 8. BY2012 coho fork length at date of tagging in the upper Shasta River. N=441.

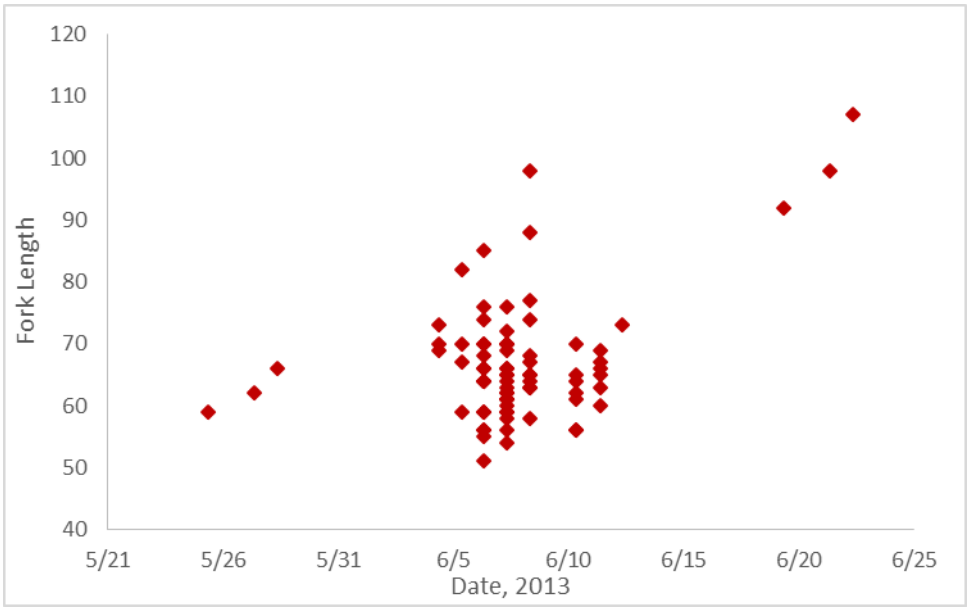

Figure 9. BY2012 age-0 coho fork length at date of capture in the Shasta River at the RKM 0 rotary screw trap in 2013. Total Captured=376 Total Measured=79.

2. Movement and Survival

The frequency of PIT tag detections at all upper Shasta PIT tag antenna stations combined was highest in May and June 2013 (Figure 10). Approximately 65% of all the BY2012 juvenile coho tagged in the mainstem Shasta River were detected as they moved upstream during this time. Only two individuals were encountered downstream of the upper Shasta River during May and June. The frequency of detections declined during the period from July to September 2013. Detections during this time period generally occurred where antenna

stations were located in cold water rearing areas such as BSC RKM 2 and Kettle Spring. An increase in detections occurred from September through December 2013. Approximately 15% of the tagged coho were detected moving from their summer rearing location to a different location to rear for the fall/winter and detection rates indicate that coho were no longer restricted to spring areas, likely due to decreasing water temperatures throughout the watershed. No BY2012 coho were detected outmigrating from the upper Shasta River during that time. Detection rates were lower during January and February, likely because fish were relatively stationary in rearing locations. Three individuals were encountered downstream of the upper Shasta River (RKM 0) in January and February 2014. During the spring outmigration period (March-May 2014) 145 age-1 coho were detected as they left the upper Shasta River (RKM 51 or upstream) and 148 were encountered at RKM 0 and RKM 12 before they entered the Klamath River. Eighteen individuals were detected at RKM 0 that were not encountered in the upper Shasta River and fifteen individuals were not detected at RKM 0, accounting for why three more individuals were detected at RKM 0 than in the upper Shasta River during the smolt outmigration period. No detections of BY2012 coho occurred after May 2014. See Appendix B for graphs of total individuals detected at each PIT tag antenna station by month.

Of the 436 tagged coho in the upper basin that were not detected outmigrating prior to March of 2014, 33% are known to have survived to reach the Klamath River as age-1 smolts in the spring of 2014. The known survival of BY2012 coho tagged at all locations combined was 82% from the initial spring release to the summer rearing encounter occasion, 72% through the summer rearing occasion, 67% through the winter rearing occasion, and 91% of the smolts known to be alive in the upper Shasta River in March 2014 or later are known to have survived to reach the Klamath River (Figure 11, Table 3). Survival from the spring tagging occasion to the summer rearing occasion was similar across the L, U, and B locations (81-88%). Ten fish were tagged in the P location (Kettle Spring) during the initial tagging occasion and 100% of them survived to the summer rearing occasion. Survival of the summer rearing encounter occasion was also similar across the U, B, and P locations (66-69%). Only one coho was known to be present in the L location during the summer rearing period and never encountered again. Known winter survival was more variable across locations, with 71% in L, 54% in U, 28% in B, and 55% in P (Figure 12).

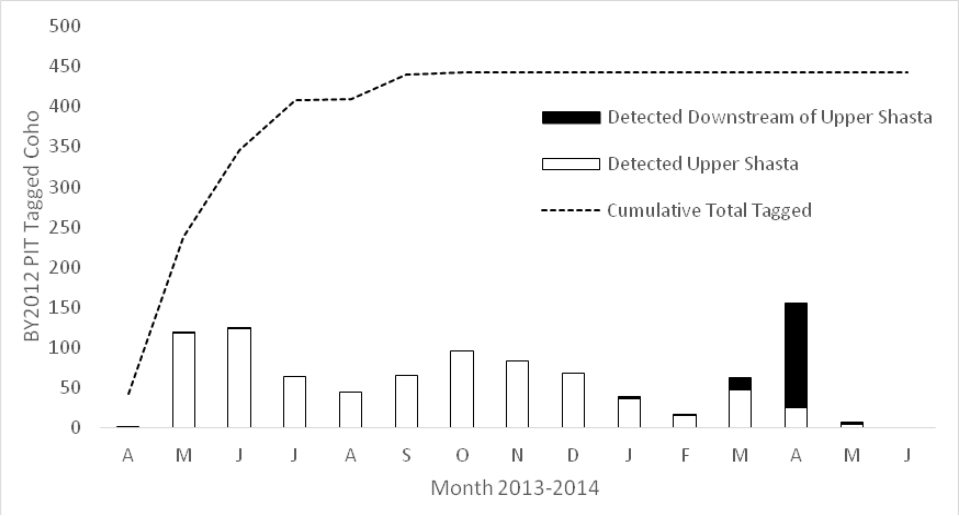

Figure 10. Total number of BY2012 coho tagged in the upper Shasta River that were detected each month at upper Shasta antenna stations (white) and downstream antenna stations (black) along with the cumulative monthly total tagged (dashed line).

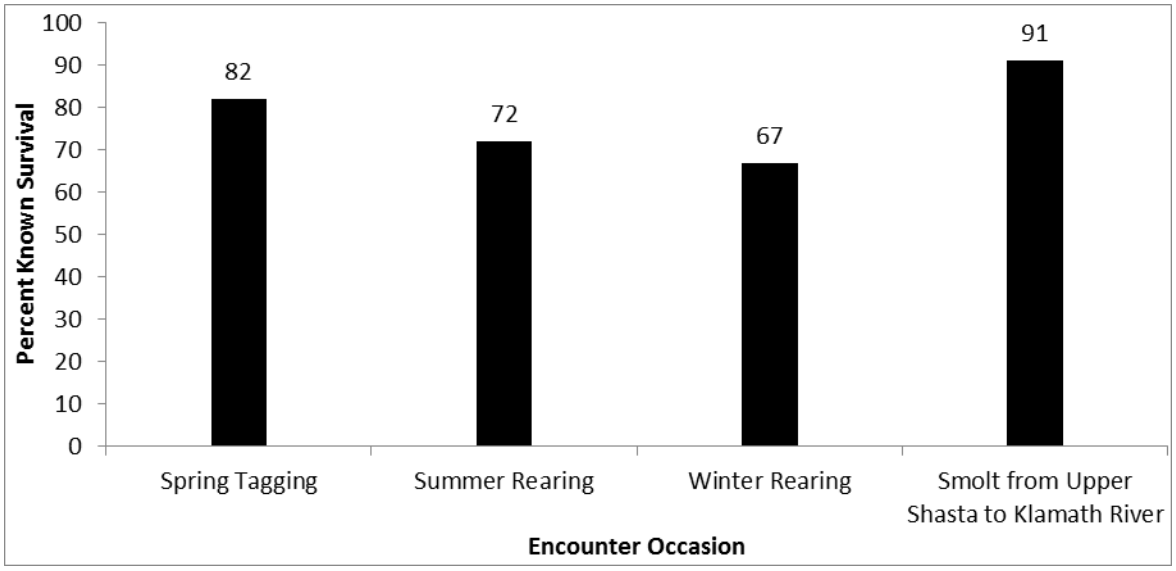

Figure 11. Known survival from each encounter occasion for all upper Shasta tagged BY2012 coho combined.

Table 3. Number of tagged BY2012 coho encountered in each reach of the Shasta River during each encounter occasion and the percentage from each reach that are known to have survived to the next encountered occasion. Note that individuals tagged after July 2013 are not included in the spring release, but are included in the summer rearing encounter occasion.

		Spring Release	Summer Rearing	Winter Rearing	Upper Shasta Smolt	RKM 0 Smolt
All upper Shasta locations combined	Total	359	371	263	163	148
	Known Survivors	294	266	176	148	
	% Known Survival	82%	72%	67%	91%	
Upper Shasta downstream of Big Springs Creek (L)	Total	166	1	14		
	Known Survivors	134	0	10		
	% Known Survival	81%	0%	71%		
Upper Shasta upstream of Big Springs Creek (U)	Total	149	215	56		
	Known Survivors	120	149	30		
	% Known Survival	81%	69%	54%		
Big Springs and Little Spring Creek (B)	Total	34	91	50		
	Known Survivors	30	60	14		
	% Known Survival	88%	66%	28%		
Parks Creek and Kettle Spring (P)	Total	10	21	47		
	Known Survivors	10	14	26		
	% Known Survival	100%	67%	55%		
Outmigrated from Upper Shasta	Total		2	3	145	148
	Known Survivors				130	
	% Known Survival				90%	
Known Alive But Not Encountered	Total		43	96	18	

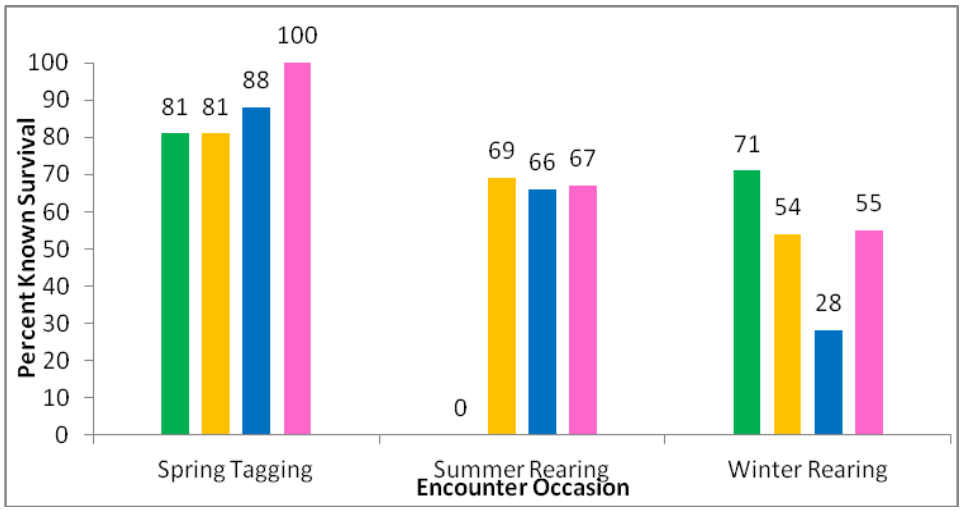

Figure 12. Known survival percentage for tagged BY2012 coho in each of the four upper Shasta River reaches through each of the three encounter occasions (does not include individuals that were known alive but not detected) (green= RKM 51-53, orange= RKM 54-60, blue=Big Springs Creek including Little Springs Creek, pink= Parks RKM 0-7 including Kettle Spring).

Approximately 65% of the coho tagged in the Shasta River downstream of Parks Creek (RKM 53, 55, 55 Spring), during the initial spring tagging occasion moved upstream during the summer rearing encounter occasion, while fish tagged in other reaches tended to remain there throughout the summer (Table 4). Of the 166 coho tagged in the mainstem Shasta River downstream of Big Springs Creek (L), 71% were encountered at upstream locations as they moved into summer rearing locations. This included 34% that were detected as they moved upstream into Big Springs Creek, 36% that were encountered upstream of Parks Creek (on the mainstem Shasta River) and 1% that were detected moving into Parks Creek. Two of the fish tagged at L were encountered at downstream locations, and these were the only upper Shasta River tagged coho that outmigrated during the summer rearing period. Movements and survival of L tagged coho are analyzed in more detail in Section IV.5 below. Of the 149 coho tagged in the Shasta River upstream of Big Springs Creek (U) during the initial tagging occasion, 54% were encountered in that same reach for the summer encounter occasion. Seventeen percent of the U tagged individuals were not detected in the summer but known to be alive, likely because they were tagged and then spent the summer between the RKM 56 and RKM 60 antenna stations. Many of the fish tagged at RKM 55 Spring were detected moving upstream; the movements and survival of the RKM 55 Spring tag group are analyzed in Section IV.4 below. Coho tagged in Big Springs Creek and Kettle Spring tended to remain there for the summer.

Movements among the five reaches from the summer rearing occasion to the winter rearing occasion are shown in Table 5. Only one coho was known to be alive and residing in the L reach during the summer rearing occasion and it was not encountered again. Of the 215 coho known to be in the U reach during the summer 20% remained there for the winter and 36% were not encountered in the winter but known to survive, likely because they remained in the reach between the RKM 56 and RKM 60 antenna stations where favorable summer conditions are known to exist in the reach downstream of Clear Spring. One percent of the coho tagged in U reach moved into each of the L and B reaches for the winter and 10% moved into Parks Creek. Of the 90 coho known to be alive and residing in Big Springs Creek, 48% remained there for the winter, 4% moved to the L reach, 4% moved into U, 2% moved into P, and 2% outmigrated from the upper Shasta River. Of the 21 coho known to be alive and residing in Parks Creek during the summer occasion, 62% remained there for the winter and 5% moved into the L reach.

Table 4. Movements among upper Shasta River locations from the initial spring release location to the summer rearing location.

		Tag Location (April-July 2013)							
		L		U		B		P	
		Total	%	Total	%	Total	%	Total	%
	Total Released	166		149		34		10	
Location Last Encountered During Summer Rearing Period (May-Sept 2013)	L	1	1%	0	0%	0	0%	0	0%
	U	59	36%	81	54%	0	0%	0	0%
	B	56	34%	4	3%	27	79%	0	0%
	P	2	1%	9	6%	0	0%	10	100%
	Outmigrated From Upper Shasta River	2	1%	0	0%	0	0%	0	0%
	Alive But Not Detected	14	8%	26	17%	3	9%	0	0%
	Not Encountered Again	32	19%	29	19%	4	12%	0	0%

Table 5. Movements among upper Shasta River locations from the summer to the winter rearing location.

		Summer Rearing Location (April-September 2013)							
		L		U		B		P	
		Total	%	Total	%	Total	%	Total	%
	Total Released	1		215		90		21	
Location Last Encountered During Winter Rearing Period (Oct 2013-February 14)	L	0	0%	3	1%	4	4%	1	5%
	U	0	0%	44	20%	2	2%	0	0%
	B	0	0%	3	1%	43	48%	0	0%
	P	0	0%	21	10%	6	7%	13	62%
	Outmigrated From Upper Shasta River	0	0%	0	0%	2	2%	0	0%
	Alive But Not Detected	0	0%	78	36%	3	3%	0	0%
	Not Encountered Again	1	100%	66	31%	30	33%	7	33%

3. Spring/Summer Fry Migrations

This set of analyses looks specifically at the group of 166 BY2012 coho tagged at RKM 53 (first several hundred meters downstream of the Big Springs Creek confluence) in April and May 2013. All of these fish were captured with hand nets or seines where grassy cut banks or submerged wood provided velocity refuge and cover. Of the 166 tagged coho, 84 (50%) were detected October 2013 or later, which may be interpreted as 50% summer survival. To investigate survival and timing/locations of movements of the coho tagged at RKM 53, the summer rearing locations for each fish was identified (if they were encountered during the summer occasion) and a

determination was made as to their survival up until October (based on any encounter at any location in October or later). Of the 166 individuals, 59 moved upstream into the Shasta River above Parks Creek (36%), 56 moved upstream into Big Springs Creek (34%), three moved downstream from the tagging site (2%), two moved upstream into Parks Creek (1%), and 46 were not detected during the summer (27%)(Table 6). Of the fish that moved upstream into Big Springs Creek, 58% are known to have survived through the summer. Of those that moved into the Shasta River upstream of Parks Creek, 63% are known to have survived summer. Of those that were not detected anywhere in the summer, 30% are known to have survived through the summer. None of the individuals that moved into Parks Creek or downstream were encountered again.

To investigate potential correlations between the timing and locations of movements, the data are represented in a bar graph that illustrates the number of coho tagged on a specific day with the summer rearing location for each fish indicated by color (Figure 13). A portion of the individuals tagged on any given tag date moved into Big Springs Creek and a portion moved into the Shasta River upstream of Parks Creek. However, there appeared to be a tendency for coho tagged on some dates to move into a particular location. To investigate correlations between movements into particular locations with stream temperatures, the cumulative daily number of RKM 53 tagged coho detected moving into Big Springs Creek or the Shasta River upstream of Big Springs Creek was plotted along with maximum daily temperature at the mouth of Big Springs Creek and the Shasta River upstream of Big Springs Creek from April-July 2013 (Figure 14). Cumulative number of coho tagged is also plotted and is important to consider since upstream movements could not be detected for individuals prior to tagging. A line at 20 C° is plotted for reference. Movements into Big Springs Creek occurred first, when maximum stream temperatures were above 20° C for several consecutive days (May 5, 2013 – May 14, 2013). Movements into the Shasta River upstream of Big Springs Creek occurred several days later, during a period when maximum daily stream temperatures remained below 20° C (May 14, 2013 – May 29, 2013). Upstream movements were not documented from June 1, 2013 – June 13, 2013 when maximum daily stream temperatures remained above 20° C. Upstream movements were again documented from June 14, 2013 – June 29, 2013 when maximum daily stream temperatures remained below 20° C. Only two additional upstream movements were documented following June 29, 2013 when maximum daily stream temperatures remained above 20° C.

Table 6. Summer rearing locations of BY2012 coho tagged as Shasta River RKM 53 in April and May 2013 and number in each location that are known to have survived to October 2013.

		Encountered in Each Location, May-Sept 2013		Known to Survive to October 2013	
		Total	Percentage	Total	Percentage
	Total	166	100%	84	50%
Summer Rearing Location	L	1	1%	0	0%
	U	59	36%	37	63%
	B	56	34%	33	59%
	P	2	1%	0	0%
	M	2	1%	0	0%
	Not Detected	46	28%	14	30%

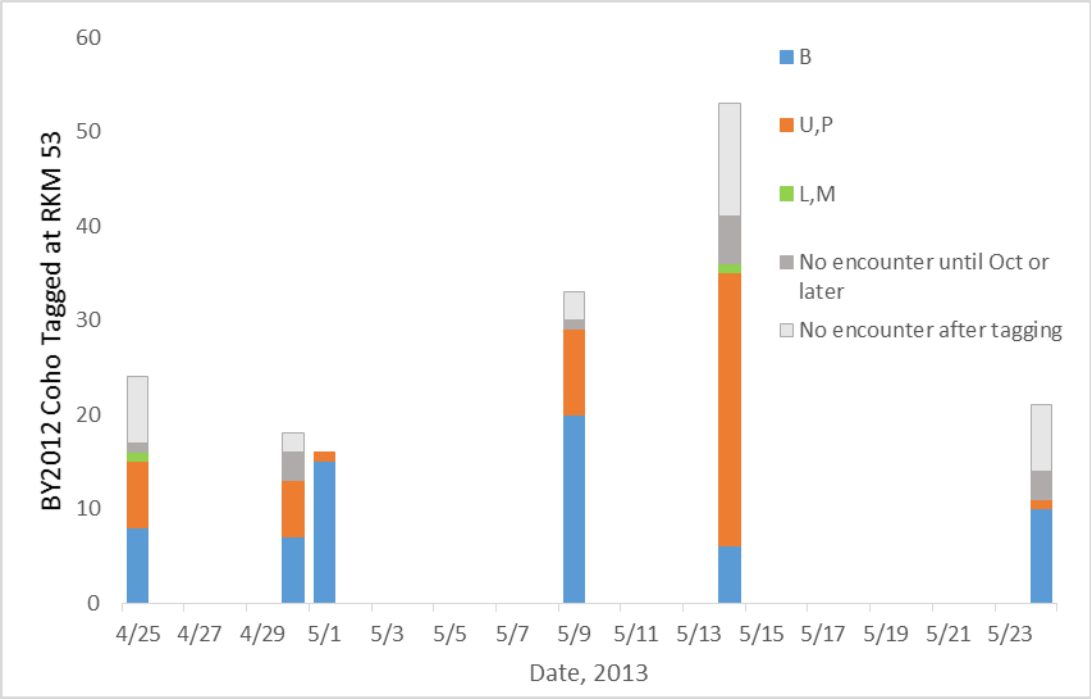

Figure 13. Number of BY2012 coho tagged at Shasta River RKM 53 each day in April and May 2013, with the summer rearing location of each individual indicated by color.

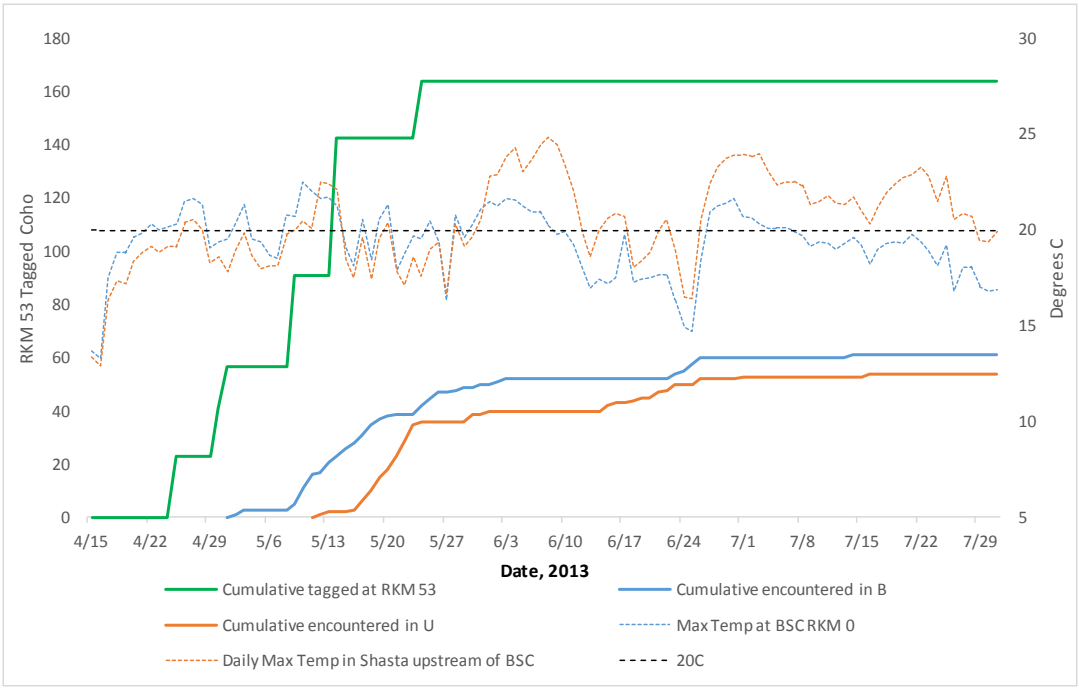

Figure 14. Cumulative number of BY2012 coho tagged at Shasta River RKM 53 (green line), cumulative number of those that were detected moving into Big Springs Creek (blue line) and into the Shasta River upstream of Parks Creek or into Parks Creek (orange line). Maximum daily temperature at the mouth of Big Springs Creek mouth is shown with a dashed blue line and maximum daily temperature in the Shasta River upstream of Big Springs Creek s shown with a dashed orange line. The dashed black line at 20 C° is shown for reference.

4. RKM 55 Spring

In mid-May over 100 juvenile coho were observed rearing in the RKM 55 Spring (Figure 15) during snorkel surveys. A total of 89 coho were captured and tagged at RKM 55 Spring during May and June 2013. Five of the coho captured at this location were recaptures. They had been had previously been tagged at RKM 53 (2 kilometers downstream). Snorkel survey observations of coho at this location declined rapidly in late June and only a couple of individuals were observed there in July. Of the 89 coho tagged at RKM 55 Spring, 47 were encountered in a different location during the summer rearing occasion; 52% moved upstream into the Shasta River above Parks Creek, 8% moved into Parks Creek, 4% moved into Big Springs Creek, and 36% were not detected during the summer rearing occasion (Table 7). Most tagged coho movements out of RKM 55 Spring occurred within several days of tagging (Figure 16), despite temperature conditions remaining favorable in the spring complex (Figure 17). Nearly half (47%) of the coho tagged at RKM 55 Spring that were not detected during the summer are known to have survived to October. However, coho were observed during snorkel surveys throughout the summer in the Shasta River immediately downstream of the confluence with RKM 55 spring.

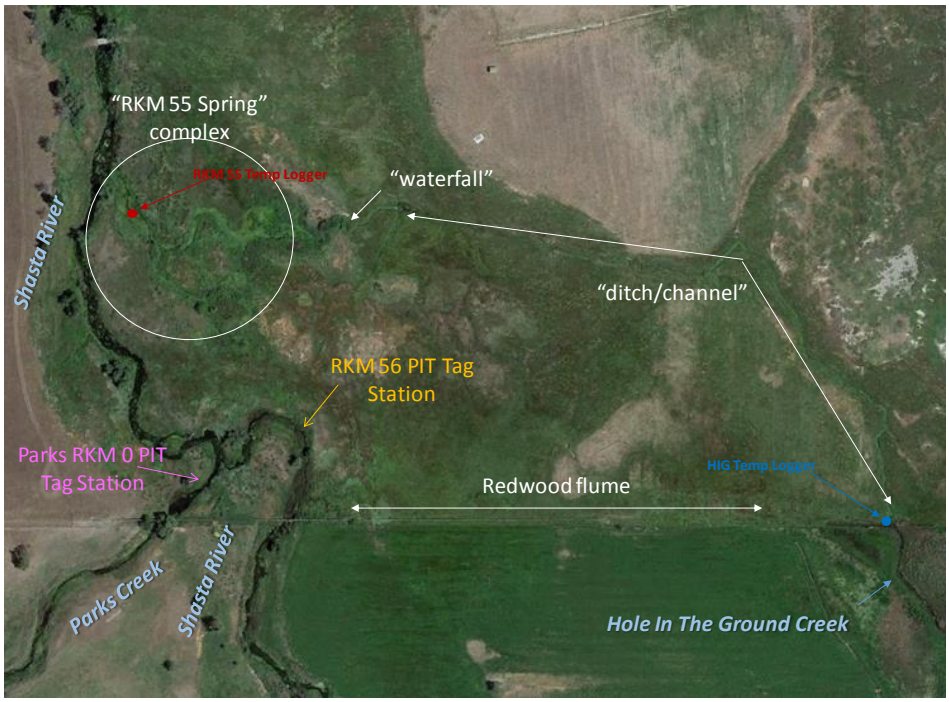

Figure 15. Map of RKM 55 spring and Hole in the Ground Creek.

Table 7. Summer rearing locations of BY2012 coho tagged in the upper Shasta River at RKM 55 Spring in May 2013 and number in each location that are known to have survived to October 2013.

		Encountered In Summer (May-Sept 2013)		Known Survival to October 2013	
		Total	Percentage	Total	Percentage
	Total Tagged at RKM 55 Spring	89	100%	55	62%
Summer Rearing Location	L	0			
	U (Shasta Upstream of Parks Creek)	46	52%	32	70%
	B	4	4%	2	50%
	P	7	8%	6	86%
	M	0			
	Undetected in Summer	32	36%	15	47%

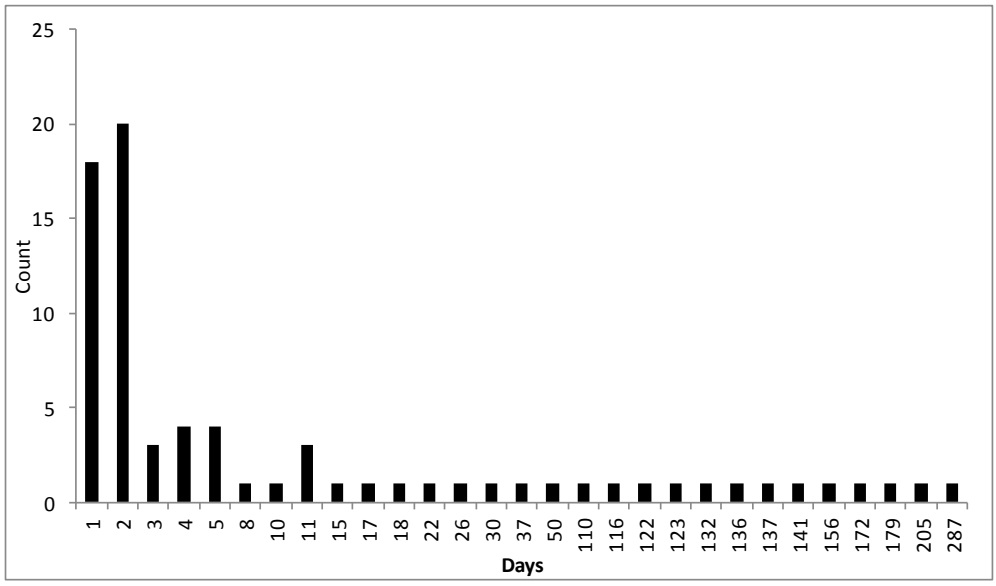

Figure 16. Travel time in days for BY2012 coho salmon tagged in RKM 55 spring from tag date to date of first detection outside of RKM 55 spring.

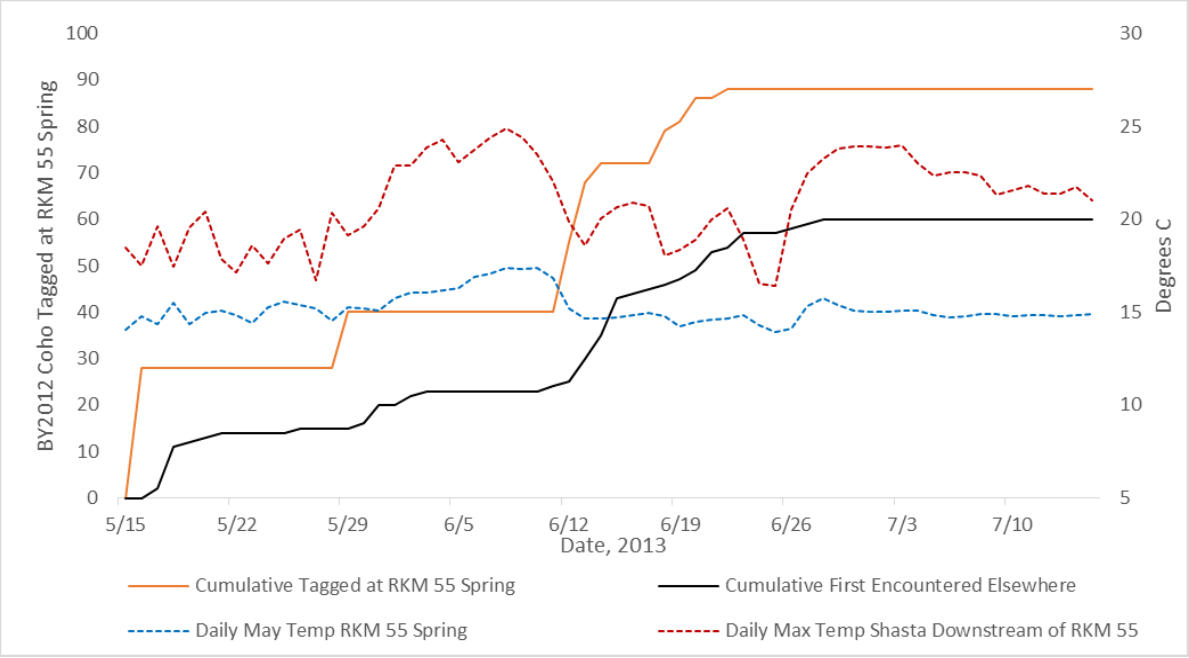

Figure 17. Cumulative BY2012 coho tagged at RKM 55 Spring and cumulative first encounters of those fish at any location outside of RKM 55 Spring along with maximum daily temperatures in RKM 55 Spring and in the Shasta River downstream of RKM 55 Spring.

5. Big Springs Creek

A total of 101 BY2012 coho were either tagged in Big Springs Creek (including Little Springs Creek) or detected there during the course of this study, 30 (30%) of which are known to have survived to the outmigration period (March 2014 or later). Known survival of all tagged coho present in Big Springs Creek and Little Springs Creek combined was 72% during April-June 2013, 77% during July-September 2013, and 54% during October 2013-February 2014. Figure 18 shows the locations of PIT tag stations within Big Springs and Little Springs Creeks. The number of coho last encountered at each location within Big Springs Creek and known survival at those locations for the initial tagging, summer, and winter rearing encounter occasions are shown in tables 8-10. Known survival rates in Big Springs and Little Springs creeks were among the lowest of any tag group in the BY2012 study. During May-June 2013, fish that moved further upstream into Big Springs Creek had higher survival than those last encountered near the mouth (BSC RKM 0) or in Little Springs Creek. Many tagged fish (40) were not detected during the summer, likely because they remained stationary in rearing locations. Snorkel surveys of Big Springs Creek revealed that juvenile coho were concentrated in constricted areas with increased velocity (bridge crossings and downstream of the water wheel structure) and at thespring outfall pool, with very few observations between those locations. Winter survival was particularly poor with only 14% of the fish rearing at BSC RKM 2 (water wheel) known to survive to the spring outmigration period.

BY2012 coho were the first cohort to be observed rearing in Little Springs Creek. Observations occurred just upstream of the Big Spring confluence in early May, and coho tagged at RKM 53 were detected moving upstream into Little Springs Creek shortly thereafter. A total of 21 BY2012 coho that had been tagged in other locations were detected in Little Springs Creek throughout the study. Observations of coho just upstream of Loiue Road first occurred in June, and coho were observed rearing in that location throughout the summer. Two BY2012 coho were detected as far upstream as LSC RKM 1, located just downstream of the second culvert.

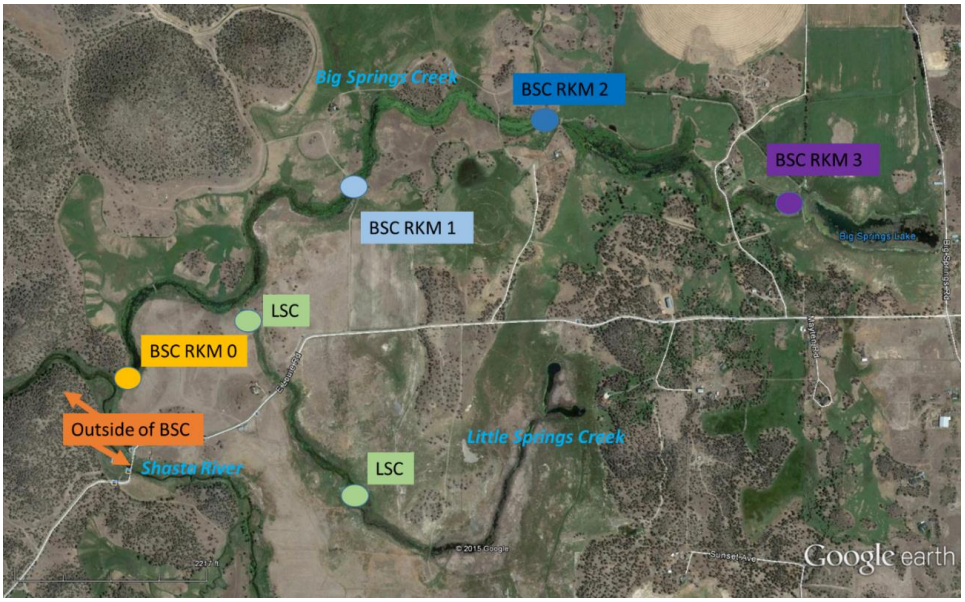

Figure 18.PIT tag antenna stations in Big Springs and Little Springs Creeks.

Table 8. Location of last encounter and known survival of tagged BY2012 coho present in Big Springs Creekduring April-June 2013, based on their detection at any location in July 2013 or later.

	Last encounter April-June 2013		Known survival to July 2013	
	Total	Percentage	Total	Percentage
Total	101	100%	73	72%
BSC 0	35	35%	13	37%
BSC 1	20	20%	16	80%
BSC 2	28	28%	22	79%
BSC 3	0	0%	0	0%
LSC	6	6%	0	0%
Not Detected	22	22%	22	100%

Table 9. Location of last encounter and known survival of tagged BY2012 coho present in Big Springs Creekduring July-September 2013, based on their detection at any location in October 2013 or later.

	Last encounter July-September 2013		Known survival to October 2013	
	Total	Percentage	Total	Percentage
Total	73	100%	56	77%
BSC 0	0	0%		
BSC 1	1	1%	0	0%
BSC 2	22	30%	10	45%
BSC 3	4	5%	1	25%
LSC	6	8%	5	83%
Not Detected	40	55%	40	100%
Outside of BSC	0	0%		

Table 10. Location of last encounter and known survival of tagged BY2012 coho present in Big Springs Creekduring October 2013-February 2014, based on their detection at any location in March 2014 or later.

	Last encounter October 2013-February 2014		Known survival/outmigrated to March 2014	
	Total	Percentage	Total	Percentage
Total	56	100%	30	54%
BSC 0	8	11%	3	38%
BSC 1	1	1%	0	0%
BSC 2	21	29%	3	14%
BSC 3	1	1%	0	0%
LSC	1	1%	0	0%
Not Detected	13	18%	13	100%
Outside of BSC	11	15%	11	100%

6. Smolt Outmigration

A total of 490 age-1 smolts were captured at the RKM 0 rotary screw trap, 34 of which were identified as having been previously tagged in the upper Shasta River (7%). Catches of age-1 coho smolts began in mid-March, peaked in mid-April, and ceased by mid-May (Figure 19). A total of 142 age-1 coho that had previoulsy been tagged in the upper Shasta River were detected at the two antenna stations at RKM0 (33% of the total tagged in the upper basin tahe were not detected outmigrating prior to March 2014). The majority of these fish were detected immediatley after the irrigation season began (April 1) and during a moderate increase in flows resulting from a release from Dwinnell Dam (Figure 20).

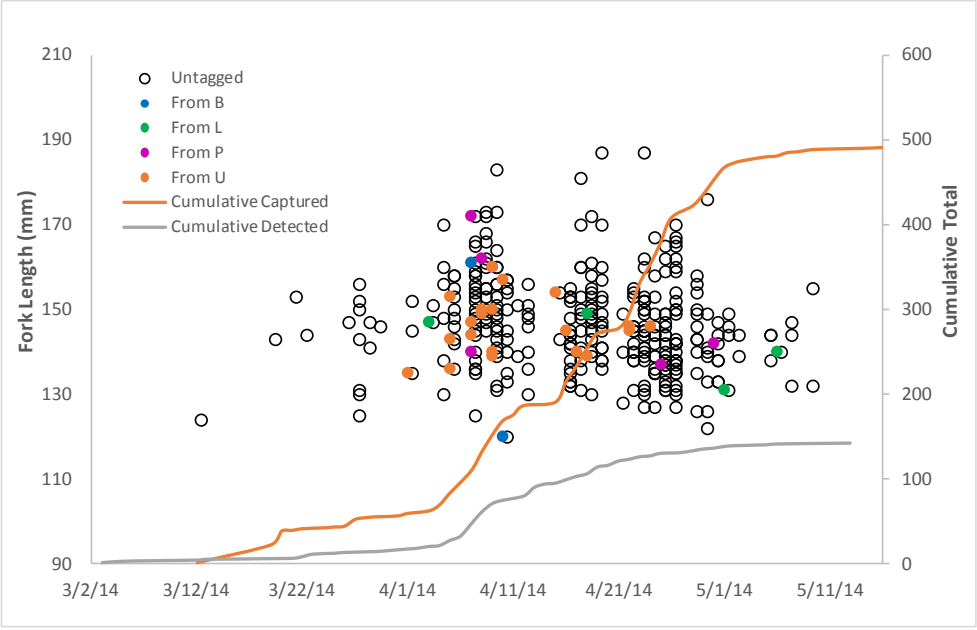

Figure 19. BY2012 Shasta River coho encountered at RKM 0 in 2014. Winter rearing location for fish captured that were previously tagged in the upper Shasta River is indicated by color.

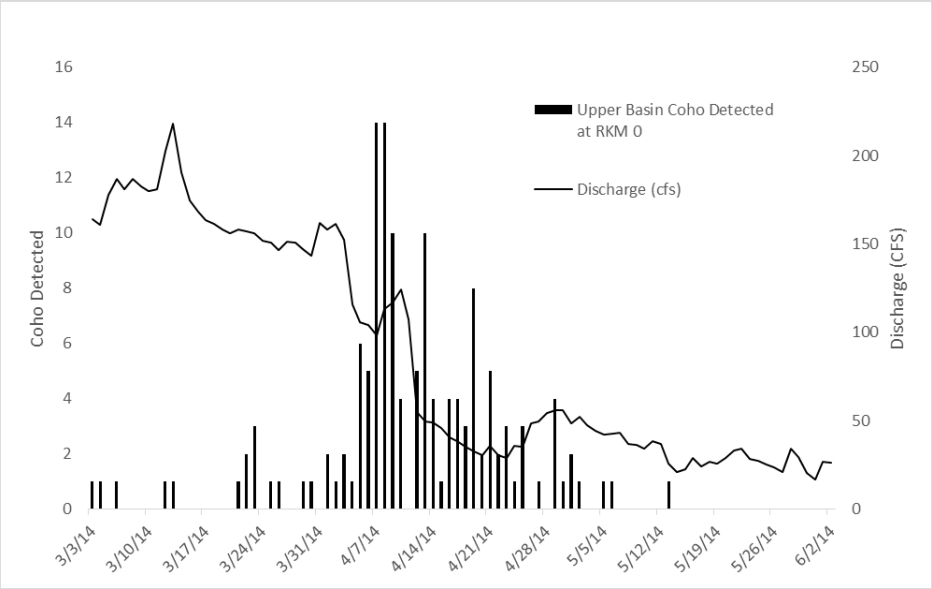

Figure 20. Upper basin tagged BY2012 coho detected at RKM 0 in 2014 and flow measured at USGS gage.

V. DISCUSSION

1. Capture/Tagging

While using PIT tags to monitor movements and survival is very informative, it is important to remember that a potentially critical life history segment exists between fry emergence and tagging that is missed by this method. By the time juvenile coho in the upper Shasta River reach the 50 mm minimum fork length required for PIT tag implantation, significant events that effect survival and movement are likely to have already taken place. Smaller fish may be more susceptible to predation or elevated water temperatures than larger fish. Coho tagged at locations upstream of redds and initial rearing locations had obviously made successful upstream migrations prior to being tagged, therefore unsuccessful upstream migrants may be under represented in the sample of tagged fish, simply because they did not survive to reach upstream capture locations. Even coho tagged just over the 50mm minimum size at RKM 53 in April could have made extensive migrations prior to being tagged.

Regular snorkel surveys in the Shasta River from RKM 51 upstream to Parks Creek and in Big Springs Creek provided valuable information on relative abundance of coho which guided tagging efforts in those locations. Surveys in Parks Creek and the Shasta River upstream of Parks Creek were limited to a couple of occasions therefore; juvenile coho in those locations may be under represented in this study. Parks Creek upstream of the Parks RKM 7 PIT station is a known spawning location for coho in most years and it is likely that BY2012 coho were present in that area. However, tagging in that area was not conducted during this study.

2. Movement and Survival Patterns

The general movement patterns observed in this study were consistent with those observed in previous studies (Chesney 2009, Adams 2013). Coho fry moved upstream from the mainstem Shasta River to locations closer to spring inflows where they reared for the summer. These upstream movements tend to be fairly evenly distributed among tributaries and it remains unclear what might influence an individual to move to a particular

location. One difference in the BY2012 study was that very few coho tagged in the upper basin outmigrated during the first summer (2, >0.5% of the tagged sample). The BY2010 study documented 19 tagged age-0 coho(approximately 5% of the tagged sample) from the upper basin outmigrating as apparent age-0 smolts in June. RKM 0 catches of untagged age-0 coho in 2011 also indicated that there was a number (128) of large (>90 mm)BY2010 age-0 outmigrants leaving the Shasta River in early summer, which did not appear to be the case in the BY2012 study when only four fish over 90 mm were captured at RKM 0 at age-0.

Across locations, known survival was comparable during the spring and summer occasions. This is somewhat surprising, considering the differences in habitat variables among the different rearing locations. Survival of BY2012 coho in the upper Shasta River was overall lowest and more varied across locations in the winter. This conflicts with findings in the BY2010 study, in which summer survival was found to be lowest. Further investigation is needed to identify the causes of winter mortality and if the cause may be addressed to improve overall survival of juvenile coho. Physical habitat changes dramatically in the Shasta River from summer to winter, when aquatic vegetation senesces and physical habitat complexity is reduced. This could lead to increased predation by birds, otters, or large rainbow trout which were observed on many occasions throughout the upper Shasta River watershed (Photo 32).

3. Spring/Summer Fry Migrations

Movements upstream from the mainstem reach below the Big Springs Creek confluence indicate that conditions in that reach become unfavorable for coho rearing. Three habitat elements change dramatically during the time when most of the movements occur out of this location. One is habitat complexity which increases as aquatic vegetation grows. The second is flow which is reduced significantly once irrigation season begins. The third is stream temperature which can increase rapidly on a daily basis. Stream temperature is influenced by solar radiation, amount of emergent vegetation providing shade, thermal mass as determined by the amount of water in the stream, and thermal inputs from tailwater re-entering the stream. Stream temperatures in the Shasta River downstream of Big Springs Creek are complicated further by the mixing of Big Springs Creek and the Shasta River which could each be contributing a range of flows and temperatures at any given time.

Increased habitat complexity resulting from growing aquatic vegetation should be favorable for juvenile coho. The changes in habitat brought on by decreased flows and increased temperature are perhaps more likely causes for juvenile coho to seek alternative habitat. The movement patterns illustrated in Figure 14 indicate that there is a relationship between maximum stream temperatures and upstream movements. Most upstream movements occurred after several consecutive days with maximum water temperatures of over 20° C during periods when maximum daily stream temperatures remain at or below 20° C. Had these periods of time with lower temperatures not occurred, many of those fish may not have made upstream movements and would have then been exposed to potentially lethal water temperatures during the summer, resulting in lower overall survival. Conversely, if maximum stream temperatures had remained below 20° C for longer or more frequent periods, additional coho may have made successful upstream movements, resulting in increased overall survival. Had stream temperatures remained below 20° C throughout the summer, upstream movements may not have occurred from locations where other sufficient physical habitat attributes existed.

Given the current low population status of coho salmon in the Shasta River, density dependent effects on survival and movement may not be occurring. However, if recovery of the population is successful and juvenile coho numbers increase, density dependent effects may become problematic in the currently limited summer

rearing habitats. Therefore, it is critical that the amount of suitable summer rearing habitat be expanded and that locations such as the reach downstream of Big Springs Creek be managed to provide adequate rearing conditions throughout the summer.

4.RKM 55 Spring

The reach of the Shasta River adjacent to RKM 55 Spring is frequently utilized for spawning by coho. Coho fry have been consistently observed in that reach as well, but are displaced by June, likely due to increasing stream temperatures. RKM 55 Spring appears to be functioning as short-term thermal refugia from the mainstem Shasta River but may not provide other habitat qualities needed to support juvenile coho throughout the summer, as indicated by the limited residence time in the spring (less than three days in most instances). While temperatures in the RKM 55 Spring remained favorable, other habitat qualities such as depth or prey availability may be lacking. It is possible that the thermal input from RKM 55 Spring may be providing summer habitat in the Shasta River just downstream of the RKM 55 Spring before it fully mixes with the mainstem Shasta River.

The flow from Hole in the Ground Creek can be routed to enter the Shasta River through a decommissioned redwood flume or through a channel/ditch and over a waterfall approximately 3 meters high (impeding upstream fish migration) where it then combines with these springs before flowing into the Shasta River. Under current management, Hole in the Ground Creek can consist primarily of tail water (irrigation runoff) and can be very warm (>20° C) at certain times of the year. The historic channel configuration of Hole in the Ground Creek is not clear. Thermal inputs from Hole in the Ground Creek are detrimental to coho rearing in the RKM 55 Spring, particularly when the flow is added abruptly.

5. Big Springs Creek

Big Springs Creek provided the largest area of thermal refuge in the upper Shasta River watershed (approximately two kilometers) during the summer, and coho moved there from downstream locations in the mainstem Shasta River. Based on snorkel surveys throughout Big Springs Creek, juvenile coho tended to be concentrated near constricted areas where velocities were increased, such as downstream of the water wheel and at bridge crossings, despite temperature conditions being suitable in other locations. The water wheel structure itself may pose fish passage issues, though some coho were able to move upstream through the structure based on detections at the outfall pool. The relatively poor known winter survival rate of coho in Big Springs Creek was unexpected (28% vs. 54-71% in other locations). Physical habitat characteristics in Big Springs Creek change dramatically in the winter as aquatic vegetation dies off and it is possible that predation rates increase as presence of cover decreases (Photos 33-38). Changes in water quality during the senescence and die-off of large amounts of aquatic vegetation may also have implications with coho movement patterns and survival in the winter.

Coho utilization of Little Springs Creek suggests there is potential for the system to provide substantial rearing habitat, given that it produces approximately seven cfs of cold water throughout the summer. Unlike observations at other spring sources, coho did not migrate upstream to the reach directly downstream of the spring source. Several culverts exist in Little Springs Creek that may themselves pose velocity barriers to fish passage. These culverts also cause impoundments to occur upstream, particularly when they become plugged with debris. These shallow impoundments can warm quickly, potentially resulting in thermal barriers to upstream movement and having detrimental effects downstream.

6. Smolt Outmigration

The survival of age-1 coho smolts outmigrating from the upper Shasta River was higher for the BY2012 cohort than was documented for BY2010 coho (91% vs. 77%, Adams 2013). Scheduled flow releases from Dwinnell Dam may have assisted outmigration. Based on dates of outmigration of upper Shasta River tagged coho and the streamflow records, it appears that outmigration is triggered by the rapid decrease in instream flows. The majority of tagged coho smolts from the upper Shasta outmigrated by mid-April, while catches of untagged smolts in the rotary screw trap continued through mid-May. This suggests that there may be an un-sampled rearing location from which coho outmigrate later than those coho from the sampled locations. With so few fish tagged in Parks Creek, it is possible that this group of later outmigrants came from that part of the watershed.

VI. POTENTIAL MANAGEMENT ACTIONS AND FUTURE MONITORING NEEDS

1. The portion of coho life history from emergence to the 50mm fry stage should be further investigated since conditions in the Shasta River can change dramatically during that time. This might include an alternative tagging and tracking method for smaller fish or more systematic snorkel surveys.
2. More extensive reconnaissance surveys should occur throughout the watershed to ensure that all segments of the coho population are represented adequately in the sample of tagged juveniles.
3. Additional PIT tag antenna stations located directly in rearing locations downstream of Big Springs Creek coupled with a more extensive network of temperature loggers could provide more resolution to coho response to increasing water temperatures in May and June. These findings could be used to inform water managers in the upper Shasta River in order to improve coho rearing habitat conditions during this critical time.
4. Some coho appear to be finding suitable habitat somewhere in the Shasta River where they were not detected by the antenna stations. Identifying, protecting, and possibly expanding those habitats may be important for coho recovery.
5. RKM 55 Spring may be transformed into long term summer rearing habitat by increasing the depth and velocity of the pool while also increasing cover and food supply by submerging existing vegetation and promoting growth of new vegetation. A simple root wad or beaver dam like structure near RKM 55 Spring's confluence with the Shasta River could provide the added depth to the spring complex. Additional PIT tag stations in the spring and in the Shasta River just downstream of the spring would provide more information on coho use of the area.
6. Further investigation into the cause of winter mortality in Big Springs Creek is recommended, particularly since many coho migrate to Big Springs Creek from other areas of the watershed after the hot summer months. The addition of in-stream structure in Big Springs Creek may increase chances of survival while perennial vegetation becomes established. Information on juvenile coho movements and survival within Big Springs Creek and Little Springs Creek is critical for informing ongoing decision making regarding water management decisions.
7. Removal of culverts on Little Springs Creek should be pursued to maximize the potential for access to cold water coho rearing habitat.
8. Comparison of smolt outmigration timing with flow and temperature data in other years may help to build an understanding of the relationship between smolt outmigration timing and success in relation to those parameters. This information should be used to inform water managers, particularly in regards to releases from Dwinnell Dam.

VII. REFERENCES

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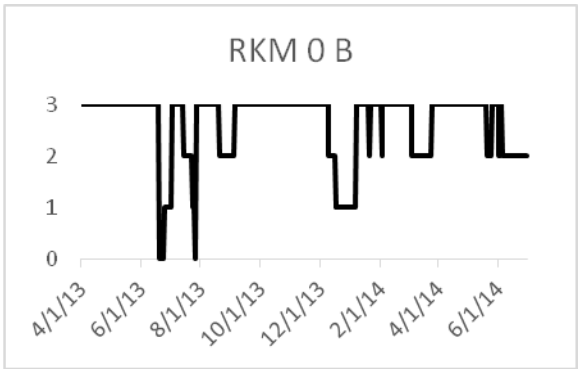
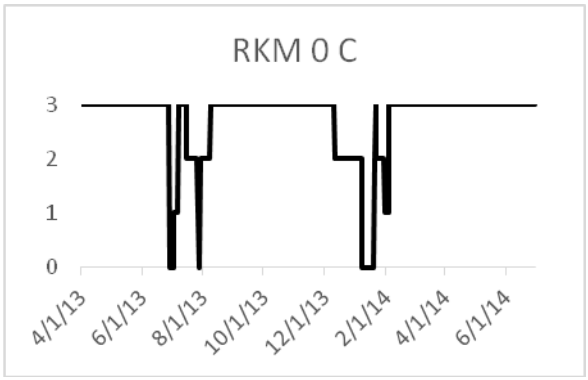
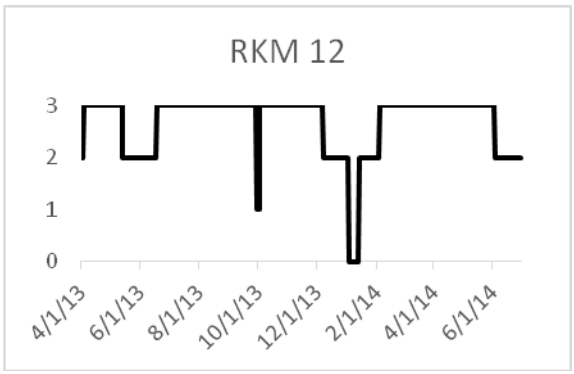
Chesney, W.R., C.C. Adams, W.B. Crombie, H.D. Langendorf, S.A. Stenhouse, and K.M. Kirkby. 2009. Shasta River juvenile coho habitat and migration study. Report prepared by California Department of Fish and Game for U.S. Bureau of Reclamation, Klamath Area Office. [unpublished report].

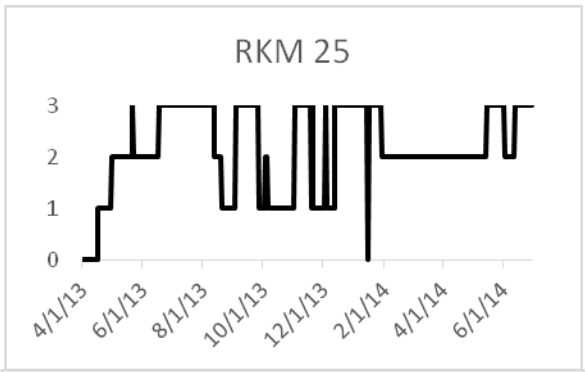
Stenhouse, S.A., C.E. Bean, W.R. Chesney, and M.S. Pisano. 2012. Water temperature thresholds for coho salmon in a spring-fed river, Siskiyou County, California. California Fish and Game 98(1).

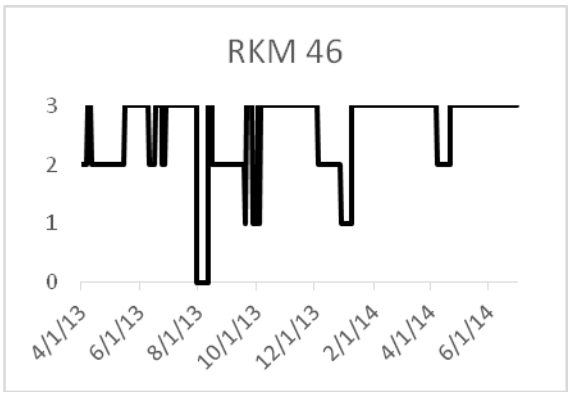
Appendix A. Daily antenna station performance based on portion of river transect covered by PIT tag detection field (0=0, 1=1-33%, 2=34-66%, 3=67-100%).

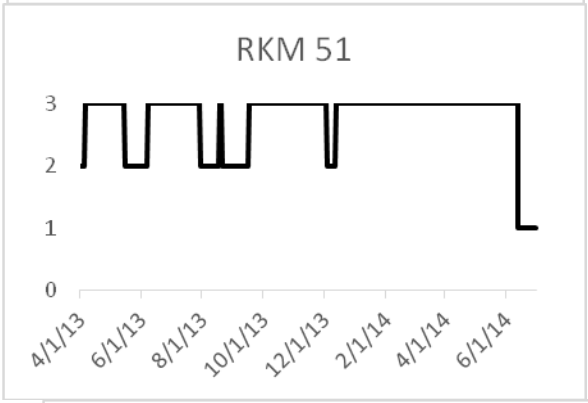


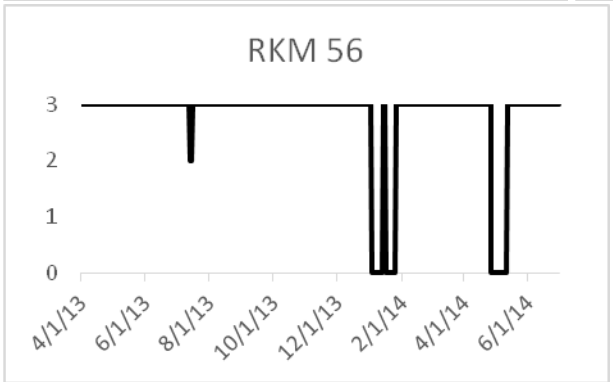


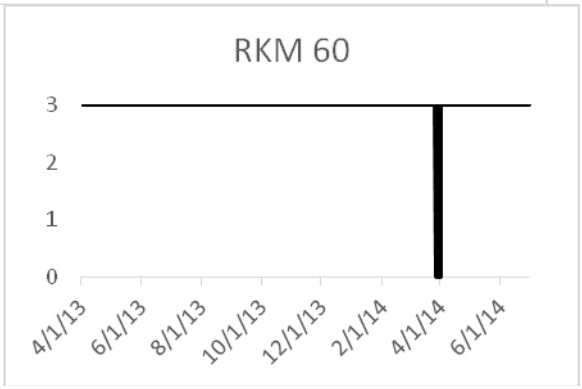


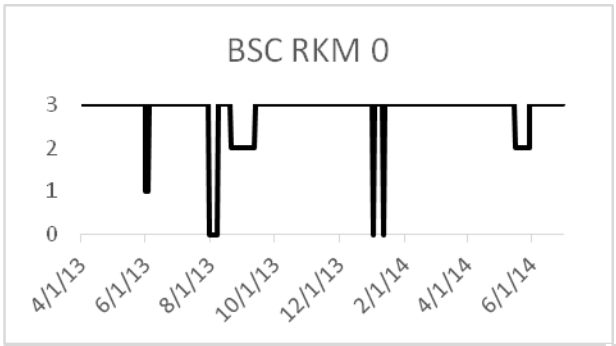








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2
1
0
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6/1/13
8/1/13
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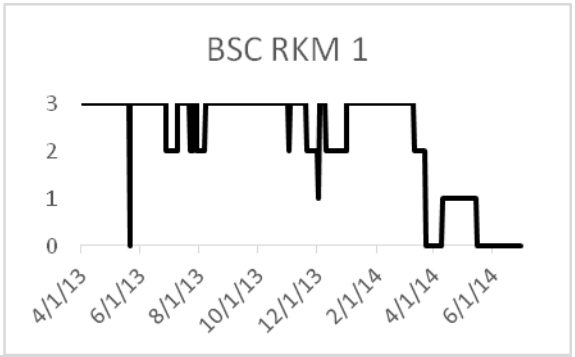
12/1/13
2/1/14
4/1/14
6/1/14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3
2
1
0
4/1/13
6/1/13
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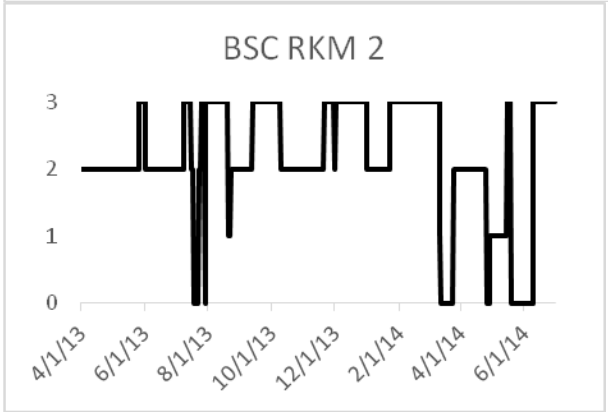
4/1/14
6/1/14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1
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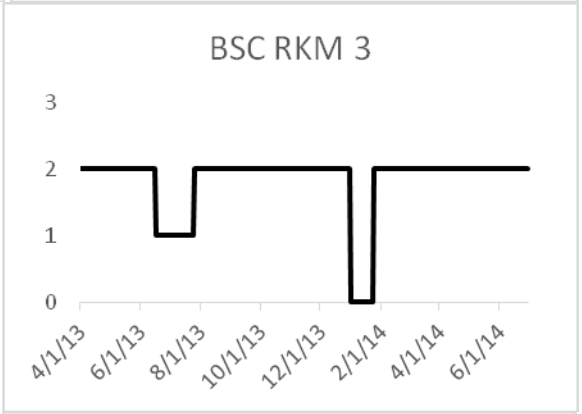
6/1/13
8/1/13
10/1/13
12/1/13
2/1/14
4/1/14
6/1/14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2
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4/1/13
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8/1/13
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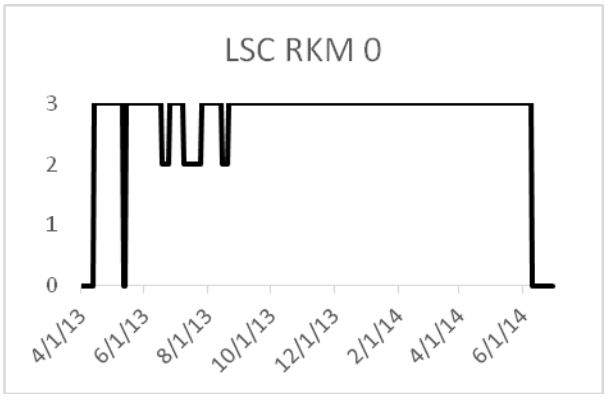
4/1/14
6/1/14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8/1/13
10/1/13
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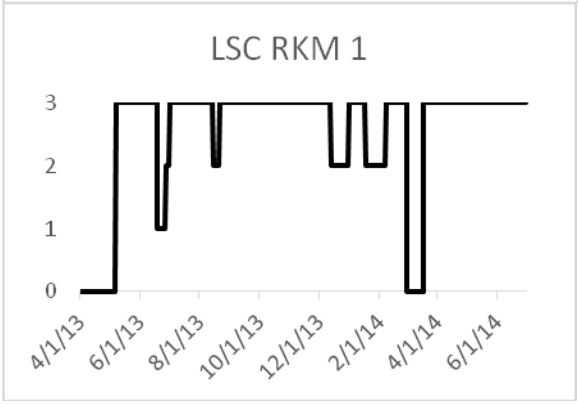
2/1/14
4/1/14
6/1/14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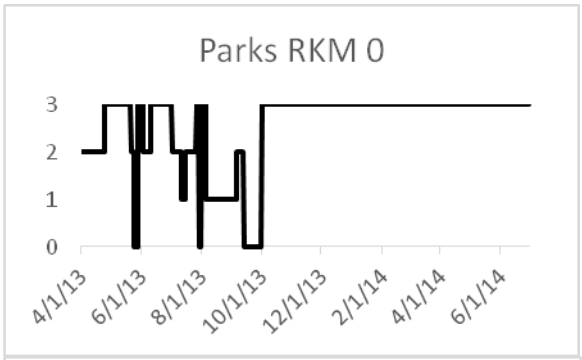
2
1
0
4/1/13
6/1/13
8/1/13
10/1/13
12/1/13
2/1/14
4/1/14
6/1/14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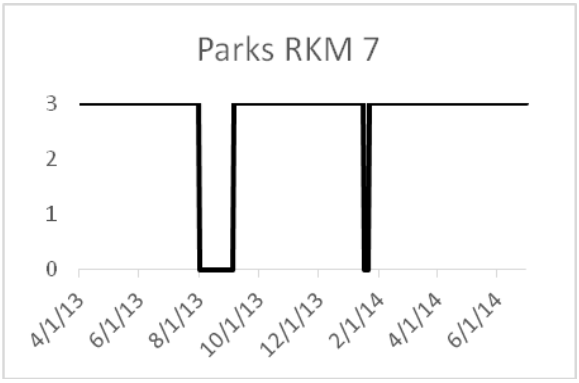
2
1
0
4/1/13
6/1/13
8/1/13
10/1/13
12/1/13
2/1/14
4/1/14
6/1/14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6/1/13
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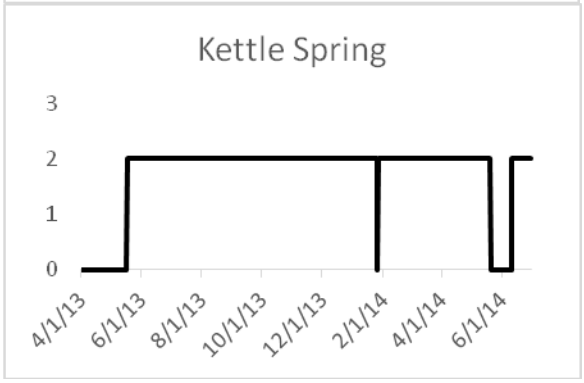
4/1/14
6/1/14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2
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4/1/13
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2/1/14
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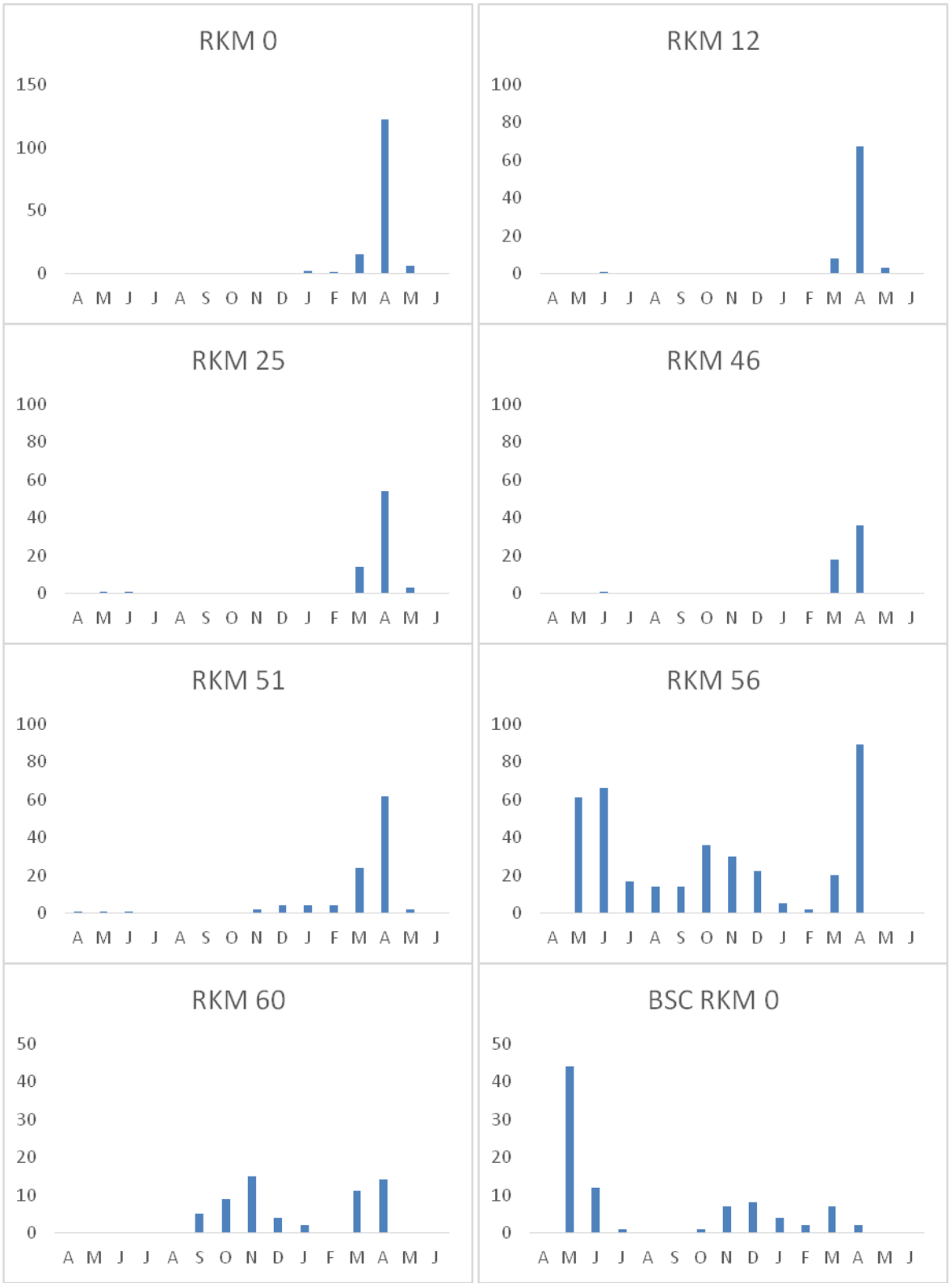
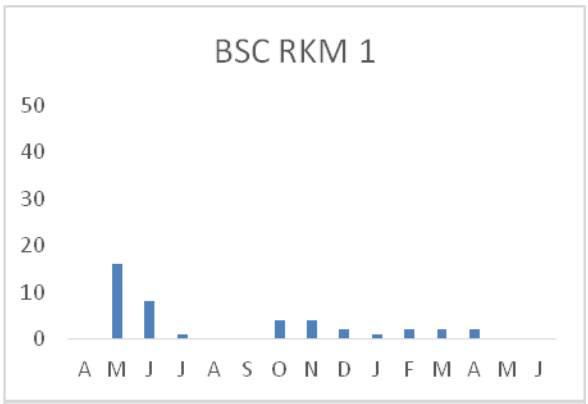
6/1/14

Appendix B. Monthly total number of individual upper Shasta River tagged BY2012 coho detected at each PIT tag antenna station.

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30
20
10
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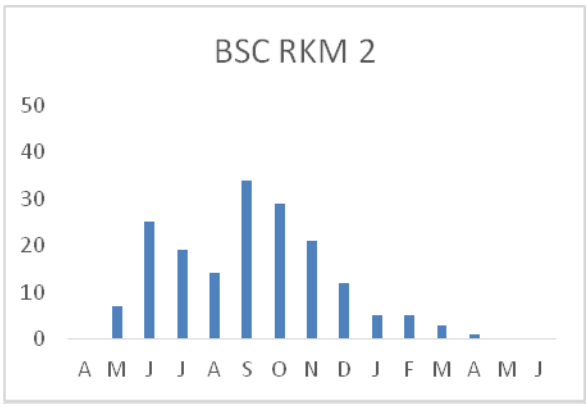
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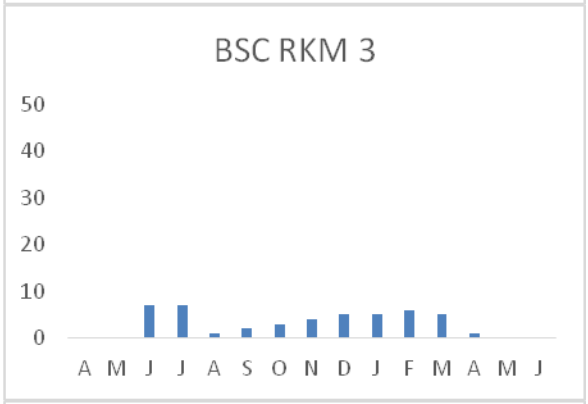
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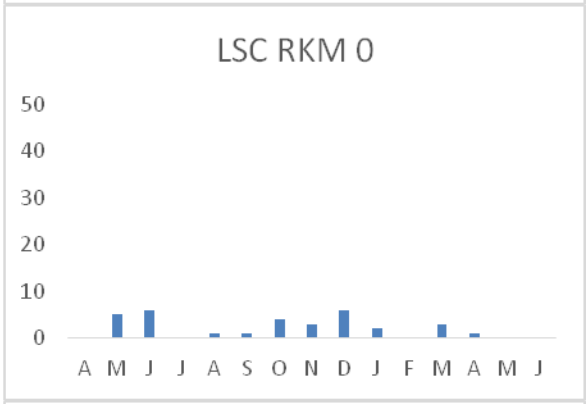
A M J J A S O N D J F M A M J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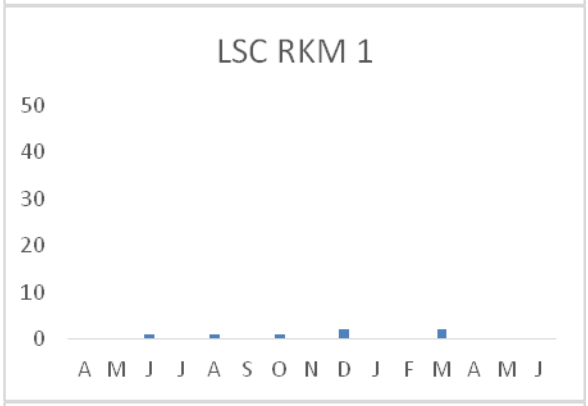
10
0
A M J J A S O N D J F M A M J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20
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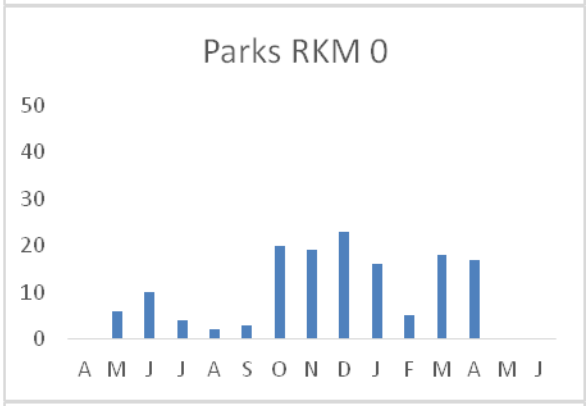
0
A M J J A S O N D J F M A M J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30
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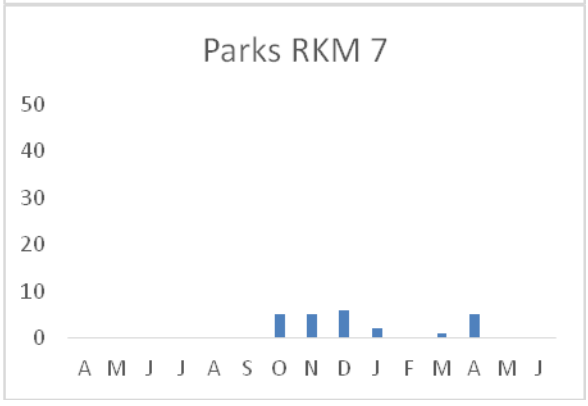
A M J J A S O N D J F M A M J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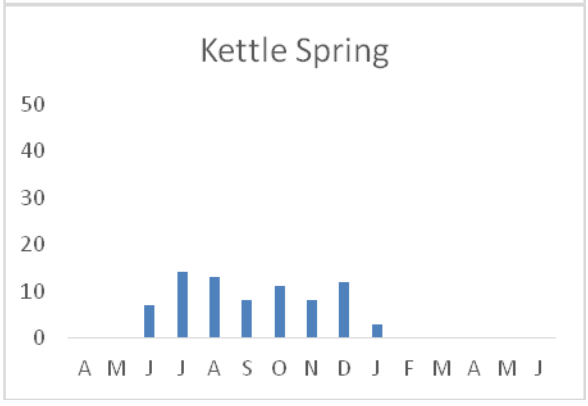
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30
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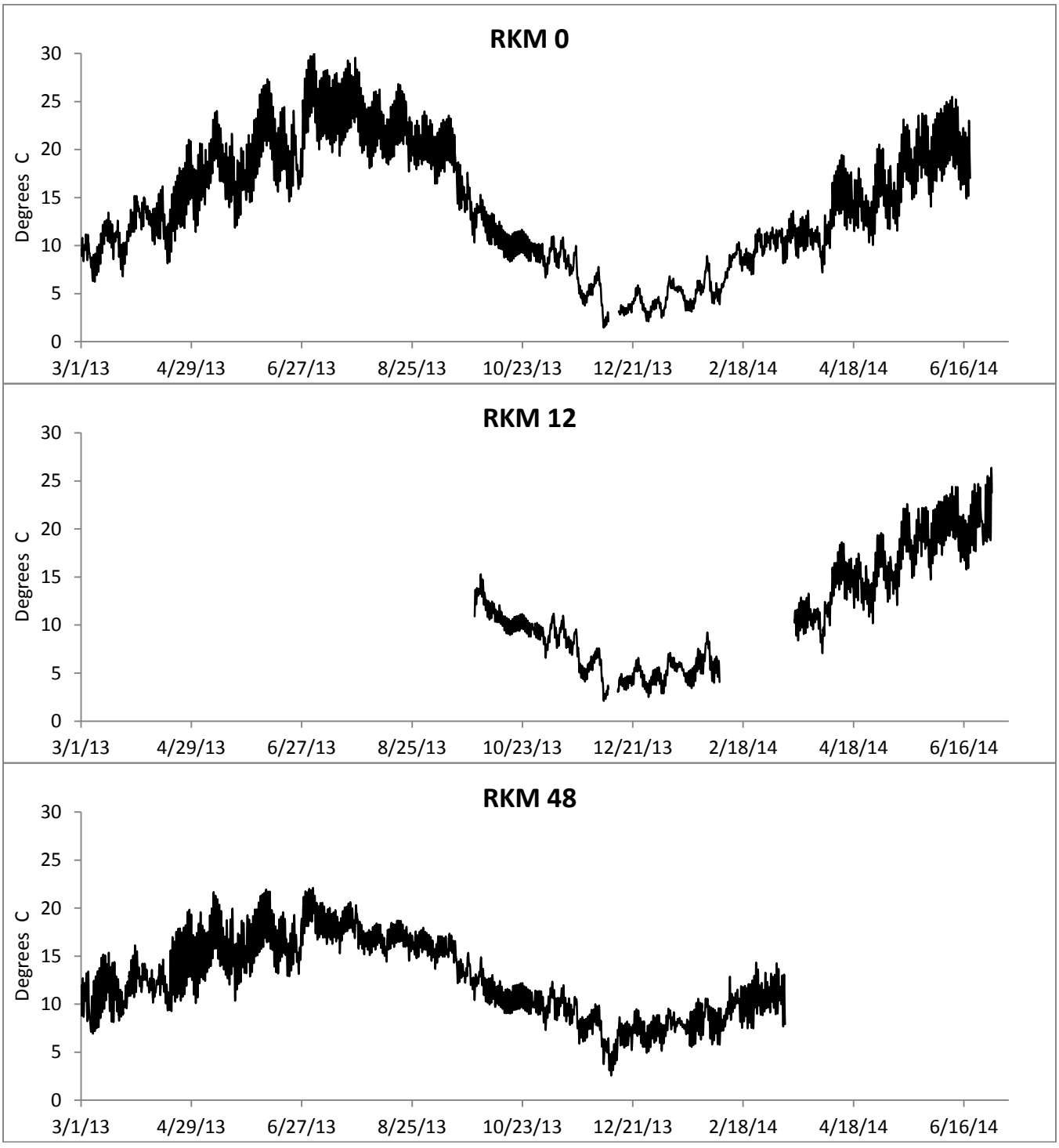
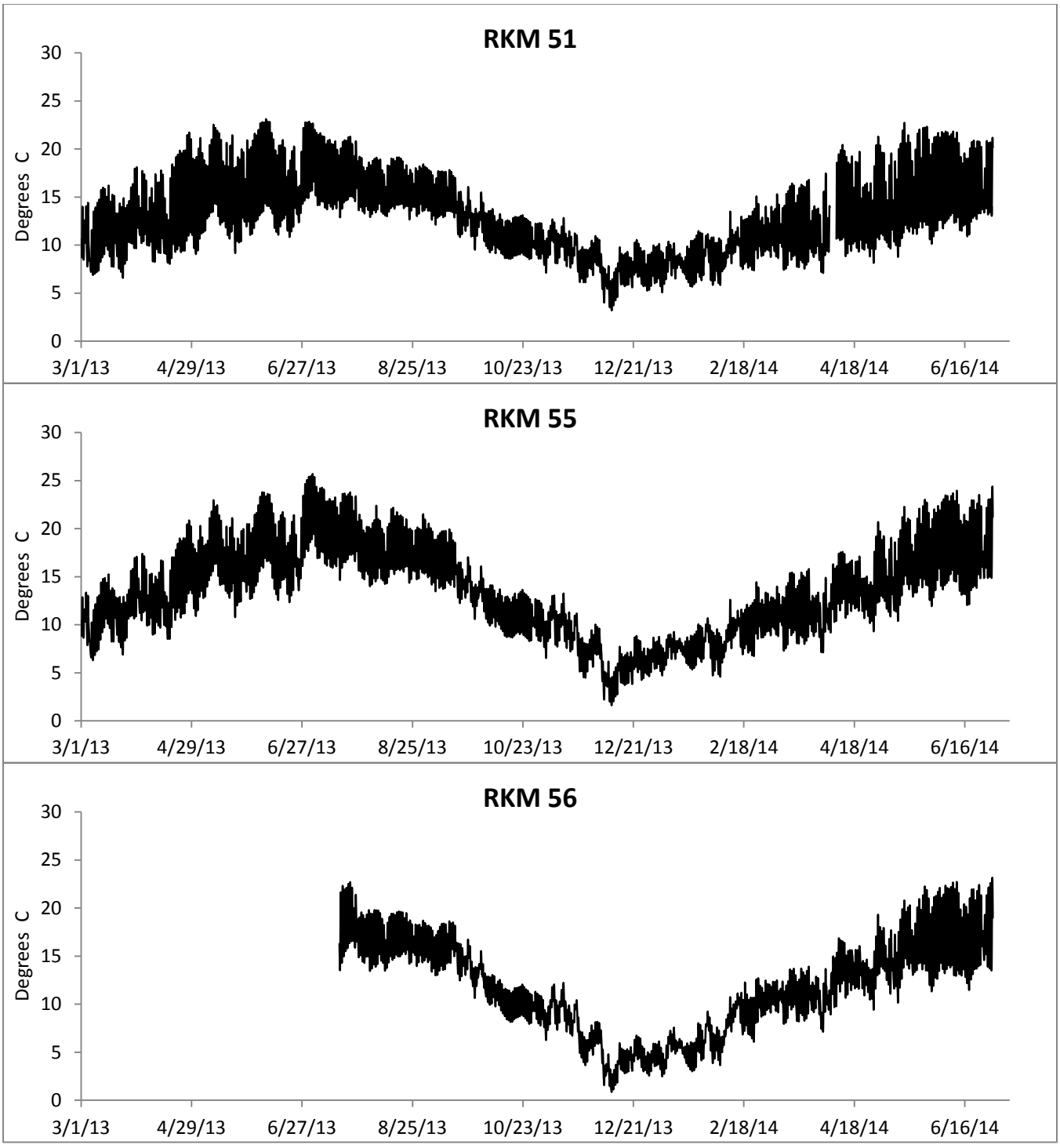
10
0
A M J J A S O N D J F M A M J

Appendix C. Temperature plots.

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15
10
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4/29/13
6/27/13
8/25/13
10/23/13
12/21/13
2/18/14
4/18/14
6/16/14
RKM 55
Degrees C
30
25
20
15
10
5
0
3/1/13
4/29/13
6/27/13
8/25/13
10/23/13
12/21/13
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4/18/14
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RKM 56
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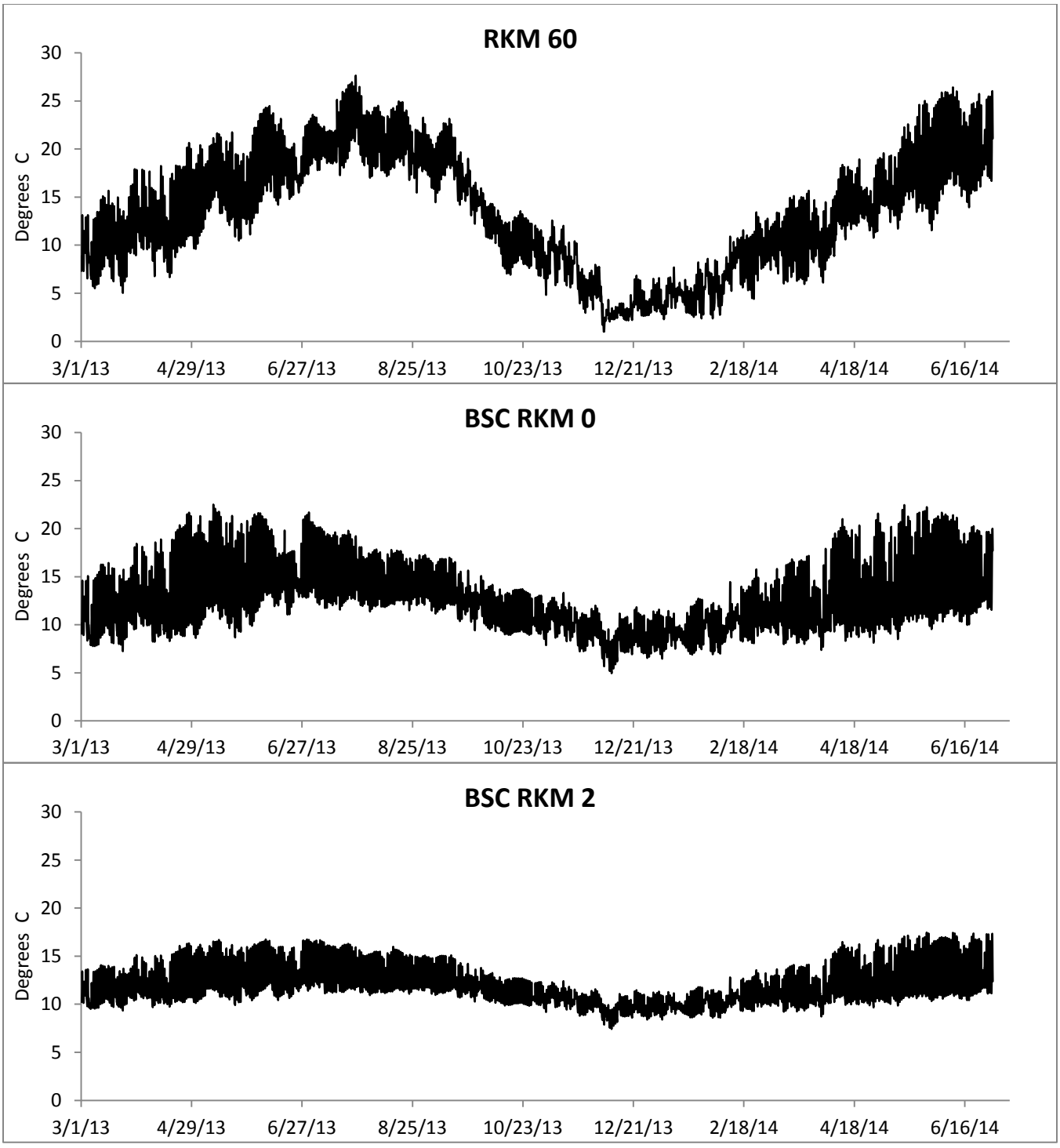
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12/21/13
2/18/14
4/18/14
6/16/14
BSC RKM 0
Degrees C
30
25
20
15
10
5
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3/1/13
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6/16/14
BSC RKM 2
Degrees C
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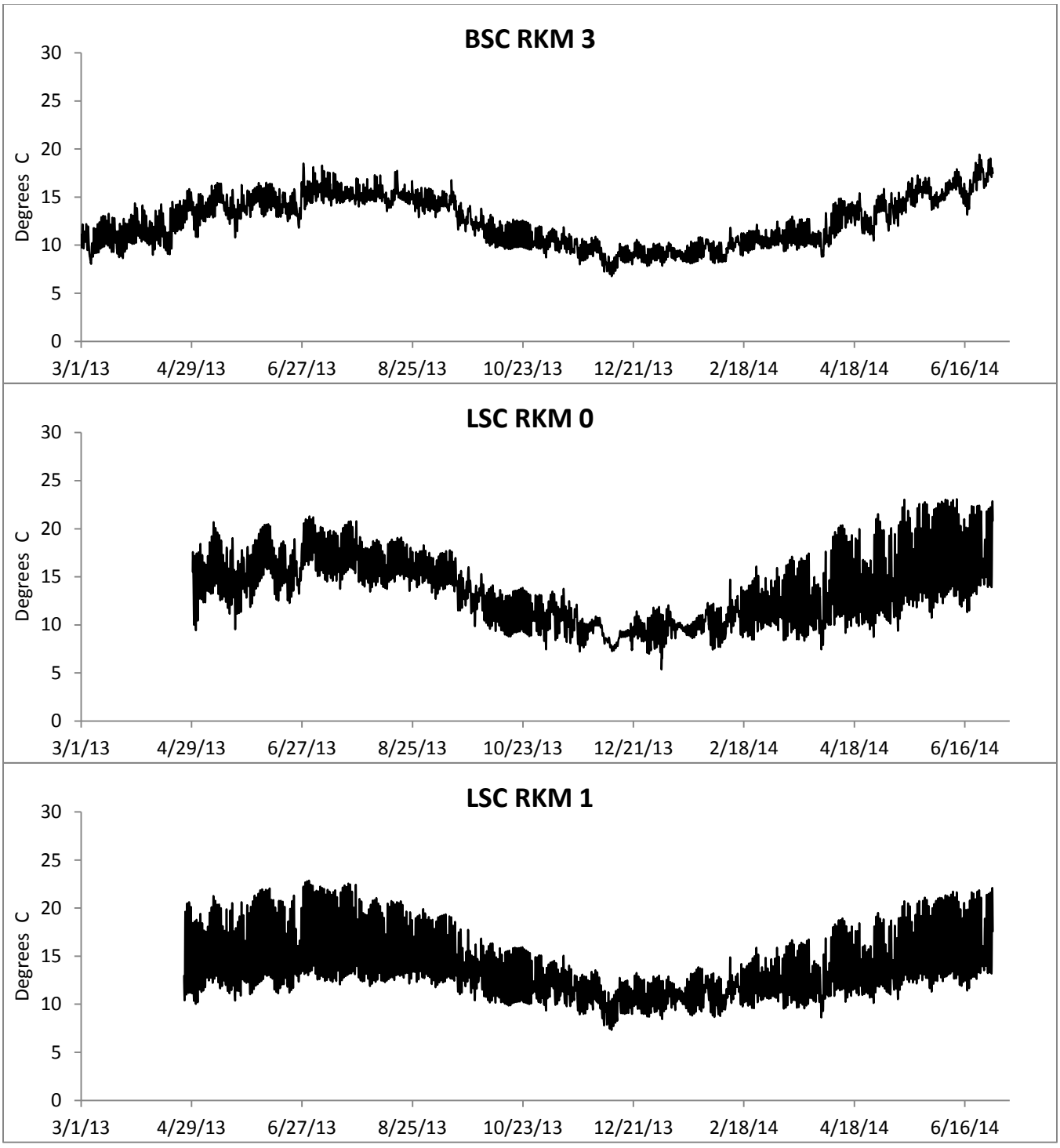
6/16/14


BSC RKM 3
Degrees C
30
25
20
15
10
5
0
3/1/13
4/29/13
6/27/13
8/25/13
10/23/13
12/21/13
2/18/14
4/18/14
6/16/14
LSC RKM 0
Degrees C
30
25
20
15
10
5
0
3/1/13
4/29/13
6/27/13
8/25/13
10/23/13
12/21/13
2/18/14
4/18/14
6/16/14
LSC RKM 1
Degrees C
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20
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10
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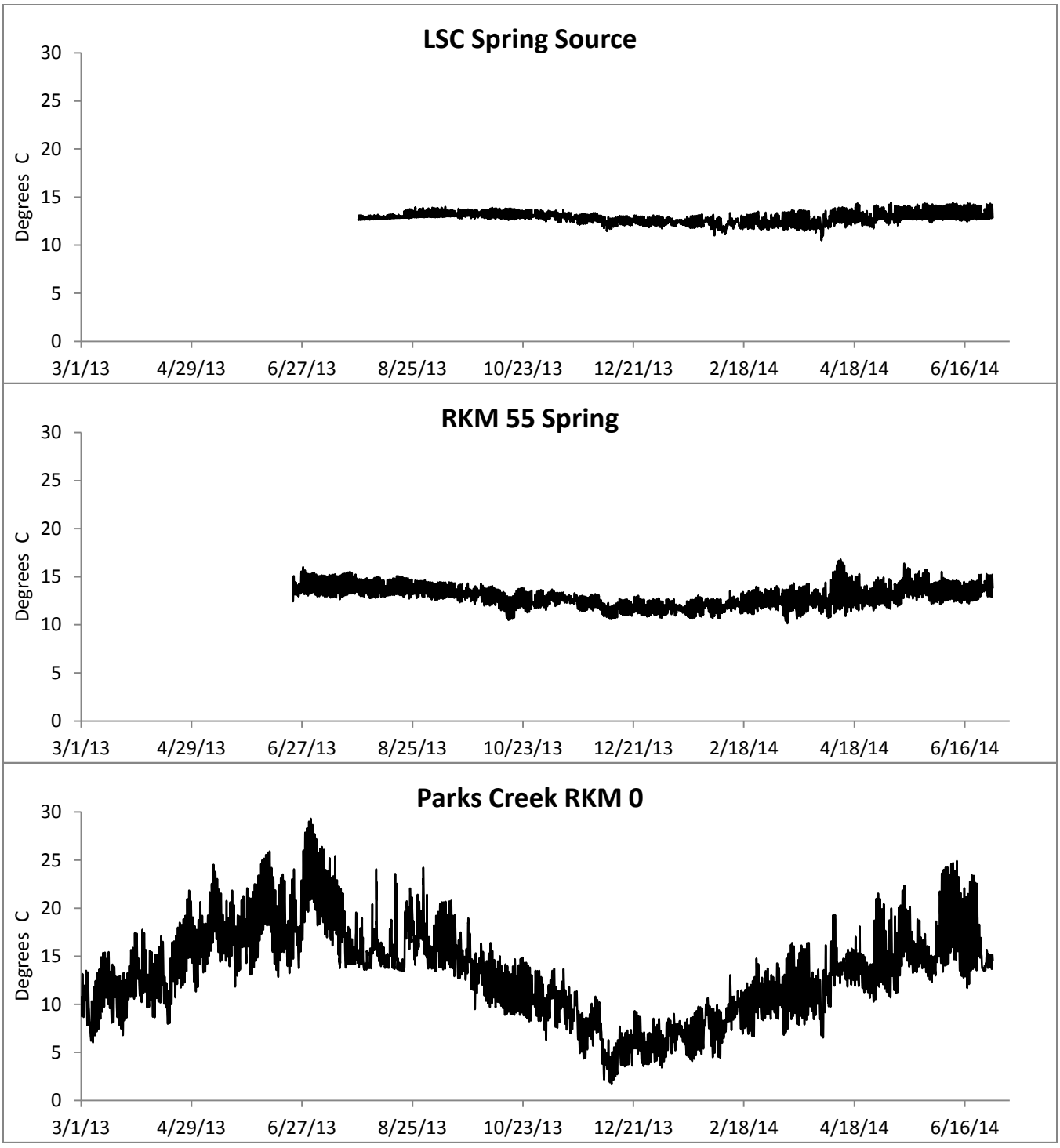
6/16/14


LSC Spring Source
Degrees C
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25
20
15
10
5
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3/1/13
4/29/13
6/27/13
8/25/13
10/23/13
12/21/13
2/18/14
4/18/14
6/16/14
RKM 55 Spring
Degrees C
30
25
20
15
10
5
0
3/1/13
4/29/13
6/27/13
8/25/13
10/23/13
12/21/13
2/18/14
4/18/14
6/16/14
Parks Creek RKM 0
Degrees C
30
25
20
15
10
5
0
3/1/13
4/29/13
6/27/13
8/25/13
10/23/13
12/21/13
2/18/14
4/18/14
6/16/14

Appendix D. Photos.

Photo 1. Looking upstream at the Shasta River/Big Springs Creek confluence (RKM 53). 8/6/2013.

Photo 3. Cut bank coho fry rearing habitat in the Shasta River downstream of Big Springs Creek (RKM 53). 3/18/13.

Photo 3. Shasta River flowing from right to left across middle of frame. Parks Creek flows in from bottom right corner. RKM 55 Spring can be seen entering the Shasta River near the left edge of the frame. 8/6/13.

Photo 4. One of several small springs at the RKM 55 Spring complex. 5/3/13.

Photo 5. RKM 55 Spring. 5/3/13.

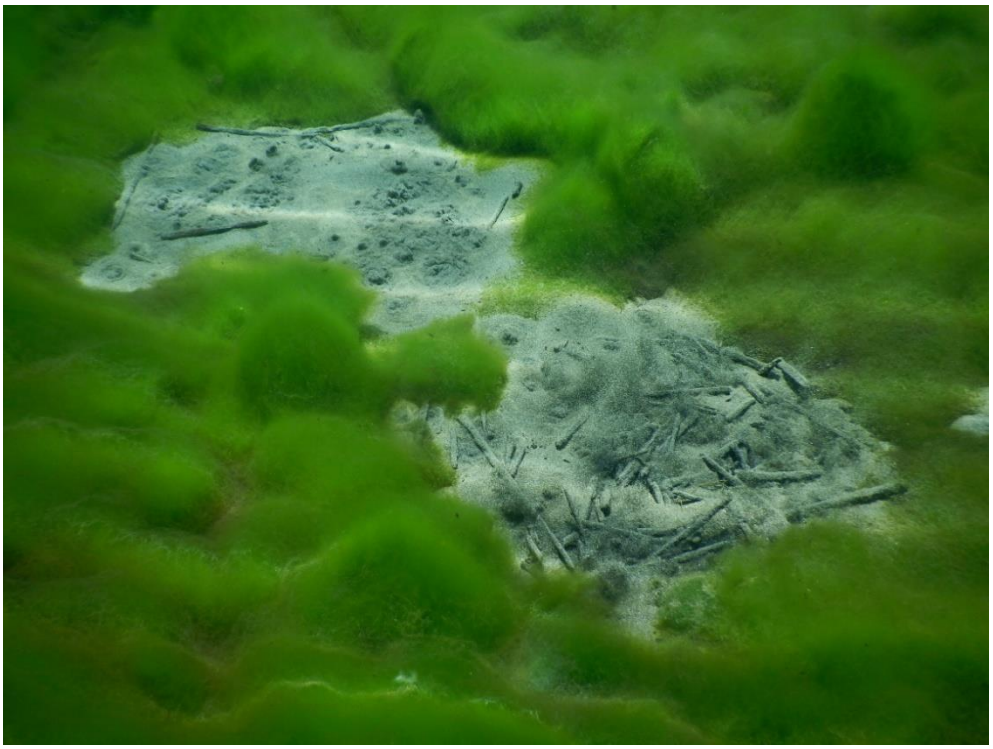

Photo 6. Springs emerging in the north arm of the Little Springs impoundment. 7/16/13.

Photo 7. Looking upstream from “beaver dam” culvert on Little Springs Creek. 5/15/13.

Photo 8. Looking downstream from “beaver dam” culvert on Little Springs Creek. 7/30/13.

Photo 9. Little Springs Creek downstream of culvert at Louie Rd. 7/3/13.

Photo 10. Little Springs Creek at Confluence with Big Springs Creek. 7/12/13.

Photo 11. RKM 0 B. 6/23/13.

Photo 12. RKM 0 C. 4/4/14.

Photo 13. RKM 12. 5/8/13.

Photo 14. RKM 25. 5/8/13.

Photo 15. RKM 46. 5/10/13.

Photo 16. RKM 51. 10/21/13.

Photo 17. RKM 56. 5/10/13.

Photo 18. RKM 60. 5/13/13.

Photo 19. BSC RKM 0. 10/23/13.

Photo 20. BSC RKM 3. 5/13/13.

Photo 21. LSC RKM 0. 7/12/13.

Photo 22. LSC RKM 1. 5/21/13.

Photo 23. Parks RKM 0. 10/28/13.

Photo 24. Parks RKM 7. 7/7/13.

Photo 25. Kettle Spring. 6/3/13.

Photo 26. Coho fry rearing in the Shasta River downstream of Big Springs Creek (RKM 53). 3/18/13.

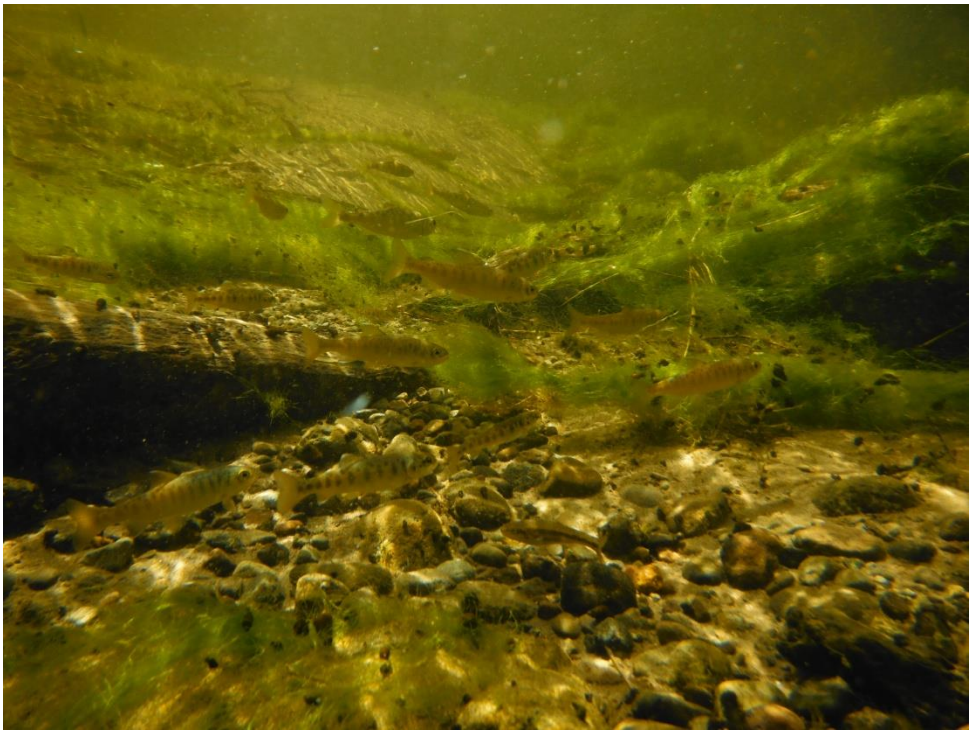

Photo 27. Juvenile coho and steelhead rearing at RKM 55 Spring. 5/16/13.

Photo 28. Juvenile coho and steelhead rearing at RKM 55 Spring. 5/28/13.

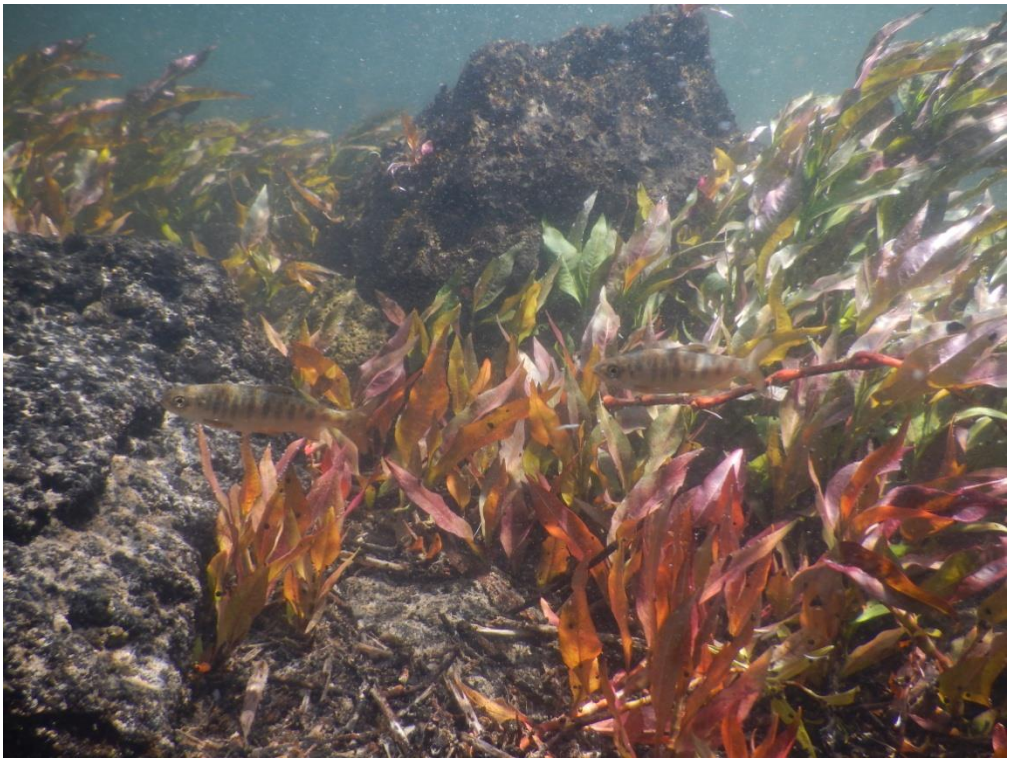

Photo 29. Coho rearing at BSC RKM 2. 7/16/13.

Photo 30. Juvenile coho in Little Springs Creek just upstream of Big Springs Creek. 5/9/13.

Photo 31. Juvenile coho and steelhead in Little Springs Creek just upstream of Louie Rd. 6/23/13.

Photo 32. Rainbow trout in Big Springs Creek.7/13/13.

Photo 33. BSC RKM 2 (the water wheel structure). 5/6/13.

Photo 34. BSC RKM 2. 6/28/13

Photo 35. BSC RKM 2. 7/30/13.

Photo 36. BSC RKM 2. 1/14/14.

Photo 37. BSC RKM 2. 3/20/14.

Photo 38. BSC RKM 2. 4/15/14.