State of California

The Natural Resources Agency

DEPARTMENT OF FISH AND WILDLIFE

SUGAR CREEK BEAVER POND JUVENILE COHO SALMON MONITORING STUDY, SISKIYOU COUNTY, CALIFORNIA

2011- 2012

By
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Note to Readers

Sugar Creek Beaver Pond Juvenile Coho Salmon Monitoring Study, Siskiyou County, 2011-2012 presents important information for understanding stream alterations caused by beaver dams and ponds in relation to coho salmon (*Oncorhynchus kisutch*) recovery in the Scott River watershed and the Southern Oregon Northern California Coho (SONCC) evolutionary significant unit (ESU). The North American beaver (*Castor canadensis*) was widely abundant in Scott Valley, in fact Hudson's Bay Company trappers referred to it as Beaver Valley. Anthropogenic impacts, including water diversions, beaver trapping, and gravel dredging highly impacted the river's ecological systems and natural flow during the 19th and 20th centuries, which contributed to the decline of coho salmon. After coho salmon were state listed in 2005, the Siskiyou Resource Conservation District along with federal and state partners implemented restoration projects, including screening water diversions to help protect juvenile fish and increase returning adults. Despite restoration efforts, the numbers of returning adults continued to decline. One of the main reasons for the recent decline was lack of surface flow, especially during irrigation season. Coho salmon usually exhibits a three year cycle that requires at least one year juvenile rearing in fresh water. Beaver dams hold back water that can provide habitat for summer and winter rearing when other parts of the stream may be dry.

This report describes data collected during the 2011-2012 juvenile coho rearing season. In particular, the author describes:

- Date tagged and fork length relationships before and after the pond freezing
- Underwater observations in habitat affected by the presence of the dam
- Timing of juveniles out-migrating from Sugar Creek into Scott River and the relationship with high flow events.

As with all of its products, Fisheries Branch is interested in comments on the utility of this document, particularly regarding its application to future juvenile coho salmon monitoring in and around habitat affected by beaver activity or artificial beaver dam analogs and how these studies can contribute to management decisions. Therefore, we encourage you to provide us with your comments. Comments should be directed to Mary Olswang, Fisheries Branch, 830 S Street, Sacramento, CA 95811, mary.olswang@wildlife.ca.gov.

November 16, 2015

Stafford Lehr
Chief, Fisheries Branch

Date

Abstract

Slow moving, off-channel ponds and still-water habitats preferred by rearing juvenile coho salmon (*Oncorhynchus kisutch*) are frequently observed as limiting factors to coho salmon recovery, since juveniles usually require one year of fresh water rearing before migrating to the ocean. Thus, interest in using beaver or beaver-type structures that create back water effects that increase or enhance coho salmon habitat has increased in the past few years. There is a need for further studies to increase our understanding of how beaver activity and associated habitat alterations can aid in the recovery of endangered coho salmon in California. Beaver were once so abundant in Scott Valley, Siskiyou County, CA that Hudson's Bay Company trappers referred to it as "Beaver Valley". In 2011, the California Department of Fish and Wildlife (CDFW) had the opportunity to study date/size correlation and migration timing of juvenile coho salmon rearing above a beaver dam in a privately owned, low gradient reach of Sugar Creek, tributary to the Scott River, tributary to the Klamath River, Siskiyou County, CA. Juvenile coho salmon rearing in the pond and back-watered stream at the head of the pond, were captured in minnow traps, tagged with passive integrated transponders (PIT) and released from 8 August 2011 to 6 May 2012. A single PIT antenna array situated near the mouth of Sugar Creek detected 28% of the tagged coho salmon migrating out of Sugar Creek from 1 January to 20 June 2012. There were no detections prior to or after this time. Data collected indicated an increase in fish migration during high flow events recorded between January and April 2012. The pond was frozen from November 2011 to February 2012 which suspended sampling and allowed data analysis to be divided into two distinct sampling periods. Analysis of the *first period*, 8 August to 30 November 2011, showed a significant ($t = 18.18$, $df = 288$, $p < 0.001$) positive linear correlation between date captured/tagged, and fork length, with 53.4% of fork length variation predicted by date tagged. The pond and the back watered stream created by the beaver dam on Sugar Creek provided summer and winter habitat for juvenile coho salmon. Higher flows may have been necessary for downstream passage. Dam breaching on 9 March 2012 drained much of the pond, but data collected showed coho salmon continued rearing in watered areas above the dam.

INTRODUCTION

When beaver (*Castor canadensis*) were abundant in North America prior to the turn of the nineteenth century, beaver activities such as felling trees and building dams that retained water had significant habitat-changing effects on streams and riparian forests (Pollock et al. 1994). The habitat changes caused by beaver activities have been shown to change the stream environment from fluvial to lacustrine (Butler and Mallanson 2005). Impoundments trap sediments which can benefit downstream spawning gravels by reducing siltation and scouring (Pollock et al. 2003). In Alaska, beaver ponds have been found to support large densities of rearing coho salmon (*Oncorhynchus kisutch*) and sockeye salmon (*O. nerka)* compared to river habitats (Murphy et al. 1989). Studies which explored the permeability of beaver dams to fish passage suggested passage may be possible, but limited during low flows (Pollock et al. 2003). In beaver ponds observed in Glacier National Park, sediment exposed after a dam breach quickly formed grasses and shrub-covered beaver meadows (Butler and Mallanson 2005).

In the summer of 2010, the California Department of Fish and Wildlife (CDFW) became aware of a large beaver dam, pond, and lodge located in a privately owned, low gradient reach of Sugar Creek, tributary to Scott River, Siskiyou County, CA. Given evidence presented by Murphey et al. that coho salmon rearing densities in Glacier National Park increased in beaver ponds, CDFW sought to study the effects of this beaver complex on coho salmon rearing in Sugar Creek. This paper describes the data collected during the 2011-2012 juvenile coho salmon rearing season. Specifically, in order to assess use of pond habitat by rearing coho salmon, this research paper describes: a) when date can help predict fork length of juvenile coho salmon collected upstream of the beaver dam and, b) the observed relationship between out-migration timing and increased stream flow.

Study Area

Most of the Scott River tributaries, including Sugar Creek, originate on the western side of Scott Valley and rely on snow melt as their primary water source. Sugar Creek enters the Scott River at river kilometer (RKM) 86.9 in an area known as *the tailings*, due to the piles of river rock left behind from gold dredging activities of the past centuries. The Scott River flows north and joins the Klamath River at RKM 233.5 (Figure 1).

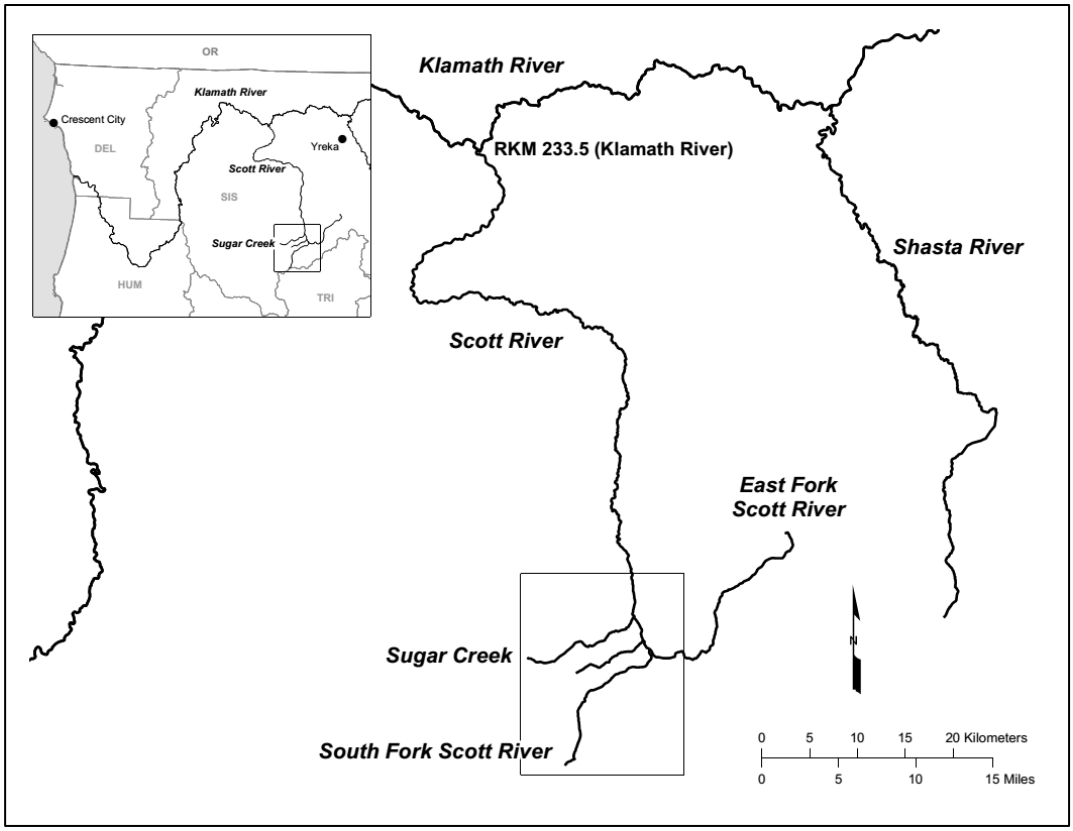

Figure 1: Location of Sugar Creek, tributary to the Scott River, Siskiyou County, CA

Adult coho salmon travel about 234 km to reach natal spawning grounds in the Scott River watershed. Scott River coho salmon belong to the federally designated Southern Oregon Northern California Coast Evolutionarily Significant Unit (SONCC ESU). The SONCC coho salmon were listed as threatened under the Federal Endangered Species Act in 1997, and formally listed as threatened under the California Endangered Species Act in 2005. Loss of backwater habitat created by beaver activities has been identified as a reason for the decline in coho salmon populations (CDFG 2004). From July through October, the typical dry season in northern California, Sugar Creek delivered quality water and provided refuge for salmon and steelhead from the warmer waters of Scott River. Tagging data collected from rescued salmonids relocated to the Scott River at the mouth of Sugar Creek from 2009 to 2010 showed tagged fish entering Sugar Creek during the dry season (Olswang 2011, unpublished raw data).

The beaver dam on Sugar Creek was located 760 m above the confluence to Scott River (Figure 2). According to adjacent property owners the dam was built about five years prior to this study. During the period 2010 to 2012, dam dimensions were approximately 91 m wide by 1.5 m height (Figure 3).

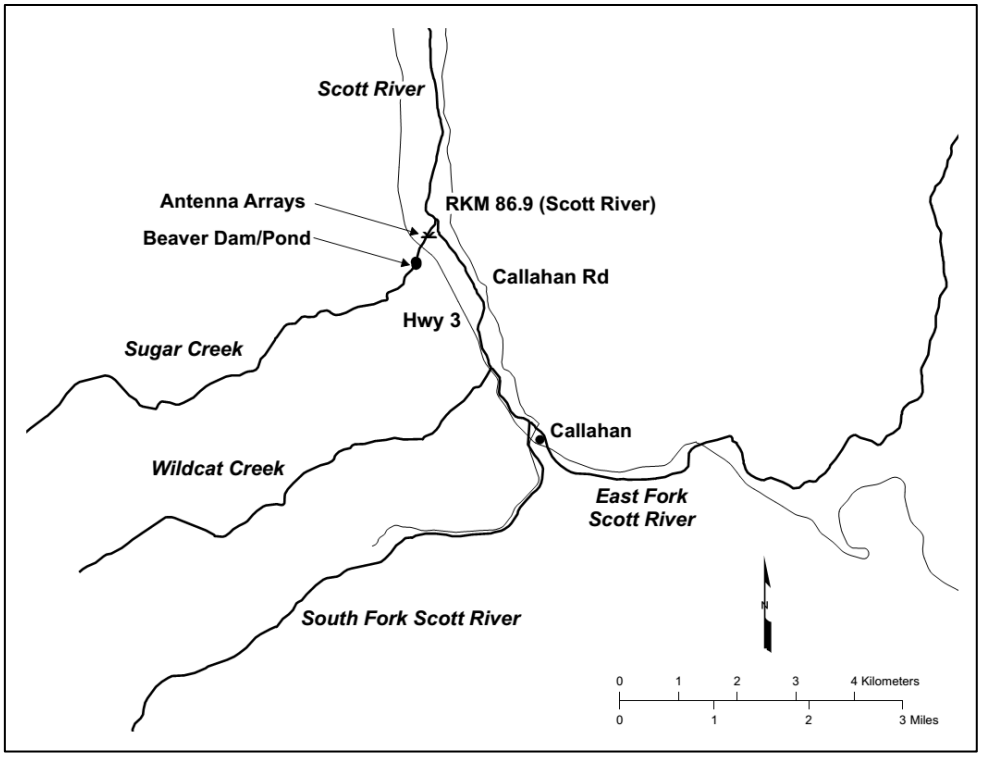

Figure 2: Location of study area, Sugar Creek, Siskiyou County, CA, 2011-2012.

Figure 3: This photo, taken in June 2010 of the Sugar Creek beaver dam is looking south with pasture in the rear. Photograph by M. Olswang.

Figure 4: Looking upstream from the dam at the pond. Beaver lodge is on the right. A large logjam at the head of the pond created additional back-water effects. Photograph by M. Olswang, June 2010.

Looking upstream from the dam, boundaries of the pond are described as a logjam situated at the head of the pond, creating some additional back-water effects, pasture fencing (which beavers built upon) on the left, and stream bank and lodge on the right (Figure 4). The pond's area measured about 2,640 m^2. Over the years, granitic sediments and organic matter accumulated behind the dam. This established a sediment wedge that appeared to have raised the creek elevation in the pond and solidified the structure. The structure and accumulated sediment also affected stream hydraulics by pushing the main flow toward river right and the adjacent pasture, much to the concern of the landowners. Although beavers built and maintained a dam along the pasture fence, the stream almost always flooded onto the pasture and juvenile coho salmon were observed on the pasture side of the fence.

METHODS

Underwater Observations

In order to detect juvenile coho salmon presence and describe rearing conditions, snorkel surveys were conducted on four occasions, from 15 June to 23 August 2011. No snorkel surveys were conducted in 2012. The snorkel survey method involved noting observations of coho salmon in the creek immediately below the downstream edge of the dam, throughout the entire pond behind the dam and along the upstream edge of the logjam at the head of the pond.

Trapping and Tagging

Fish were captured for tagging using unbaited minnow traps with one inch openings set for 24 hours. Prior field studies showed that baited traps attracted unwanted salamanders and snakes into the trap (Olswang, unpublished data). Two traps were placed along banks upstream of the logjam, two in the middle of the pond, and two underneath the logjam. Once tagged, fish were returned to the same location where they were trapped. Trapping and tagging occurred in the back-watered section of the creek at the head of the pond from 8 August to 10 October 2011. Trapping and tagging in the pond occurred over two periods due to pond freezing: 11 October to 30 November 2011, and 10 February to 6 May 2012.

On 9 March 2012 the dam was breached to divert flows away from the pasture. Additional traps were placed below the breach on 12 March, 19 March, 11 April, 25 April, 30 April, 4 May, and 6 May 2012 to capture tagged fish that may have been flushed out due to breaching. These fish were placed back into the pond in order to provide the opportunity to continue rearing in the pond. Tagged fish recaptured a second time were to be released in the trapping location.

Juvenile coho salmon were tagged using PIT tags to describe the timing of out-migrating fish. Following the "rule of thumb" in Biomark™ Fish Tagging Methods, coho salmon greater than 65 mm fork length (FL) were implanted with 12.5 mm FDX-134.2 kHz Allflex™ PIT tags and 9.0 mm tags were used for fish between 56 and 65 mm. Fish were anaesthetized with two 2.4 gram Alka-Seltzer™ Gold tablets dissolved in approximately 1 liter of stream water. All fish were scanned with a hand-held pit tag reader to determine whether an individual had been previously tagged. PIT tags and 14 gage syringe needles were sterilized with 90% ethanol. Each PIT tag was implanted by creating a small incision with the needle tip about 10 mm anterior to the base of the left pelvic fin (CDFW 2015). The PIT tag was then inserted into the body cavity through the incision by hand. The fork length was measured to the nearest millimeter for each fish and scales taken from under the adipose fin on the fish's left side. Fish were held for 20-30 minutes to recover in an ice chest filled with aerated water before being released at capture site or in the pond. All PIT tag data was entered into a Microsoft® Access database. Data was also sent to the Klamath River Basin PIT Tagging Database, managed by the U.S. Geological Survey in Klamath Falls, Oregon.

Monitoring

Once deployed, PIT tagged fish were detected by a single PIT tag array consisting of four antennas (Figure 5) spanning the channel downstream of the beaver dam, about 93 m above the mouth of Sugar Creek (see Figure 2, page 6). The logging station was attached to a pole at a high point along the bank. Two 9-volt batteries powered the logging station where fish detections were recorded on a flash drive. When possible, solar energy charged the batteries, but during cloudy winter months used batteries were replaced with charged batteries every three days.

Scott River average daily flow in cubic feet per second (cfs) for the study period was accessed through the California Data Exchange Center reporting data from USGS Scott River gage in Fort Jones, about 52 km downstream from the mouth of Sugar Creek (USGS 2011 and 2012). In addition, Sugar Creek average daily discharge was measured and recorded by the California Department of Water Resources (CDWR) in partnership Siskiyou Resource Conservation District's (Siskiyou RCD) stream gage located 1.84 km upstream from the beaver pond at Sugar Creek RKM 2.6.

CDFW uses rotary screw traps (RSTs) located at Scott RKM 7.2 to collect and identify juvenile fishes migrating out of the Scott River and into the Klamath River. This location is about 80 km downstream from the mouth of Sugar Creek. For the 2012 season, traps were in operation from 12 February to 30 July 2012 (Daniels et al. 2012). Scanning of pit tags at this location occurred infrequently due to the large numbers of down migrating fish captured in the trap. Data collected regarding tagged coho from Sugar Creek was to be used to identify the timing of juveniles or smolts migrating out of Scott River.

The Siskiyou RCD, along with agency partners and volunteers, conduct annual coho spawner surveys. In the 2010-2011 season, surveys began on 17 November 2010 and ended on 12 January 2011. Sugar Creek was surveyed on seven occasions from 22 November to 30 December 2010. The Sugar Creek survey was divided into three reaches: lower, middle, and upper. The beaver pond was located in the middle of the middle reach.

Figure 5: A single PIT array consisting of four antennas spanned the channel approximately 93 m above the mouth of Sugar Creek. The unique PIT tag codes identified individual fish passively as they move near the antenna array. Photograph by M. Olswang, Sept. 2011.

Temperature

CDFW deployed and maintained HOBO® temperature loggers at the upstream end of the pond under the logjam and at the antenna array located downstream of the pond, beginning November 2011. The Siskiyou RCD monitored temperature upstream of the pond as part of a separate monitoring project. Their equipment was not operational for the entire study period.

Breaching the Dam

With increasing early spring flows, the intensity of stream-flow pushing toward the right bank due to the dam increased, flooding the pasture and private properties downstream. Also, as the re-directed stream flowed over the right bank and across the pasture, the potential for coho salmon stranding increased. On 9 March 2012, the pasture landowner and CDFW notched the center of the dam to ease the flows away from the right bank.

RESULTS

Underwater Observations

Snorkel surveys were conducted intermittently from 15 June to 23 August 2011. Pond substrate consisted of sandy, granitic sediments and decomposing leaves. Wood in the pond consisted of mostly branches, sticks and snags. With the exception of the logjam, few pieces of large woody debris or root wads were observed. The underwater observations are delineated in table 1. Steelhead trout *Oncorhynchus mykiss* were observed, but not recorded. The first survey on 15 June 2011 revealed no coho salmon in the pond, but about 100 age-0 coho salmon were observed in the creek immediately downstream of the downstream edge of the dam, where water was seeping through interstitial spaces. On 24 June 2011, the number of fish below the dam increased to about 200, but no fish were observed in the pond. On 12 July 2011, the first coho salmon were observed upstream of the dam, one under the logjam at the upstream end of the pond, and another 75 to 100 individuals along the right bank upstream of the logjam. However, at that time, there were no coho salmon observed in the main body of the pond and the number rearing on the downstream side of the dam was reduced to about ten. All fish appeared too small to PIT tag (approximately 40 to 50 mm) and were assumed to be age-0.

During the final snorkel survey on 23 August 2011, there were no fish observed rearing on the downstream side of the dam. These fish may have moved downstream, since coho salmon were observed rearing from downstream of the dam to the mouth of Sugar Creek. The other possibility is that these fish were able to move upstream, through or around the dam, or through the pasture. On 23 August 2011 about 1,200 to 1,500 coho salmon were observed in the pond. Of these, a sizable school was observed foraging in moving water beneath the logjam at the head of the pond. Most fish were observed near the lodge entrances, and at the head of the pond near the logjam, moving between the moving stream and back-water habitats. Fish were observed feeding in the stream section just at the head of the pond. Sticks, branches and snags provided cover, especially in the slower moving water where coho salmon were observed.

Table 1: Approximate counts of coho salmon observed underwater in and around Sugar Creek beaver pond.

Date	**Downstream side of dam**	**Pond**
6/15/11	100	0
6/24/11	200	0
7/12/11	10	75-100
8/23/11	0	1200-1500

Trapping and Tagging

A total of 371 juvenile coho salmon were captured upstream of the beaver dam in lower Sugar Creek and PIT tagged from 8 August 2011 to 6 May 2012. The pond was frozen December 2011 to February 2012, which suspended field work until the ice thawed. This resulted in a division of data collection and analysis into two sampling periods. The first sampling period in 2011 resulted in 46 fish tagged in August, 32 in September, 108 in October and 107 in November. The second sampling period in 2012 resulted in 15 fish tagged in February, 43 in March, 17 in April, and three in May. Table 2 shows average fork lengths for both sampling periods. A complete list of tag dates and fork lengths for each fish is included in Appendix I.

Table 2: Average fork lengths of tagged coho by month, August 2011 to May 2012, Sugar Creek, CA. The pond was frozen December 2011 to February 2012 which divided sampling into two periods.

	1st Period – 2011					2nd Period – 2012			
	Aug	Sept	Oct	Nov		Feb	Mar	Apr	May
Average FL (mm)	65	75	87	91		89	92	90	101

Monitoring

Tagged coho salmon from above the beaver dam were first detected by the antenna array located near the mouth of Sugar Creek on 1 January 2012, although tagging began on 8 August 2011. From 1 January 2012 to 20 June 2012, 104 (28%) tagged coho salmon were recorded out-migrating past the antenna array (15 in January, seven in February, 44 in March, 25 in April, 11 in May, and two in June). The last detection was recorded on 20 June 2012 and the final day of field operation was 5 September 2012. Of these recorded out-migrants, 75 (72%) fish were tagged prior to the winter freeze, but it is unknown if winter rearing occurred in the pond below the ice, or the creek upstream of the pond. Figure 6 shows the relationship between out-migration and stream flow in Scott River and Sugar Creek. No detected movement was recorded 15 February to 14 March 2012 when recorded mean discharge was stable and equipment was 86% operational with limited range due to tuning problems. It is likely many more fish passed the array during high flow events, when deeper and wider channel conditions gave room for fish to pass undetected. Available data showed that dam breaching on 9 March 2012 did not directly increase the number of out-migrants.

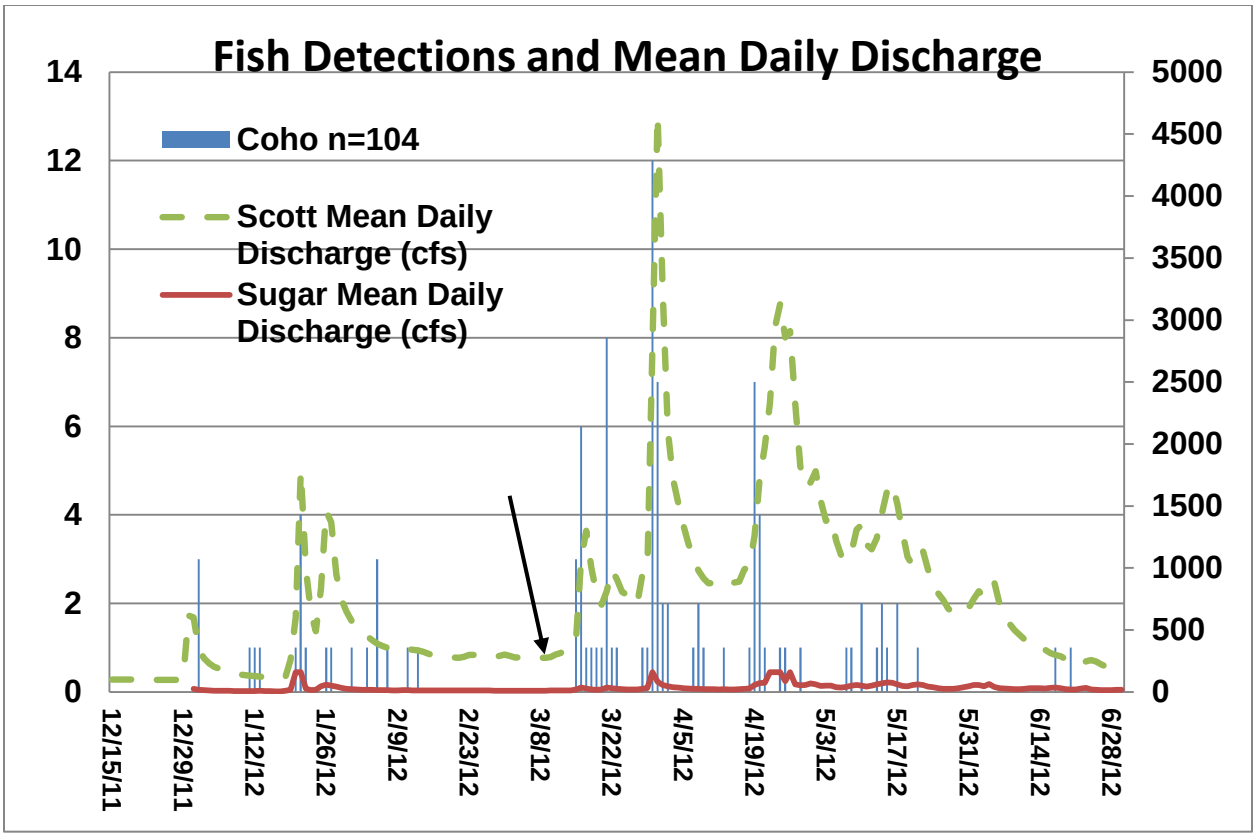

Figure 6: Numbers of tagged juvenile coho salmon detected passing the antenna array located near Sugar Creek mouth. Lines indicate Scott River and Sugar Creek mean daily discharge from December 2011 to June, 2012. Arrow denotes dam breaching on 9 March 2012. Source: Scott Valley USGS gage at Fort Jones and Sugar Creek CDWR/Siskiyou RCD gage at Sugar RKM 2.6, 1.84 km upstream from the beaver pond.

CDFW opportunistically scanned coho salmon caught in out-migrant traps at Scott RKM 7.2 to help detect PIT tagged fish from the beaver pond. One tagged beaver pond fish was captured and measured on 6 June 2012, which is fish #4 in table 2. Data showed fish #4, which measured 78 mm FL when tagged on 3 February 2012, reared in the study site until detected out-migrating from Sugar Creek on 24 April 2012. It then spent about six weeks in the Scott River system before being captured in the rotary screw trap on 6 June 2012 and measured 111 mm FL (33 mm growth in four months). This single observation may indicate that suitable habitat is available for out-migrants to stop for resting and foraging. To further understand out-migration, future studies should include diligent methods for monitoring tagged fish moving in the mainstem Scott River and the out-migrant traps.

There were five physical recaptures in the beaver pond (Table 3). Fish #5 and #6 were re-captured in traps placed below the breach in the dam and released back into the pond. The remainder of recaptured fish were captured in the pond and released in the pond. Fish #6 showed more accelerated growth during spring months from 12 March to 30 April 2012, while Fish #3 showed the same amount of growth (6 mm) over a longer period of time, through the winter months from 30 November 2011 to 12 March 2012.

Table 3: Date tagged, fork length, Sugar Creek array detections, physical recaptures (BP = Beaver Pond or RST = Rotary Screw Trap) and fork length of recaptures from 13 October 2011 to 6 June 2012.

#	Tag Date	FL (mm)	Sugar array detection	BP trap recap	RST recap	FL (mm)
1	10/13/11	87	-	11/3/11	-	90
2	11/8/11	89	-	3/12/12	-	95
3	11/30/11	88	-	3/12/12	-	94
4	2/13/12	78	4/24/12		6/6/12	111
5	3/12/12	91	-	4/11/12	-	91
6	3/12/12	74	6/20/12	4/30/12	-	82

In a separate study, Yurok Tribe biologists observed two physical re-captures (fish #7 and 8) in Waukell Creek, a tributary to Klamath River at Klamath RKM 53.0, 180.5 km downstream from Sugar Creek (Table 4). Fish #7 was tagged on 21 October 2011 and measured 89 mm FL. It escaped detection from Sugar Creek, but was detected entering Waukell Creek on 4 February 2012. Collected data of physical (captured) and array detections showed this fish reared in Waukell Creek for a little over three months before continuing its downstream migration on 10 May 2012. Fish #8 was tagged on 21 October 2011 and measured 88 mm. It also escaped detection when exiting Sugar Creek, was physically captured entering Waukell Creek on 14 February 2012, and measured 93 mm (S.Silloway, pers. comm). There was no data collected which indicated fish #8 exited Waukell Creek. In summary, the Yurok Tribe data showed that Waukell Creek provided additional rearing habitat for the Sugar Creek fish. Out-migrant coho salmon estimates for Waukell Creek in 2012 were 11,955 ± 869 and were all non-natal fish (S.Silloway, pers. comm).

Table 4: Date tagged, fork length, array detection entering Waukell Creek, array detection exiting Waukell Creek, physical recaptures in fyke net entering or exiting Waukell Creek, fork length of physical recaptures 21 October 2011 to 10 May 2012. Note: Fish escaped detection exiting Sugar Creek.

#	Tag Date	FL (mm)	Sugar array	Waukell array detection entering	Waukell array detection exiting	Waukell fyke recap	FL (mm)
7	10/21/11	89	-	2/4/12	5/10/12	5/10/12 (exit)	112
8	10/21/11	88	-	-	-	2/14/12 (enter)	93

Figure 7 illustrates a correlation analysis between fork length and date tagged in sampling periods (*first period, second period* and *all*). *First period* included analysis of data collected from 293 tagged coho salmon, August to November 2011 (pre-pond freezing). *Second period* included analysis of data collected from 78 tagged coho salmon, February to May 2012 (post-pond thaw). *All* included analysis of data collected from all 371 tagged coho salmon from both sampling periods. Correlation values can range between -1.0 to +1.0; where ± 1.0 indicates a perfect linear association between the variables (fork length and date tagged) and 0 indicates no linear association variables. The observed correlation coefficient of 0.73 in the *first period*

indicated a significant positive linear association between date tagged and fork length (t=18.18, df 288, p< 0.001) and the observed correlation coefficient of 0.1 in the *second period* indicated an insignificant positive linear association (t=0.87, df=76, p= 0.389). Figure 7 also showed smaller individuals were present late in the rearing season of 2011 which may indicate later hatching due to a longer spawning season. Coho salmon adults may have had access to the higher reaches later in the season when flows improved access through the valley portions of Scott River, into Sugar Creek and over the dam.

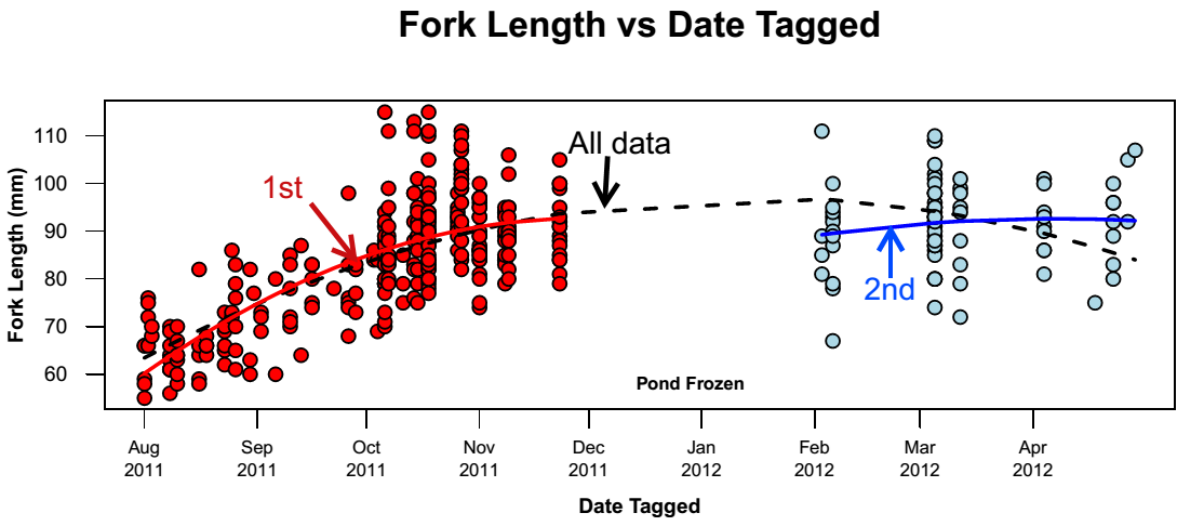

Figure 7: Date tagged vs. fork length coho salmon August 2011 to May 2012, Sugar Creek, CA
***First sampling period* (before pond frozen): sample size (n) = 293, r = 0.73, r^2 = 53.4 % (t=18.18m df=288, p<0.001)**
***Second sampling period* (after pond thaw): sample size (n) = 78, r = 0.1, r^2 = 1% (t=0.87, df=76, p = 0.389)**
***All* (both periods): sample size (n) = 371, r = 0.49 r^2 = 24.4 % (t=10.88, df=366, p <0.001)**
Note: r = correlation coefficient, r^2 = regression analysis

The r^2 value for *second period* of 1% showed that date tagged explained little of the variation in fork length, with 99% unexplained. In contrast, when data collected for the *first period* was analyzed, 53.4% of fork length variation could be predicted by date tagged and 46.6% remained unexplained. In other words, both analyses showed that date tagged could help predict the fork length of coho salmon better during the summer and autumn seasons (*first period*) than the spring season (*second period*), but there was still high percentage of unexplained fork length variation in the *first period*.

The Siskiyou RCD's 2010/2011 coho salmon annual spawning ground survey reported coho salmon redds in Sugar Creek, four (plus one incomplete) in the middle reach, one in the upper reach and three in the lower reach between 22 November and 2 December 2010 (Yokel, 2011). The middle reach contained the study site, but the report did not specify if the redds observed were above or below the dam. Additional adults could have entered the creek undetected after the surveys ended in December.

Temperature

Average daily temperature data showed lower average temperatures (1 to5 ^{o}C) in the beaver pond and upstream of the pond then near the mouth during the autumn, winter and spring months. Pond temperatures warmed by 5 to 10 ^{o}C during the summer months for peak late summer temperatures around 18 ^{o}C. Pond temperatures dropped to 15 ^{o}C in early September, about 1 ^{o}C cooler than the mouth (Figure 8). Hyporheic flows, which entered from the tailings near the mouth, may explain the cooler August temperatures and warmer winter temperatures at the array site.

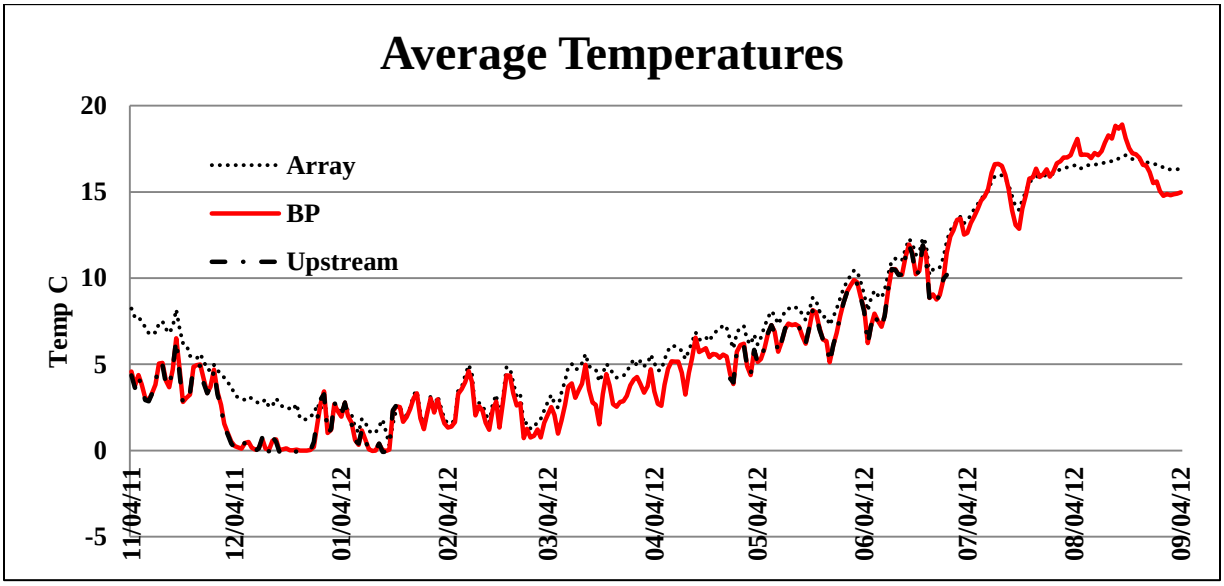

Figure 8: Average temperatures near the mouth of Sugar Creek (Array), in the pond (BP) and approx. 2.24 km upstream of the pond (Upstream). The Upstream equipment was not operating January 22 to April 25 and June 29 to September 4, 2012.

Breaching the Dam

By March 2012, beavers appeared to have abandoned the pond and the lodge, and were observed in bank dwellings just upstream near the logjam. Some activity was also observed just below the dam. A notch was cut into the center of the dam on 9 March 2012 to re-direct flows away from the pasture. The beavers did not repair the breach, and the pond elevation dropped, which exposed fertile sediments that quickly sprouted grasses and sedges. Four Google Earth© images depict physical changes in Sugar Creek due to beaver activity (Figures 9A-D). Photo (A) was taken in 2006, when riparian trees were continuous and no beaver activity was apparent. Photo (B) was taken in 2010, when dam age was estimated to be about five years old. Photo (C) shows the pond site a few months after the dam was breached on 9 March 2012. Photo (D) was taken in 2014 and shows pond habitat changing to meadow.

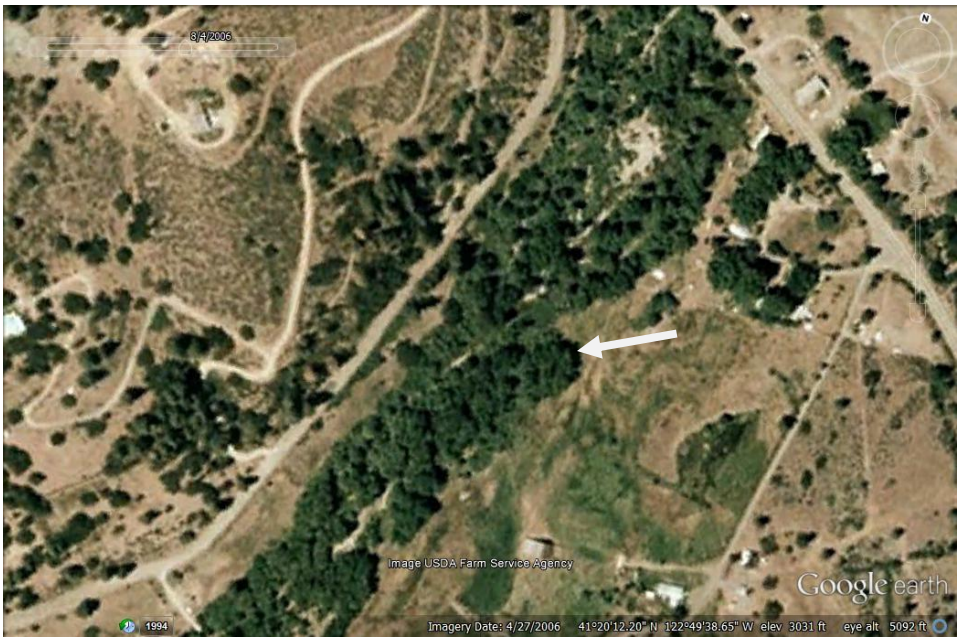

Figure 9 (A): Future Sugar Creek beaver pond Google Earth© image, 27 April 2006.

Figure 9 (B): Sugar Creek beaver pond Google Earth© image, 4 August 2010.

Figure 9 (C): Sugar Creek beaver pond Google Earth© image, 7 July 2012.

Figure 9 (D): Sugar Creek beaver pond Google Earth© image, 11 July 2015.

DISCUSSION

The Google Earth© images nicely illustrate the temporary and cyclical nature of habitat alterations caused by beavers. Beaver dam and pond complexes create dynamic systems due to the instability of dam construction (Bylak et al. 2014). Aquatic organisms are therefore only temporarily isolated from downstream sections of the stream, and regain the ability to move past the dam with sufficient flows. Observations made in this study have shown that backwater effects created by the Sugar Creek beaver dam provided year-round habitat for juvenile coho salmon, but could have also been a temporal barrier to fish passage depending on stream flow. PIT tagging proved to be a useful method in documenting coho salmon out-migration timing and associated high flow events. PIT tagging methods could be useful for collecting passage data in future studies to address this question.

Most fish were observed along the margins between the pond and the flowing stream at the head of the pond and feeding was observed in this flowing section. In spite of flushing flows, fish were able to rear in the remaining habitat after the dam was breached. Future studies should include the monitoring of dissolved oxygen and how changes influence fish movement between stream and pond habitats.

Sugar Creek redd surveys conducted from 22 November to 30 December 2010 documented coho salmon spawning both below and above the dam. Additional spawning may have occurred after the survey season ended— when higher stream-flows increased river access and passage over the dam. The smaller sized juvenile fish sampled in late 2011 may have been the progeny of these late spawners. A long spawning period could account for the unexplained variation in fork length of the juveniles in the *first period*, since hatch dates would be spread out over a longer period of time. Another potential source of variation in fork length could be that the sampling periods contained multiple year classes. Future studies should collect and age scales to determine age class.

In a prior out-migrant study focusing on Scott River tributaries, Yokel 2007 hypothesized that juveniles were finding additional rearing habitat in the mainstem Scott River after leaving Sugar Creek and other tributaries during high flow events. As the Scott River meanders throughout Scott Valley, juvenile coho salmon may be finding refuge in slow moving braided channels or back-waters caused by log jams or beaver dams. In the past, the presence of multiple beaver ponds throughout the valley would have provided this type of habitat for high numbers of migrating, re-distributing or displaced juvenile coho salmon. Known coho salmon rearing habitats should be protected to increase species survival. Future and multiple years of studies are needed to understand some of the observations made in this single season.

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Appendix I: Sugar Creek juvenile coho salmon tagged as part of this study (n=371). Table includes date fish were tagged behind the beaver dam and fork length (mm) for the period 8 August 2011 to 6 May 2012. Some values missing.

Date	FL (mm)
8/8/2011	66
8/8/2011	66
8/8/2011	55
8/8/2011	59
8/8/2011	58
8/9/2011	66
8/9/2011	76
8/9/2011	72
8/9/2011	75
8/10/2011	68
8/10/2011	70
8/15/2011	64
8/15/2011	70
8/15/2011	66
8/15/2011	69
8/15/2011	63
8/15/2011	61
8/15/2011	61
8/15/2011	63
8/15/2011	
8/15/2011	
8/15/2011	63
8/15/2011	56
8/15/2011	61
8/17/2011	63
8/17/2011	67
8/17/2011	58
8/17/2011	70
8/17/2011	64
8/17/2011	64
8/17/2011	60
8/23/2011	59
8/23/2011	64
8/23/2011	82
8/23/2011	66
8/23/2011	58
8/25/2011	64
8/25/2011	66

Date	FL (mm)
8/25/2011	68
8/25/2011	66
8/30/2011	69
8/30/2011	70
8/30/2011	65
8/30/2011	62
8/30/2011	73
8/30/2011	66
9/1/2011	72
9/1/2011	86
9/1/2011	73
9/2/2011	83
9/2/2011	79
9/2/2011	61
9/2/2011	70
9/2/2011	65
9/2/2011	76
9/6/2011	63
9/6/2011	60
9/6/2011	82
9/7/2011	77
9/9/2011	69
9/9/2011	73
9/9/2011	72
9/13/2011	60
9/13/2011	80
9/17/2011	70
9/17/2011	78
9/17/2011	85
9/17/2011	83
9/17/2011	72
9/17/2011	71
9/20/2011	64
9/20/2011	87
9/23/2011	80
9/23/2011	83
9/23/2011	75
9/23/2011	74

Date	FL (mm)
9/23/2011	83
9/29/2011	78
10/3/2011	98
10/3/2011	76
10/3/2011	75
10/3/2011	68
10/3/2011	83
10/3/2011	74
10/5/2011	82
10/5/2011	83
10/5/2011	73
10/5/2011	77
10/10/2011	86
10/10/2011	84
10/11/2011	69
10/11/2011	84
10/13/2011	94
10/13/2011	91
10/13/2011	80
10/13/2011	79
10/13/2011	80
10/13/2011	85
10/13/2011	70
10/13/2011	85
10/13/2011	92
10/13/2011	71
10/13/2011	73
10/13/2011	79
10/13/2011	88
10/13/2011	115
10/13/2011	79
10/13/2011	87
10/13/2011	83
10/13/2011	83
10/13/2011	80
10/13/2011	85
10/13/2011	89
10/13/2011	77

Date	FL (mm)
10/14/2011	89
10/14/2011	80
10/14/2011	83
10/14/2011	85
10/14/2011	84
10/14/2011	91
10/14/2011	83
10/14/2011	95
10/14/2011	84
10/14/2011	111
10/14/2011	79
10/14/2011	99
10/14/2011	88
10/18/2011	85
10/18/2011	75
10/18/2011	79
10/21/2011	98
10/21/2011	92
10/21/2011	113
10/21/2011	83
10/21/2011	88
10/21/2011	76
10/21/2011	82
10/21/2011	111
10/21/2011	98
10/22/2011	92
10/22/2011	82
10/22/2011	95
10/22/2011	94
10/22/2011	79
10/22/2011	89
10/22/2011	89
10/22/2011	88
10/22/2011	91
10/22/2011	75
10/22/2011	101
10/22/2011	86
10/25/2011	83

Date	FL (mm)
10/25/2011	105
10/25/2011	110
10/25/2011	79
10/25/2011	84
10/25/2011	93
10/25/2011	82
10/25/2011	78
10/25/2011	87
10/25/2011	88
10/25/2011	100
10/25/2011	87
10/25/2011	80
10/25/2011	111
10/25/2011	94
10/25/2011	94
10/25/2011	90
10/25/2011	97
10/25/2011	100
10/25/2011	82
10/25/2011	83
10/25/2011	93
10/25/2011	85
10/25/2011	92
10/25/2011	91
10/25/2011	98
10/25/2011	77
10/25/2011	92
10/25/2011	115
10/25/2011	80
10/25/2011	90
10/25/2011	90
10/25/2011	97
10/25/2011	84
10/25/2011	93
11/2/2011	92
11/2/2011	86
11/2/2011	90
11/2/2011	93

Appendix I *continued*: Sugar Creek juvenile coho salmon tagged as part of this study (n=371). Table includes date fish were tagged behind the beaver dam and fork length (mm) for the period 8 August 2011 to 6 May 2012. Some values missing.

Date	FL (mm)
11/2/2011	95
11/2/2011	90
11/2/2011	94
11/2/2011	98
11/2/2011	91
11/2/2011	90
11/2/2011	93
11/2/2011	89
11/3/2011	91
11/3/2011	99
11/3/2011	84
11/3/2011	101
11/3/2011	107
11/3/2011	
11/3/2011	91
11/3/2011	99
11/3/2011	82
11/3/2011	100
11/3/2011	92
11/3/2011	85
11/3/2011	96
11/3/2011	111
11/3/2011	110
11/3/2011	88
11/3/2011	103
11/3/2011	102
11/3/2011	101
11/3/2011	100
11/3/2011	108
11/3/2011	104
11/3/2011	104
11/8/2011	95
11/8/2011	93
11/8/2011	97
11/8/2011	96
11/8/2011	85
11/8/2011	89

Date	FL (mm)
11/8/2011	86
11/8/2011	81
11/8/2011	87
11/8/2011	86
11/8/2011	86
11/8/2011	84
11/8/2011	74
11/8/2011	100
11/8/2011	80
11/8/2011	75
11/8/2011	93
11/8/2011	86
11/8/2011	97
11/8/2011	95
11/8/2011	90
11/8/2011	86
11/8/2011	84
11/8/2011	89
11/8/2011	85
11/8/2011	97
11/15/2011	89
11/15/2011	94
11/15/2011	84
11/15/2011	94
11/15/2011	88
11/15/2011	84
11/15/2011	95
11/15/2011	84
11/15/2011	83
11/15/2011	90
11/15/2011	85
11/15/2011	79
11/15/2011	93
11/16/2011	89
11/16/2011	89
11/16/2011	88
11/16/2011	82

Date	FL (mm)
11/16/2011	90
11/16/2011	91
11/16/2011	90
11/16/2011	102
11/16/2011	89
11/16/2011	80
11/16/2011	106
11/16/2011	85
11/16/2011	95
11/16/2011	95
11/16/2011	88
11/16/2011	93
11/30/2011	89
11/30/2011	99
11/30/2011	84
11/30/2011	88
11/30/2011	87
11/30/2011	85
11/30/2011	84
11/30/2011	95
11/30/2011	91
11/30/2011	105
11/30/2011	81
11/30/2011	92
11/30/2011	91
11/30/2011	100
11/30/2011	93
11/30/2011	79
11/30/2011	100
2/10/2012	111
2/10/2012	81
2/10/2012	85
2/10/2012	89
2/13/2012	93
2/13/2012	92
2/13/2012	94
2/13/2012	90

Date	FL (mm)
2/13/2012	78
2/13/2012	87
2/13/2012	95
2/13/2012	67
2/13/2012	79
2/13/2012	100
2/13/2012	89
3/12/2012	80
3/12/2012	96
3/12/2012	109
3/12/2012	88
3/12/2012	109
3/12/2012	94
3/12/2012	102
3/12/2012	98
3/12/2012	86
3/12/2012	80
3/12/2012	85
3/12/2012	98
3/12/2012	89
3/12/2012	92
3/12/2012	110
3/12/2012	104
3/12/2012	93
3/12/2012	95
3/12/2012	95
3/12/2012	87
3/12/2012	87
3/12/2012	80
3/12/2012	101
3/12/2012	93
3/12/2012	91
3/12/2012	95
3/12/2012	90
3/12/2012	92
3/12/2012	93
3/12/2012	74

Date	FL (mm)
3/12/2012	93
3/12/2012	88
3/12/2012	100
3/12/2012	98
3/19/2012	88
3/19/2012	99
3/19/2012	83
3/19/2012	72
3/19/2012	101
3/19/2012	79
3/19/2012	98
3/19/2012	95
3/19/2012	94
4/11/2012	91
4/11/2012	94
4/11/2012	90
4/11/2012	101
4/11/2012	86
4/11/2012	86
4/11/2012	100
4/11/2012	93
4/11/2012	81
4/25/2012	75
4/30/2012	96
4/30/2012	89
4/30/2012	80
4/30/2012	92
4/30/2012	96
4/30/2012	83
4/30/2012	100
5/4/2012	92
5/4/2012	105
5/6/2012	107