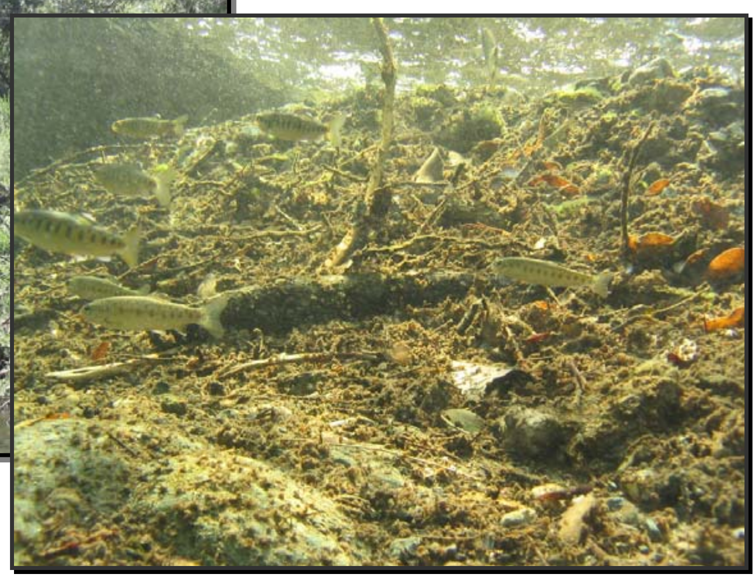
RECLAMATION

Managing Water in the West

Technical Memorandum No. 86-68290-01-07

Klamath River Thermal Refugia Study, 2006



U.S. Department of the Interior
Bureau of Reclamation

April 2007

United States Department of the Interior

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BUREAU OF RECLAMATION
Technical Service Center, Denver, Colorado
Fisheries and Wildlife Resources Group, 86-68290

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Klamath River Thermal Refugia Study, 2006

Klamath Project, Oregon
Klamath Basin Area Office
Mid-Pacific Region

Ron Sutton April 2, 2007

Prepared: Ron Sutton
Fishery Biologist, Fisheries and Wildlife Resources Group 86-68290

Torrey J. Tyler April 2, 2007

Peer Review: Torrey Tyler
Fishery Biologist, Klamath Basin Area Office KO-700

Toz Soto 4/2/07

Peer Review: Toz Soto
Fishery Biologist, Karuk Fisheries Department, Karuk Tribe

Steve Hiebert 5-14-2007 5-14-2007

Technical and Managerial Approval: Steve Hiebert | Date
Manager, Fisheries and Wildlife Resources Group 86-68290

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Prepared by:

Ron Sutton
Fisheries and Wildlife Resources Group, 86-68290

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Summary

The Bureau of Reclamation (Reclamation) conducted a study in two thermal refugia in the Klamath River during the summer of 2006 to refine our knowledge of coho juvenile use of thermal refugia with respect to thermal tolerances and habitat requirements. The study was conducted at the Klamath River confluences with Beaver Creek and Tom Martin Creek. Reclamation and Karuk Tribal personnel monitored coho juveniles using snorkel counts in the thermal refugia from late July to late August to document microhabitat use, including temperatures, of coho in the refugia. Mainstem Klamath River flows dropped from 3,000 cfs in June to 1,000 cfs in July and August when the snorkel effort occurred. The thermal refugia had already formed by late June. Mainstem temperatures remained in the 20-25ºC range through August, even after flows declined to 1,000 cfs. The hottest day occurred on July 26th when air temperature reached 39ºC. The average air temperature experienced considerable diel variability during the study period, and as the study progressed the air temperatures generally showed a cooling trend primarily in response to reduced solar radiation. The fish species observed in greatest abundance was steelhead trout. Similar to past summers, the number of fish counted in the refugia generally increased as each day progressed. Coho observed did not exclusively use the coolest areas. Instead, fish tended to cluster in areas that met their species-specific biological needs within their range of thermal tolerance. Most all coho at the Beaver Creek site were observed nearshore within the thermal refugia in slow velocity water with extensive cover at locations between 16.6-23.8ºC. At the Tom Martin Creek site, most coho were observed in slow velocity associated with cover within the creek. Tom Martin Creek and refuge temperatures where coho were located ranged from 12.7-23.7ºC. Most juvenile coho utilized focal velocities of about 0.1-0.2 ft/sec and 2-3 ft deep water. Tracking movements of juvenile coho during June – August within thermal refugia would help address the question about the source and fate of these fish in summer and fall (i.e., do they move into the tributaries, downstream, or do they succumb to high water temperatures).

Introduction

The Bureau of Reclamation's (Reclamation) Klamath River thermal refugia study has shown that, during the hottest portions of the summer, juvenile coho (*Oncorhynchus kisutch*) occur in a few mainstem areas with suitable habitat (Sutton et al. 2004; Deas et al. 2006). However, coho in the thermal refugia do not necessarily seek out the coolest temperatures, but appear to be concentrated in areas with most suitable physical habitat (i.e., low velocity and good cover). To date, the thermal refugia study has not focused on specific microhabitat selection of coho juveniles. Coho counts have been conducted in a separate effort from the physical measurements of temperatures using sensors. Even when a sensor was in the same grid section as a group of fish, it may not have represented the temperature of the water where most fish inhabited (Alex Corum, personal communication, February 6, 2006). For example, fish count sections were approximately 50' long by 15' wide. During afternoon observations, most fish were observed very closely packed together and not distributed evenly throughout the grid section where they were located. This led to a situation where fish counted on the edge or in the corner of a section where there was no sensor nearby may have been assigned temperatures (within the same grid section) very different from the temperatures that fish were "selecting". Thus, Reclamation conducted a study in summer, 2006 that builds upon this knowledge from the thermal refugia study conducted in 2004 and 2005 to gain a better understanding of temperature and physical habitat selection by coho within selected thermal refugia. The study objective was as follows:

- Refine our knowledge of coho juvenile use of thermal refugia with respect to thermal tolerances and habitat requirements.

The study was a partnership effort among the Karuk Tribe of California and Reclamation offices.

Study Area

The study was conducted at the Klamath River confluences with Beaver Creek and Tom Martin Creek (Figure 1). Based on past observations, both sites contained juvenile coho salmon. Beaver Creek originates at an elevation in excess of 6000 feet in the Siskiyou Mountains of southern Oregon and flows southward into the Klamath River at approximately RM 163. The refugia can generally be described as a long, shallow area dominated by alluvial outwash from Beaver Creek. Figure 2 shows two photos of the area taken in separate summers and areas where juvenile coho were concentrated. High winter flows in early 2006 scoured the bank on river right, effectively removing the pool that was present in 2003-2005 studies. The local gradient of Beaver Creek is about a 1 percent slope and access to the mainstem Klamath River is unrestricted (i.e., fish can readily move from tributary to mainstem and back).

Tom Martin Creek is a steep gradient stream that originates from a high elevation and is the first major tributary that enters the Klamath River downstream from the Scott River confluence. This is a small stream that flows northward into the Klamath River at approximately RM 143 (Figures 1 and 3).

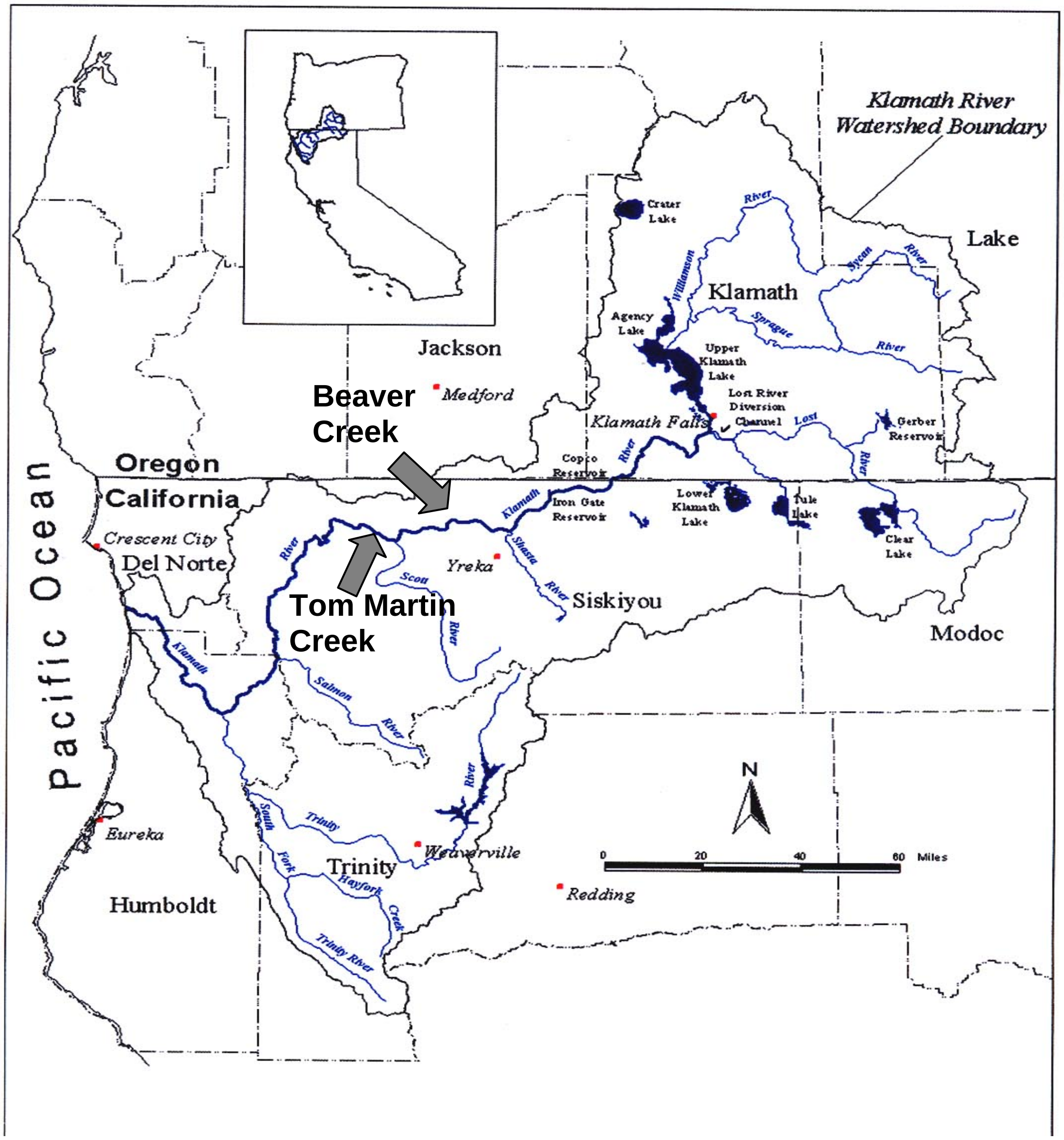


Figure 1 Locations of Klamath River thermal refugia study sites, 2006.

Beaver Creek thermal refugia looking upstream – summers, 2004 and 2005

Beaver Creek thermal refugia looking upstream – summer, 2006

Figure 2. Beaver Creek thermal refugia. Black ovals indicate coho juvenile concentrations.

Figure 3 Tom Martin Creek thermal refugia and snorkeler, summer, 2006.

Methods

Reclamation and Karuk personnel monitored coho juveniles in the Beaver Creek and Tom Martin thermal refugia from late July to late August. The intent of this monitoring effort was to document microhabitat use, including temperatures, of coho in the refugia. Methods generally followed those used during the 2004-2005 thermal refugia study:

1. Spot-dives by a Karuk crew were conducted in June and July at the confluence of Beaver Creek and Tom Martin Creek with the Klamath River to determine when coho started using thermal refugia. Snorkeling occurred during the hottest portions of the day.
2. In late-July to late-August, snorkeling by a Karuk crew was used to count all species and record locations of all species in each refuge using a grid system (Figures 4 and 5). At Beaver Creek, two divers worked together counting fish in an upstream direction separately in lanes B and C. One diver counted fish in a downstream direction in lane A. At Tom Martin Creek, one diver counted fish in all lanes. Seven counts were made each day during daylight. Counts were spaced every other hour starting at 0700 hours. One day of counts was conducted each week between July 26 and August 4 and once during the week of August 28 during the sample period for a total of 3 days of counts at each refugia. Divers marked locations where most coho were observed in each grid section (cell) with flagging attached to a weight.

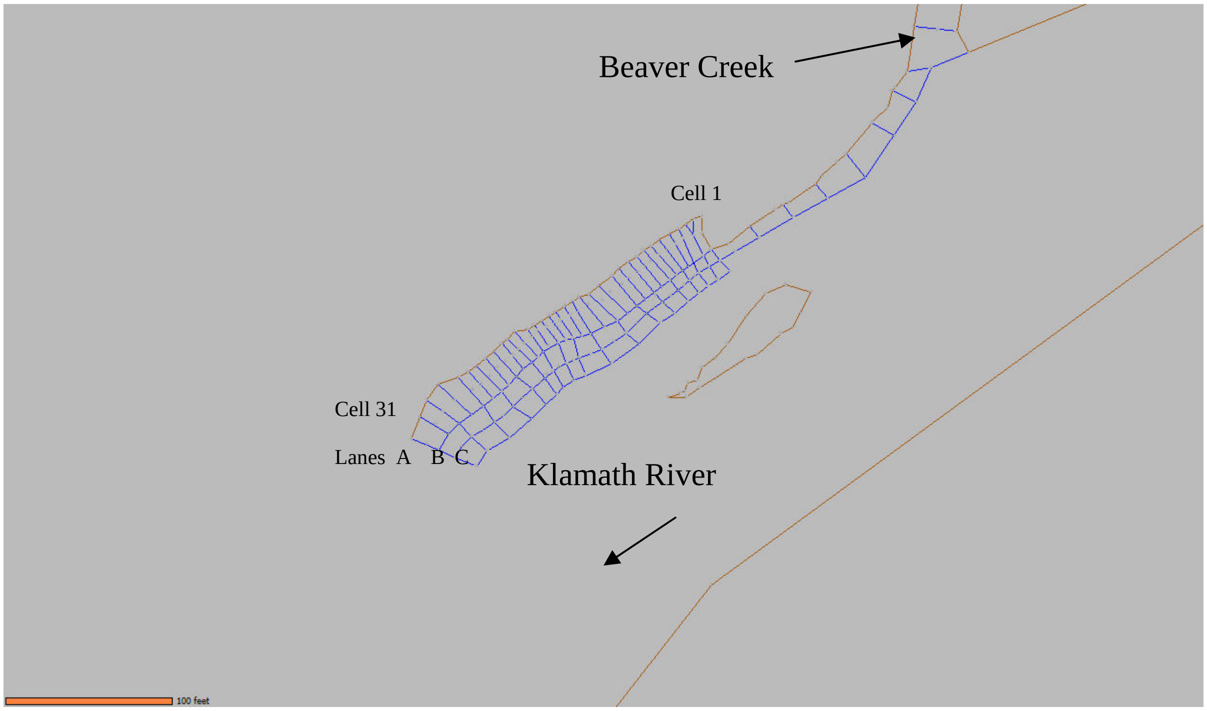


Figure 4 Fish counting lanes for Beaver Creek thermal refugia study, 2006.

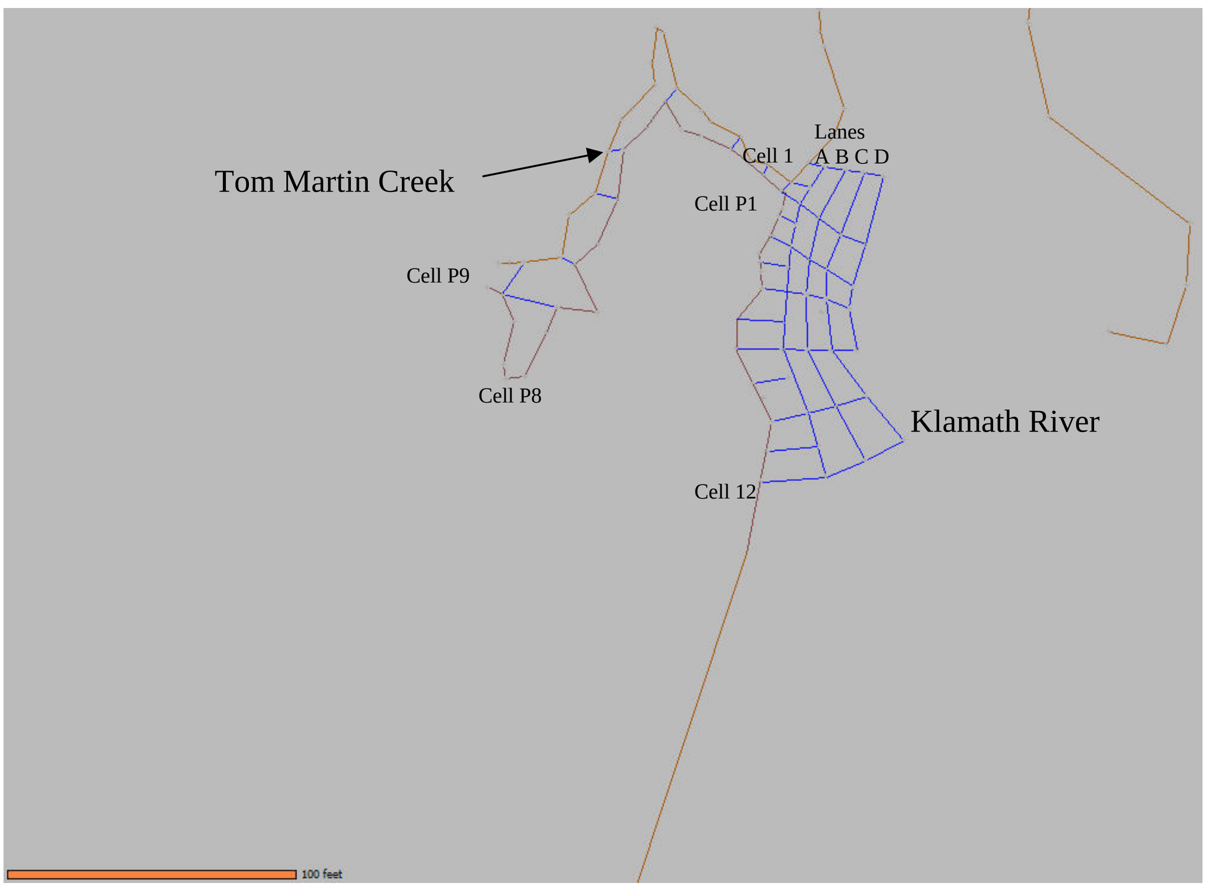


Figure 5 Fish counting lanes for Tom Martin Creek thermal refugia study, 2006.

3. Immediately after fish counts were completed, temperatures were instantaneously recorded using a portable Yellow Springs Instrument (YSI) temperature recorder where most coho were observed in each grid section. Also, velocities and depths were measured using a Marsh McBirney Model 2000 FloMate velocity meter and top-set wading rod at the same locations where temperatures were taken. Substrate and cover, including distance to escape cover, were also subjectively recorded and a total station was used to get precise local coordinates of where most coho were located.
4. A topographic survey of the thermal refugia areas was also conducted.
5. Temperature sensors (iBCod) were placed in each fish counting lane to record temperatures every 30 minutes to characterize spatial and temporal thermal conditions within the refugia. Depths and velocities at each sensor location were recorded at the start of the study. Onset Tidbit sensors were deployed in late June to document how temperature regime in refugia developed during the summer season. Additional sensors were deployed in the Klamath River mainstem upstream from each thermal refugia. One sensor recorded air temperatures at each site. All sensors were retrieved by the end of August.
6. All temperature loggers were tested and certified prior to shipment from Alpha Mach, Inc. (iBCod) and Onset (Tidbits). There is no method to calibrate the loggers in the field. Thus, we assumed they provided accurate recordings so that the data could be used in side-by-side comparisons. The iBCod logger performance fell within the range of factory specifications a precision of ±0.5°C and a range of -40°C to 85°C (Type G). Tidbits had a precision of ±0.2°C and a range of -20°C to 30°C. The study design included a large number of loggers, essentially building in considerable redundancy which overcame the rare loss of data from a single logger.
7. Periodic measurements of turbidity (NTUs) and dissolved oxygen (% saturation and ppm) were also recorded where coho were observed.
8. Instantaneous flow measurements were taken in Beaver Creek and Tom Martin Creek each day that fish counts were conducted. Flow measurements in the Klamath River were retrieved from the USGS gage site below Iron Gate Dam. A Global Water pressure transducer was deployed in Beaver Creek to monitor water levels at 15-minute intervals.

Data analysis involved evaluating microhabitat use by coho juveniles within thermal refugia to gain a better understanding of habitat-use patterns, including thermal tolerances in the Klamath River. Habitat suitability criteria for coho juveniles can be developed from the data and compared with criteria from other studies (e.g., Hardy Phase II). Locations where most coho were observed were given greatest weight.

Results and Discussion

Pursuant to the U.S. District Court ruling CIV. NO CO2-2006 SBA, Reclamation operated the Klamath Project in 2006 so that Klamath River flows at Iron Gate Dam (IGD) met or exceeded the operational criteria in Table 1. Table 1 incorporates the requirements of Phase

III of the 2002 NOAA BO for an "above average" water year type. Mainstem flows ranged from 1,000 cfs to 3,000 cfs between June and August.

Table 1 Scheduled flow regimes at Iron Gate Dam, 2006.

Flow Regime Period	Flow Regime at Iron Gate Dam cfs
June 1- June 30	3,000
July 1 – August 31	1,000

Physical Characterization

Figures 6 and 7 show graphs of Klamath River temperatures at Beaver Creek and Tom Martin Creek compared to air temperatures and Iron Gate Dam releases between late June and mid August, 2006. Figure 6 shows minimal, if any, influence of releases from Iron Gate Dam on Klamath River mainstem temperatures at Beaver Creek. For example, Reclamation personnel deployed temperature sensors in the Klamath River just upstream from Beaver Creek on June 29th, when Iron Gate Dam releases were over 3,000 cfs. Mainstem water temperature at that location at the time of deployment was 23.4ºC at 1930 hours. Beaver Creek temperature was 16.4ºC at this time. Thus, the thermal refugia had already formed by late June. Mainstem temperatures remained in the 20-25ºC range through August, even after flows declined to about 1,000 cfs (Figure 6). The hottest day occurred on July 26th when air temperature reached 39ºC (Figure 7). Coincidentally, snorkeling occurred at Beaver Creek on that day. The average air temperature experienced considerable diel variability during the study period, and as the study progressed the air temperatures generally showed a cooling trend primarily in response to reduced solar radiation (reduced solar altitude and day length). The average water temperatures in the Klamath River reflected this cooling trend. Otherwise, meteorological conditions were relatively stable during the study period (e.g., no major cold fronts) (Figure 7).

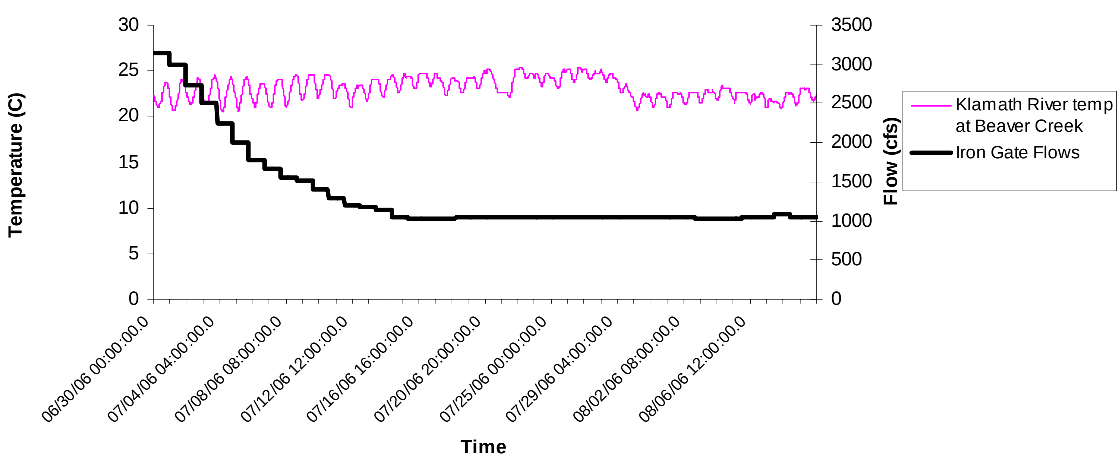


Figure 6 Comparison of Klamath River temperatures at Beaver Creek with flow releases from Iron Gate Dam, 2006.

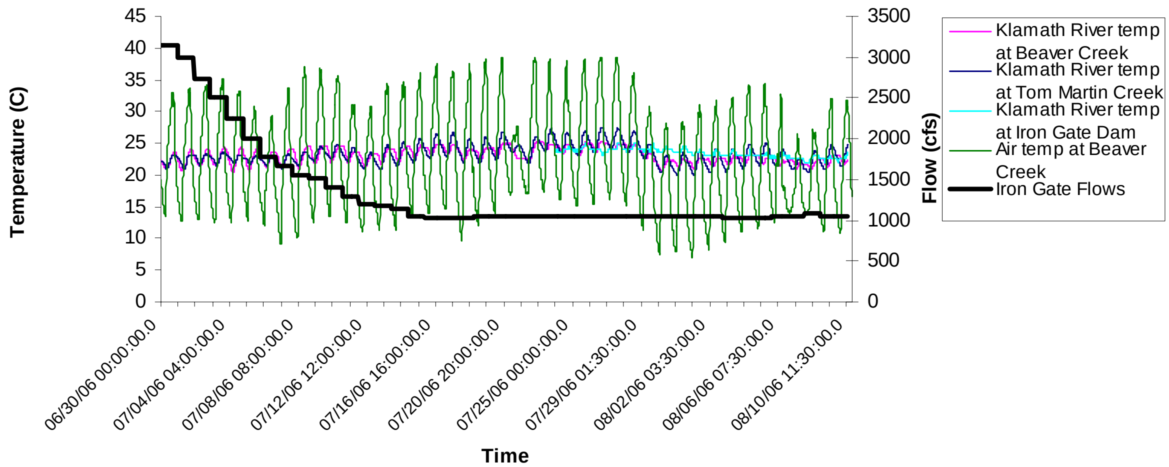


Figure 7 Klamath River temperatures at Beaver Creek and Tom Martin Creek compared to air temperatures and Iron Gate Dam releases, 2006.

Mainstem flows from IGD were held at about 1,000 cfs at all times during the period of fish counting (Table 2). Thus, an assessment of fish behavior in the refugia under various mainstem flows was not possible. For a thermal refuge to be present the water coming in from the creek must be colder than the water in the mainstem, otherwise there is little thermal benefit from the inflowing creek water. Mainstem Klamath River temperatures were always warmer than Beaver Creek and Tom Martin Creek (Table 2). Mainstem temperatures ranged from 20.0 to 27.4°C during the study period and were slightly more variable at Tom Martin than Beaver Creek. Refugia temperature monitoring showed the refugia expanded during the night and morning hours and then contracted during the afternoon and evening, similar to past observations (Deas et al. 2006). Temperature traces for the entire study period indicated that Beaver Creek experienced a notably larger diurnal temperature change than the Klamath River (Table 2). Temperature fluctuations were less variable in Tom Martin Creek (Table 2).

Table 2 Dive dates, main-stem Klamath River flow regimes, and river, creek, and air temperature ranges in 2006.

Intensive Dive Date	Iron Gate Flow Regime (cfs)	Temperature Range (ºC)					
		Klamath River		Creek		Air	
		Min	Max	Min	Max	Min	Max
Beaver Creek							
July 26	1,050	24.3	26.1	16.5	21.0	15.4	38.5
August 1	1,050	21.5	23.3	12.3	17.0	7.0	31.1
August 29	1,020	21.0	22.1	13.7	18.3	9.2	30.5
Tom Martin Creek							
July 27	1,040	24.0	27.4	16.6	19.1	19.0	37.0
August 2	1,040	20.4	24.0	13.0	16.1	11.0	31.0
August 29	1,020	20.0	23.2	13.4	15.6	12.0	30.5

Water level traces in Beaver Creek near the confluence with the Klamath River showed diel variation and a general decline during the study (Figure 8). A stage-discharge relationship was developed for Beaver Creek (Figure 9) using these water level traces and several instantaneous discharge measurements (Table 3). Flows in Beaver Creek ranged from about 30 cfs to 70 cfs during the study. Tom Martin Creek flows were relatively stable and substantially lower than in Beaver Creek with instantaneous readings ranging from 1.3 to 1.8 cfs (Table 3).

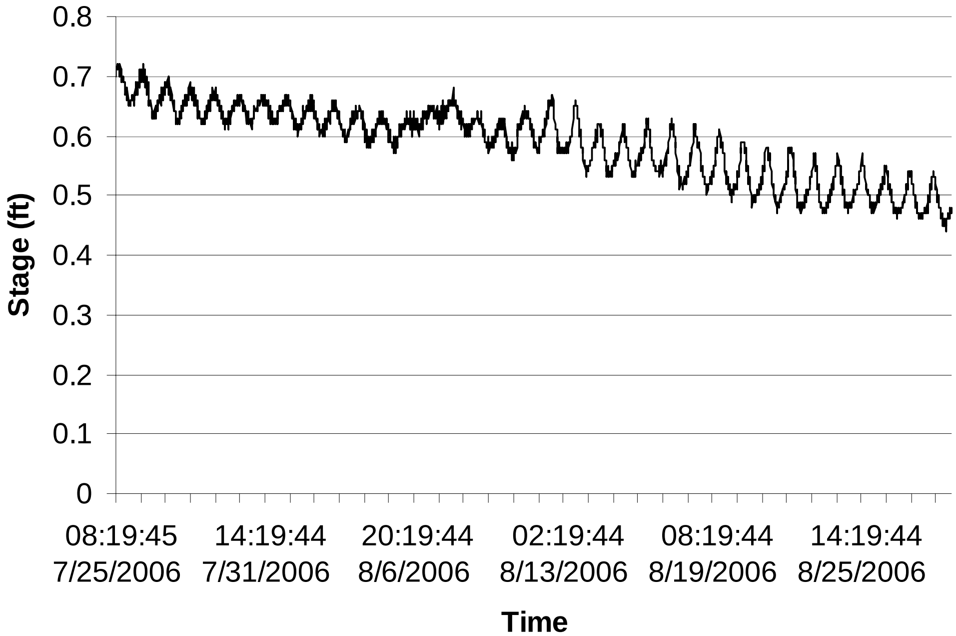


Figure 8 Water levels in Beaver Creek during thermal refugia study, 2006.

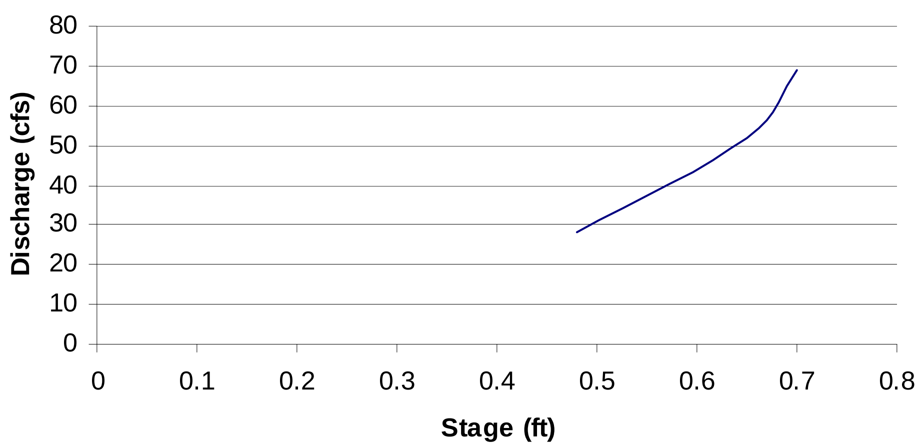


Figure 9 Stage-discharge relationship for Beaver Creek.

Table 3 Instantaneous stream flow measurements in Beaver Creek and Tom Martin Creek, summer 2006.

	Date	Flow (cfs)
Beaver Creek	25-Jul	69
	1-Aug	59
	8-Aug	52
	29-Aug	28
Tom Martin Creek	27-Jul	1.4
	2-Aug	1.3
	8-Aug	1.8

Of the 34 temperature sensors (Tidbit and iBCod) deployed at Beaver Creek, 28 were recovered (Table 4). At Tom Martin Creek, 27 of 29 deployed sensors were recovered (Table 5). Figures 10 and 11 show locations of recovered sensors at Beaver Creek and Tom Martin Creek refugia, respectively. Generally, the closer to the mouth of each creek, the greater the influence the colder creek had on water temperatures (Figures 10 and 11; Tables 4 and 5). A groundwater seep was observed near sensors 1 and 2 at Beaver Creek in a small backwater area (Figure 10) and temperatures were considerably cooler at this location compared to other sensors in the refuge (Table 4). Similar seeps were not observed at the Tom Martin Creek refuge (Figure 11; Table 5). Most coho were observed in the P8 cell (iBCod #22) at Tom Martin Creek in low velocity water with heavy cover.

Table 4 Temperature sensor readings at Beaver Creek thermal refugia (July 26-August 29, 2006). Note: sensor #26 – July 26-August 9. Note – see Figure 10 for sensor locations

		Temperatures (ºC)					
Number[1]	Type	Min	Max	Avg	Depth (ft)	Velocity (ft/sec)	Substrate[2]
1	iBCod	14.5	18.5	15.7	2.8	0.08	3
2	iBCod	15.5	20.0	16.9	2.4	0.05	3
3	iBCod	16.5	22.5	18.9	2.4	0.14	4
4	iBCod	15.5	22.5	18.6	4.1	0.16	4
5	iBCod	16.0	22.5	18.9	5.3	0.32	4
6	iBCod	15.5	21.5	18.1	5	0.14	4
7	iBCod	15.0	22.0	18.2	3.8	0.21	5
8	iBCod	15.5	22.5	18.7	2.4	0.34	5
9	iBCod	17.0	23.5	19.8	1.5	0.04	5
10	iBCod	15.5	22.5	17.7	2.8	0.03	3
12	iBCod	16.5	23.5	19.6	4.3	0.91	4
14	iBCod	16.5	23.0	19.3	3	1.13	5
15	iBCod	16.5	23.0	19.2	2.7	0.69	5
16	iBCod	16.0	23.0	19.0	4.2	0.21	5
17	iBCod	16.0	23.0	19.1	4.1	0.99	6
18	iBCod	16.5	23.5	19.6	2.2	0.01	6
20	iBCod	17.0	23.5	19.7	2.8	1.26	5
21	iBCod	16.5	23.0	19.2	3.2	0.98	5
23	iBCod	11.5	21.0	15.6	1	4.44	7
24	iBCod	11.0	20.5	14.9	1.4	3.36	7
25	iBCod	20.5	26.0	22.8	1.9	2.81	7
26	iBCod	20.0	24.5	22.1	-	-	-
27	Tidbit	16.3	21.1	17.5	2.7	0.01	3
30	Tidbit	12.0	21.4	15.9	-	-	-
28	Tidbit	18.4	24.5	21.0	-	-	-
29	Tidbit	20.5	26.1	22.6	-	-	-
	Tidbit[3]	11.9	21.2	15.8	-	-	-
	Tidbit[4]	5.6	38.5	20.3	-	-	-

[1]Sensors that were recovered
[2]Substrate Code: 1-veg/organics, 2-mud/clay, 3-silt, 4-sand (<.3cm), 5-gravel(.3-7cm), 6-cobble(7-22.5cm), 7-boulder(>40cm), 8-bedrock
[3]Beaver Creek at Hwy 96 Bridge
[4]Air Temperature

Table 5 Temperature sensor readings at Tom Martin Creek thermal refugia (July 28-August 29, 2006). Note – see Figure 11 for sensor locations.

		Temperatures (ºC)					
Number	Type	Min	Max	Avg	Depth (ft)	Velocity (ft/sec)	Substrate[1]
1	Tidbit	19.8	26.7	22.3	-	-	-
2	iBCod	11.5	18.0	14.4	0.6	2.51	5
3	iBCod	16.5	23.5	19.1	0.5	0.02	4
4	iBCod	15.5	23.0	18.9	1.9	0.1	8
5	iBCod	16.0	23.5	19.4	1.1	0.03	8
6	iBCod	18.0	26.5	21.6	1.6	0.1	8
7	iBCod	17.0	25.5	20.7	1.6	0.17	8
8	iBCod	17.0	24.5	20.2	2.0	0.22	8
9	iBCod	17.5	25.0	20.4	2.9	0.09	8
10	iBCod	16.0	23.5	19.2	1.4	0.11	8
11	iBCod	15.5	22.5	18.6	0.7	0.03	4
12	iBCod	16.0	24.0	19.2	1.8	0.02	4
13	iBCod	15.0	22.5	17.8	1.4	0.05	8
15	iBCod	15.5	22.5	18.3	2.4	0.03	8
16	iBCod	17.5	25.5	20.8	1.2	0.16	8
17	iBCod	15.0	22.0	17.8	2.0	0.55	8
18	iBCod	15.5	23.0	18.4	3.0	0.04	8
19top[2]	iBCod	18.0	25.5	20.9	-	-	-
19middle	iBCod	18.0	25.5	21.0	-	-	-
19bottom	iBCod	16.5	24.5	19.7	3.0	0.04	8
20	iBCod	11.5	18.0	14.2	1.7	0.36	7
21	Tidbit	12.3	18.3	14.9	1.7	0.38	7
22	iBCod	12.0	19.0	15.1	1.9	0.03	8
23	Tidbit	19.4	26.6	22.1	-	-	-
24	Tidbit	19.5	27.0	22.3	-	-	-
	Tidbit[3]	12.2	18.6	14.9	-	-	-
	iBCod[4]	8.5	35.0	21.1	-	-	-

[13]Substrate Code: 1-veg/organics, 2-mud/clay, 3-silt, 4-sand (<.3cm), 5-gravel(.3-7cm), 6-cobble(7-22.5cm), 7-boulder(>40cm), 8-bedrock
[2]Three sensors on vertical T-post
[3]Tom Martin Creek upstream from Hwy 96 culvert
[4]Air Temperature

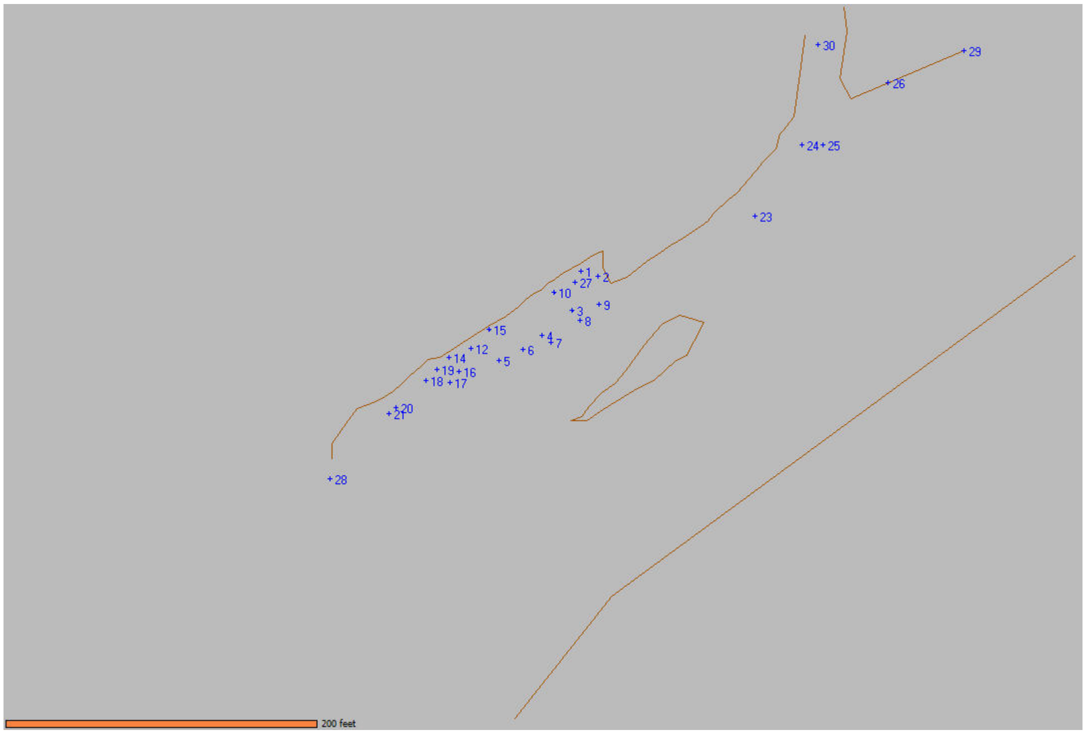


Figure 10 Locations of temperature sensors in Beaver Creek thermal refugia, 2006.

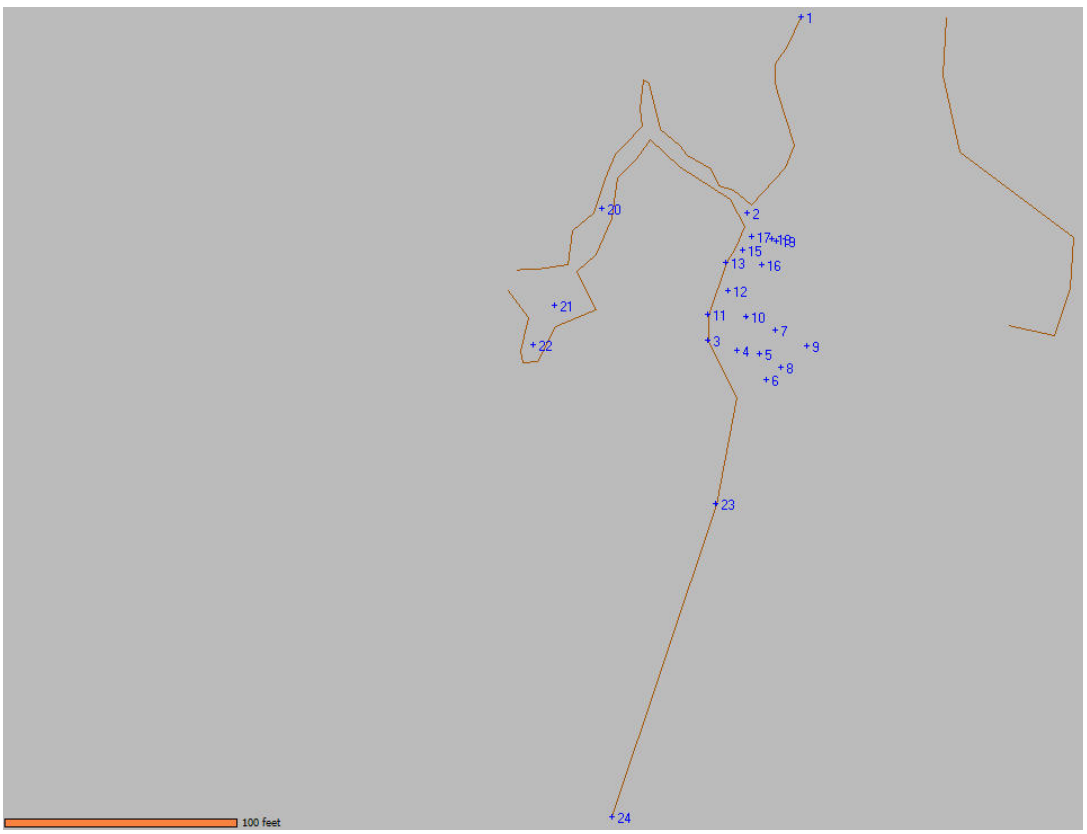


Figure 11 Locations of temperature sensors at Tom Martin Creek thermal refugia, 2006.

Fish Observations

Tables 6 and 7 summarize the intensive dive dates and times, and total number of fish observed in 2006 at Beaver Creek and Tom Martin Creek refugia, respectively. The fish species in greatest abundance (aggregating all age categories together) was steelhead trout. Similar to past summers, the number of fish counted in the refugia generally increased as each day progressed.

Table 6 Number of coho, Chinook, and steelhead counted for each day and time at the Beaver Creek thermal refugia, 2006.

Time/Date	7/26/2006[1]	8/1/2006[1]	8/29/2006[1]	Grand Total [1]
07:00	17-31-80	13-14-7	0-1-24	30-46-111
09:00	19-40-128	7-20-9	0-4-59	26-64-196
11:00	20-57-166	16-6-11	4-62-83	40-125-260
13:00	25-123-323	15-12-41	6-83-67	46-218-431
15:00	18-169-455	9-6-37	8-67-88	35-242-580
17:00	9-158-325	9-2-19	8-125-138	26-285-482
19:00	8-78-318	12-4-23	5-92-69	25-174-410

[1] XXX-YYY-ZZZ: XXX is the number of coho counted, YYY is the number of Chinook, and ZZZ is the number of steelhead (aggregating all age categories).

Table 7 Number of coho, Chinook, and steelhead counted for each day and time at the Tom Martin Creek thermal refugia, 2006.

Time/Date	7/27/2006[1]	8/2/2006[1]	8/29/2006[1]	Grand Total [1]
07:00	0-2-34	1-0-5	0-0-0	1-2-39
09:00	0-0-44	0-0-0	0-0-0	0-0-44
11:00	2-0-48	0-0-4	0-0-1	2-0-53
13:00	8-0-70	0-0-8	0-0-0	8-0-78
15:00	7-0-129	1-0-7	0-1-1	8-1-137
17:00	14-0-238	1-0-7	0-0-0	15-0-245
19:00	7-0-314	1-0-16	0-0-2	8-0-332

[1] XXX-YYY-ZZZ: XXX is the number of coho counted, YYY is the number of Chinook, and ZZZ is the number of steelhead (aggregating all age categories).

Coho observed in the Beaver Creek refuge did not exclusively use the coolest areas. Instead, fish tended to cluster in areas that met their species-specific biological needs within their range of thermal tolerance. For example, the preferred temperature range for juvenile coho salmon is 12-14ºC (Brett, 1952; Moyle, 2002; NRC 2004) and optimal growth occurs at about 14-18ºC (Sullivan *et al*., 2000). At Beaver Creek, coho were observed at locations between 16.6-23.8ºC with no obvious preference (Table 8). Although the Karuk tribe found coho in a cool area caused by groundwater inflow near sensors #1 (14.5-18.5ºC) and #2 (15.5-20.0ºC) (Table 4) in a small backwater in early July during reconnaissance dives (Toz Soto, personal communication), this cool area did not attract coho in late July-August. Instead, coho concentrated in a nearshore area (Figure 12) near woody debris where temperatures ranged from 16.5-23.0ºC. However, lack of coho in the backwater was likely confounded by associated low dissolved oxygen readings. A spot check in this backwater on August 1 showed a dissolved oxygen reading of 2.6 ppm. Also, a fish-eating blue heron was sighted in this area in early July (Toz Soto, personal communication). At Beaver Creek, most coho were located near the bank in slow velocity at the mid-point of the refuge next to overhanging cover and woody debris that provided suitable habitat consistent with their expected behavior (Table 8). It is also possible that they were selecting the best combination of factors that created the most suitable conditions, such as water clarity, distance to escape cover, temperature, velocity shelter, depth, substrate, dissolved oxygen, food resources, and predator avoidance. Chinook salmon showed a similar decline (Table 6). Steelhead numbers were relatively stable. Steelhead generally were associated with different habitat (faster velocities near the edge of the refugia with the mainstem) than coho, so aggressive behavior of steelhead was probably not a factor in the decline of the coho.

Coho numbers at the Beaver Creek refuge were low compared to counts made in 2005, but higher than those in 2004, and reflected relatively moderate year class strength. The most coho observed in the refuge at any time was 25 at 1300 hours on July 26th (Table 8). Based on past observations and the three-year cycle for coho, it is expected that summer, 2007 will be a weak year class.

Turbidity levels were relatively low, ranging from 0.87-3.37 NTUs at Beaver Creek refuge (Table 9). A thick blue green algal bloom in August affected diver visibility and may have contributed to lower fish counts. When dissolved oxygen was measured, levels were always above the lethal threshold of 5 mg/l where coho were observed (Table 9). Substrate observations were made but did not appear to influence fish distribution.

Tom Martin Creek temperatures where coho were located ranged from 12.7-23.7ºC (Table 10) with most coho located in a cool backwater area of Tom Martin Creek near IbCod sensor number 22 (Figures 5 and 11; Table 5). The only coho observed within the refugia were scattered nearshore in slow velocity and closely associated with overhanging vegetation and undercut banks (Figure 13; Table 10). Fewer coho were observed in the refuge and more were counted in the creek as the summer progressed (Table 10). It is interesting to note that at Beaver Creek, where all coho were observed within the thermal refugia in slow velocity water with extensive cover, no coho were observed in Beaver Creek. This was possibly because velocities were too high in Beaver Creek and/or some other habitat features were not suitable for coho use. However, at Tom Martin Creek, most coho were observed in Tom Martin Creek in slow velocity water with extensive cover (cell P8) and relatively few coho were observed within the thermal refugia (Figure 13). Again, it appeared that coho were selecting best overall habitat conditions (i.e., combinations of preferred velocities, cover, temperature, etc.) and not necessarily the coldest water available.

Turbidity levels were relatively low, ranging from 0.23-2.15 NTUs at the Tom Martin refuge and creek (Table 11). A thick blue green algal bloom in August affected diver visibility and may have contributed to lower fish counts in the refuge. When dissolved oxygen was measured, levels were always above the lethal threshold of 5 mg/l where coho were observed (Table 11). Substrate observations were made but did not appear to influence fish distribution.

Most coho observations were made at mainstem temperatures >23ºC late in the afternoon on the hottest day of the summer, July 26. However, numbers of coho observed that day declined dramatically from 25 at 1300 hours to 8 at 1900 hours as refuge temperatures rose and exceeded 23ºC (Table 8). Although observed maximum temperatures on that day were less than the acute lethal level for coho (25.6ºC) (Bell 1991), they were greater than the 22-23ºC mainstem temperatures observed when coho have been observed moving into refugia (Sutton et al. 2004; Deas et al. 2006). One question is whether coho move into refugia at mainstem temperatures less than 22-23ºC.

Table 12 summarizes temperatures and fish counts in two fish count cells at the Beaver Creek thermal refugia on July 26. These cells consistently held the most coho during the study. These data provide insight into the upper thermal tolerance of juvenile coho salmon in the Klamath River. Examination of Table 12 shows fish numbers increase during the day as the mainstem temperatures rise. However, after 1500 hours, fish numbers decline rapidly as the cell temperatures exceed 23.3ºC. It is uncertain whether the refuge coho numbers declined in late afternoon on July 26 because they were dying from chronic lethal high temperatures or because they moved to cooler locations, such as Beaver Creek. Divers reported seeing some very dark coho that looked stressed (Toz Soto, personal communication). Radio telemetry would allow tracking of coho as temperatures change during the day.

Table 8 Juvenile coho observations at Beaver Creek refugia, 2006

Grid #	Time (hours)	# 0+ Coho	Depth (ft)	Fish Depth (ft)	MCV (ft/sec)	Focal (nose) Vel (ft/sec)	Nose Temp ºC
				July 26			
13A	700	14	3.5	1.7	0.72	0.62	21
14A	700	2	3.1	1.6	0.92	0.79	20.6
24A	700	1	1.7	0.8	0.25	0.24	21
12A	900	3	3.2	1.6	0.18	0.1	20.6
13A	900	8	3.3	1.7	0.58	0.69	20.5
14A	900	5	2.9	1.5	0.67	0.83	20.5
26A	900	1	2.3	1.2	1.21	0.82	20.8
31A	900	2	2.8	1.4	0.54	0.23	21
12A	1100	7	3.1	1.0	0.12	0.17	21.3
13A	1100	6	3.9	1.0	1	0.97	21
14A	1100	5	3.6	1.0	0.91	1.11	21.1
24A	1100	1	2.8	1.0	0.9	0.68	20.7
27A	1100	1	3	1.0	0.95	0.78	21.4
13A	1300	17	3.4	0.8	0.51	0.58	22.6
14A	1300	4	3.7	0.8	1.01	1	22.7
31A	1300	4	2.8	0.8	0.23	0.23	23.3
12A	1500	2	2.9	0.8	0.03	0.13	23.4
13A	1500	16	4.5	0.8	0.31	0.87	23.3
12A	1700	4	3.6	1.5	0.56	0.56	23.7
13A	1700	5	3.7	1.5	0.86	0.86	23.8
12A	1900	5	4.6	2.0	0.45	0.45	23.8
13A	1900	3	3.5	1.5	0.71	0.71	23.4
				August 1			
14A	700	9	2.4	0.5	0.49	0.46	17.4
31A	700	4	2.6	0.5	0.46	0.44	18.4
13A	900	7	3	0.5	0.29	0.35	17.5
12A	1100	6	3	0.5	0.25	0.31	17.7
13A	1100	7	3.3	0.5	0.65	0.64	17.9
31A	1100	3	2.5	0.5	0.32	0.61	18.5
13A	1300	9	2.7	0.5	0.28	0.23	19
31A	1300	5	2.9	0.5	0.53	0.43	20.1
2C	1300	1	1.5	0.3	2.84	2.56	16.6
13A	1500	9	2.7	0.5	0.37	0.26	20.2
13A	1700	9	2.7	0.5	0.26	0.3	20.5
13A	1900	8	2.8	0.5	0.23	0.34	20.1
31A	1900	4	2.8	0.5	0.36	0.58	21.2
				August 29			
12A	1100	4	3.5	0.5	0.43	0.32	20.3
14A	1300	6	2.9	0.5	0.39	0.44	20.2
14A	1500	4	5	2.5	0.36	0.36	21.1
14A	1700	7	5	2.5	0.36	0.36	20.9
20A	1700	1	2.5	0.5	0.77	0.84	21
14A	1900	5	5	2.5	0.3	0.3	20.9

Table 9 Habitat observations at Beaver Creek refugia, 2006.

Grid #	Time	DO ppm	Turb NTUs	[1]Substrate w/in 1ft		Dist (ft) to	Dist (ft) to	% of Cover Type[4]						
				Dom	SubD	Vel Cov[2]	Hid Cov[3]	None	Sml	Med	Lrg	OHV	R/UC	Wood
						July 26								
13A	700		2.61	4	5		0					100		
14A	700			5	4	4	0					100		
24A	700			5	4	4	0		100					
12A	900	11.2		4	5	20	2						100	
13A	900			4	5	10	0					50		50
14A	900			4	5	0	0					50		50
26A	900			5	5		30	100						
31A	900			8	6	1	0					50		50
12A	1100			4	6	20	2					50		50
13A	1100			4	6	10	1					50		50
14A	1100			5	6	0	0				50	50		
24A	1100			6	5		20	100						
27A	1100			6	5		30	100						
13A	1300			4	5	10	0					50		50
14A	1300			5	6	1	0					50		50
31A	1300			8	7		0				50	50		
12A	1500			4	6	20	0						100	
13A	1500			5	4	10	4					50		50
12A	1700			4	6	20	0						100	
13A	1700			6	4	10	0						100	
12A	1900			4	6	20	0					100		
13A	1900			4	6	5	0					50		50
						August 1								
14A	700	9.5	1.83	4	6	5	0					50		50
31A	700	9.53	1.8	6	4	4	0					50		50
13A	900	9.8	2.28	4	6	10	0					50		50
12A	1100	10.5	2.47	4	6	15	1						50	50
13A	1100	10.5	2.1	4	6	10	1					25	25	50
31A	1100	10.2	1.96	6	4	4	0					50		50
13A	1300	10.3	1.73	4	6	10	0					50		50
31A	1300	10.3	1.7	6	4	4	0					50		50

Grid #	Time	DO ppm	Turb NTUs	[1]Substrate w/in 1ft		Dist (ft) to	Dist (ft) to	% of Cover Type[4]						
				Dom	SubD	Vel Cov[2]	Hid Cov[3]	None	Sml	Med	Lrg	OHV	R/UC	Wood
2C	1300	11	0.87	5	5		20					100		
13A	1500	9.38	2.06	4	6	10	0					50		50
13A	1700	8.72	3.37	4	6	10	0					50		50
13A	1900	8.5	2.23	4	6	10	0					50		50
31A	1900	8.45	2.27	6	4	4	0					50		50
						August 29								
12A	1100	10.3	1.12	4	3	15	0.5					50		50
14A	1300	10.5	1.21	4	6	5	0					50		50
14A	1500	-	-	4	5	2	2					50		50
14A	1700	10	1.37	4	5	2	2					50		50
20A	1700	10	1.05	5	4		0					100		
14A	1900	9.67	1.17	4	5	2	2					50		50

[1]Substrate Code: **1**-veg/organics, **2**-mud/clay, **3**-silt, **4**-sand (<.3cm), **5**-gravel(.3-7cm), **6**-cobble(7-22.5cm), **7**-boulder(>40cm), **8**-bedrock

[2]Velocity Cover: presence or absence of a pronounced velocity barrier

[3]Hiding Cover: instream or out-of-water (w/in 18" of surface), not including turbulence, distance=0 if directly overhead

[4]Cover (w/in **4**' of fish): **Sml**-objects<15cm diameter, **Med**-objects 15-30cm, **Lrg**-objects>30cm, OHV-overhanging vegetation w/in 18" of surface, R/UC-rootwads or undercut banks, Turb-surface turbulence, Wood-woody debris

Table 10 Juvenile coho observations at Tom Martin Creek refugia, 2006.

Grid #	Time (hours)	# 0+ Coho	Depth (ft)	Fish Depth (ft)	MCV (ft/sec)	Focal (nose) Vel (ft/sec)	Nose Temp ºC
			July 27				
P4(creek)	700	1					16.2
P7(creek)	700	10					16.3
P9(creek)	700	1					16.4
P6(creek)	900	1					16.6
P7(creek)	900	3					16.6
P8(creek)	900	17					16.8
2A	1100	2	2.5	0.2	0.1	0.53	21.5
P3(creek)	1100	1					17.7
P4(creek)	1100	1					17.6
P7(creek)	1100	4					17.5
P8(creek)	1100	14					18.1
2A	1300	1	2.5	0.2	0.13	0.36	20.4
4A	1300	4	2.4	0.2	0.33	0.4	21.8
6A	1300	3	2.3	0.2	0.12	0.02	22.9
P4(creek)	1300	1					18.6
P7(creek)	1300	1					18.4
P8(creek)	1300	13					18.9
2A	1500	2	2.2	0.2	0.03	0.05	22.5
4A	1500	4	2.4	0.3	0.11	0.28	22.8
5A	1500	1	2.3	0.2	0.02	0	22.6
P4(creek)	1500	1					18.9
P7(creek)	1500	3					18.8
P8(creek)	1500	13					19.4
2A	1700	1	1.6	0.2	0.48	0.12	21.9
2A	1700	2	2.9	0.2	0.09	0.06	23.7
4A	1700	4	2.5	0.2	0.2	0.09	23.2
5A	1700	2	2.4	0.2	0.13	0.17	22.8
7A	1700	1	2.2	0.2	0.04	0.11	22.6
6B	1700	3	2.2	0.2	0.31	0.09	23.6
P1	1700	1					19.1
4A	1900	7	2.4	0.2	0.2	0.23	22.8
P3(creek)	1900	1					18.6
P4(creek)	1900	1					18.6
P7(creek)	1900	4					18.4
P8(creek)	1900	14					18.6
P9(creek)	1900	1					18.4
			August 2				
2A	700	1	2.5	0.2	0.04	0.28	15.8
P7 (creek)	700	1	1.8	0.2	0.03	0.03	12.7
P8 (creek)	700	26	2	0.2	0	0.03	12.8
P6 (creek)	900	1	1.7	0.2	0.21	0.27	13.1
P7 (creek)	900	1	2	0.2	0.05	0.05	13.1
P8 (creek)	900	17	1.7	0.2	0.01	0.01	13.1
P6 (creek)	1100	1	1.5	0.2	0.02	0.07	14.1
P7 (creek)	1100	2	2.2	0.2	0.04	0.02	14.4
P8 (creek)	1100	22	1.8	0.2	0.03	0.03	14.7
P6 (creek)	1300	1	1.5	0.2	0.08	0.14	15.1

Grid #	Time (hours)	# 0+ Coho	Depth (ft)	Fish Depth (ft)	MCV (ft/sec)	Focal (nose) Vel (ft/sec)	Nose Temp ºC
P8 (creek)	1300	19	1.8	0.2	0	0.04	15.6
2A	1500	1	1.8	0.2	0.56	0.56	17.1
P4 (creek)	1500	1	1.7	0.2	0.17	0.17	15.8
P7A (creek)	1500	1	1.9	0.2	0.07	0	15.8
P7B (creek)	1500	2	2.1	0.2	0.04	0.02	15.8
P8 (creek)	1500	19	1.7	0.2	0	0.04	16.1
2A	1700	1	2.1	0.2	0.12	0.04	18.2
P6 (creek)	1700	1	1.6	0.2	0.4	0.17	15.8
P7 (creek)	1700	1	1.9	0.2	0.06	0.04	15.8
P8 (creek)	1700	19	1.9	0.2	0.05	0.09	16.1
2A	1900	1	1.4	0.2	0.07	0.59	16.8
P7 (creek)	1900	4	2	0.2	0.03	0.06	15.1
P8 (creek)	1900	19	1.8	0.2	0.04	0.1	15.7
			August 29				
P4 (creek)	700	1				0.01	13.2
P7 (creek)	700	9				0.01	13.2
P8 (creek)	700	23				0	13.4
P4 (creek)	900	1				0	13.6
P7 (creek)	900	9				0	13.4
P8 (creek)	900	19				0	13.4
P4 (creek)	1100	1				0	14.8
P6 (creek)	1100	1				0.04	14.4
P7 (creek)	1100	7				0.03	14.6
P8 (creek)	1100	17				0	14.8
P4 (creek)	1300	1				0.28	15.5
P7 (creek)	1300	5				0	15.4
P8 (creek)	1300	17				0	15.8
P4 (creek)	1500	1	0.7	0.2	0.07	0.03	15.5
P7 (creek)	1500	5	1.8	0.2	0.09	0.02	15.7
P8 (creek)	1500	19	1.9	0.2	0.08	0	15.9
P4 (creek)	1700	1				0.09	15.7
P7 (creek)	1700	6				0.01	15.5
P8 (creek)	1700	19				0	15.6
P4 (creek)	1900	1				0.03	15.5
P6 (creek)	1900	1				0.05	15.2
P7 (creek)	1900	9				0.01	15.2
P8 (creek)	1900	17				0	15.3

Table 11 Habitat observations at Tom Martin Creek refugia, 2006.

Grid #	Time	DO ppm	Turb NTUs	[3]Substrate w/in 1ft Dom	SubD	Dist to Vel Cov[5]	Dist to Hid Cov[6]	None	Sml	Med	Lrg	OHV	R/UC	% of Cover Type[7] Turb	Wood
						July 27									
2A	1100			4	8		2						100		
2A	1300			4	8		2						100		
4A	1300			3	8		0					100			
6A	1300			8	3	1	4						100		
2A	1500			4	8								100		
4A	1500			8	3							100			
5A	1500			8	3	0.5	4					100			
2A	1700			4	8		6							100	
2A	1700			8	3		6					100			
4A	1700			8	3		0					100			
5A	1700			8	3		2					100			
7A	1700			4	8	1	4					100			
6B	1700			8	3	1	2						100		
4A	1900			8	3		0					100			
						August 2									
2A	700	9	1.8	5	4		2						100		
P7	700	10.1	0.44	5	7b		2				100				
P8	700	9.82	0.23	7b	4		2				100				
P6	900	12.6	0.30	5	4		4				100				
P7	900	12	0.46	7b	8		6				100				
P8	900	11.8	0.57	3	8		0					50			50
P6	1100	12.5	0.69	5	7b		6				50		50		
P7	1100	11.7	1.42	7b	8		3						100		
P8	1100	11.5	1.64	3	8		0					50			50
P6	1300	12.1	0.61	5	7b		6				50		50		
P8	1300	11.9	0.86	3	8		0					50			50
2A	1500	12	1.24	5	4		2						100		
P4	1500	11.8	1.21	8	7b		6						100		
P7A	1500	11.5	1.21	8	7b		0.5						100		
P7B	1500	11.8	1.2	7b	3		3						100		

Grid #	Time	DO ppm	Turb NTUs	[3]Substrate w/in 1ft		Dist to	Dist to	% of Cover Type[7]							
				Dom	SubD	Vel Cov[5]	Hid Cov[6]	None	Sml	Med	Lrg	OHV	R/UC	Turb	Wood
P8	1500	11.5	2.05	3	8		0					50			50
2A	1700	11.5	2.15	3	5		1.5						100		
P6	1700	11.7	0.55	5	8		1				50		50		
P7	1700	11.4	0.67	8	7b	0.5	0.5				50		50		
P8	1700	10.7	0.43	3	8		0					50			50
2A	1900	11.5	1.14	5	4		1.5						100		
P7	1900	11.3	0.7	8	7b		2						100		
P8	1900	9.69	0.76	3	8		0					50			50
						August 29									
P4	1500	10.8	0.57	3	4	0.5	0						100		
P7	1500	10.6	0.24	7b	3		2				100				
P8	1500	10.3	0.37	3	8		1					100			

[1]Substrate Code: **1**-veg/organics, **2**-mud/clay, **3**-silt, **4**-sand (<.3cm), **5**-gravel(.3-7cm), **6**-cobble(7-22.5cm), **7**-boulder(>40cm), **8**-bedrock

[2]Velocity Cover: presence or absence of a pronounced velocity barrier

[3]Hiding Cover: instream or out-of-water (w/in 18" of surface), not including turbulence, distance=0 if directly overhead

[4]Cover (w/in **4**' of fish): **Sml**-objects<15cm diameter, **Med**-objects 15-30cm, **Lrg**-objects>30cm, OHV-overhanging vegetation w/in 18" of surface, R/UC-rootwads or undercut banks, Turb-surface turbulence, Wood-woody debris

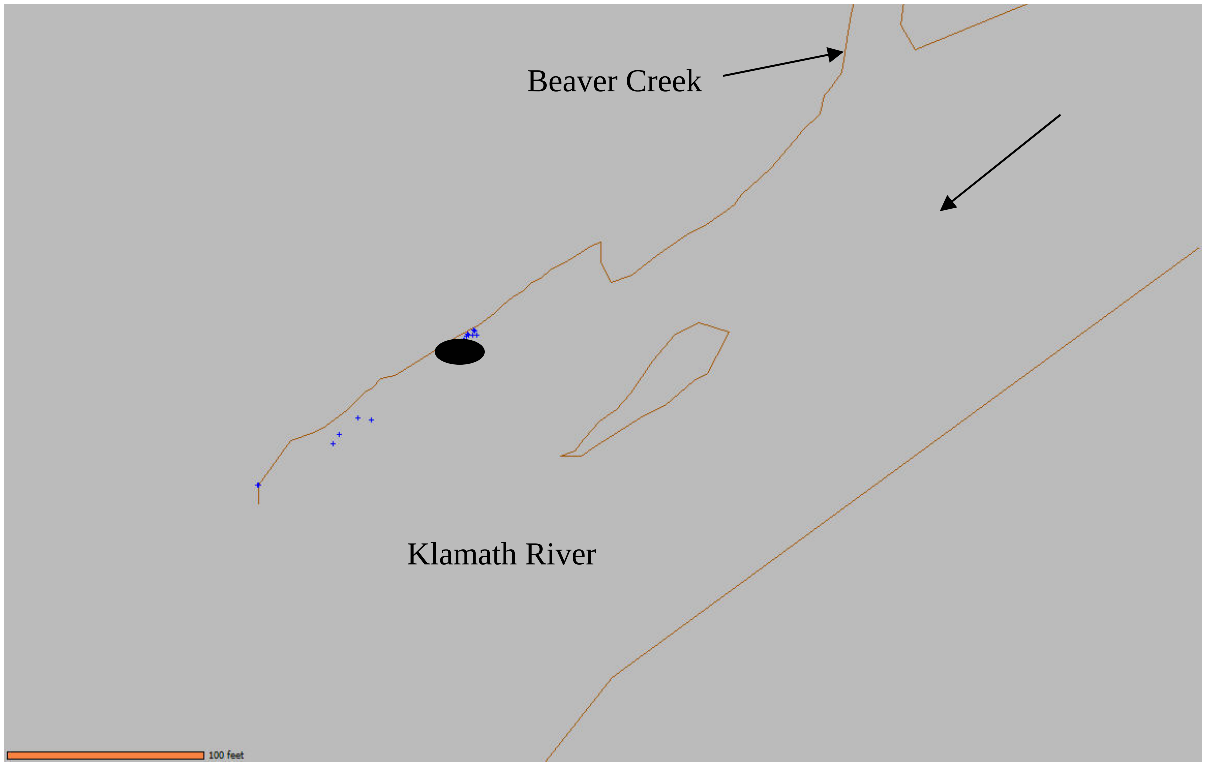


Figure 12 Map of 2006 Beaver Creek thermal refugia waters edge and locations of juvenile coho. Black oval indicates highest numbers (cells 12A, 13A, and 14A).

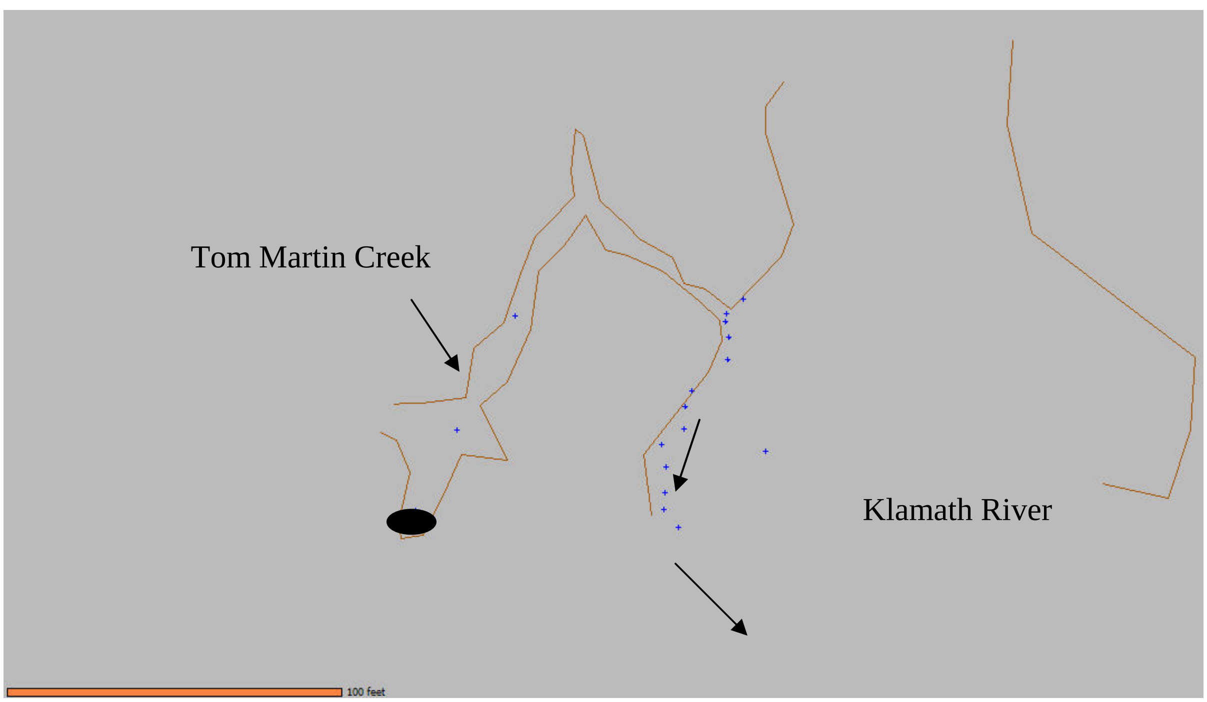
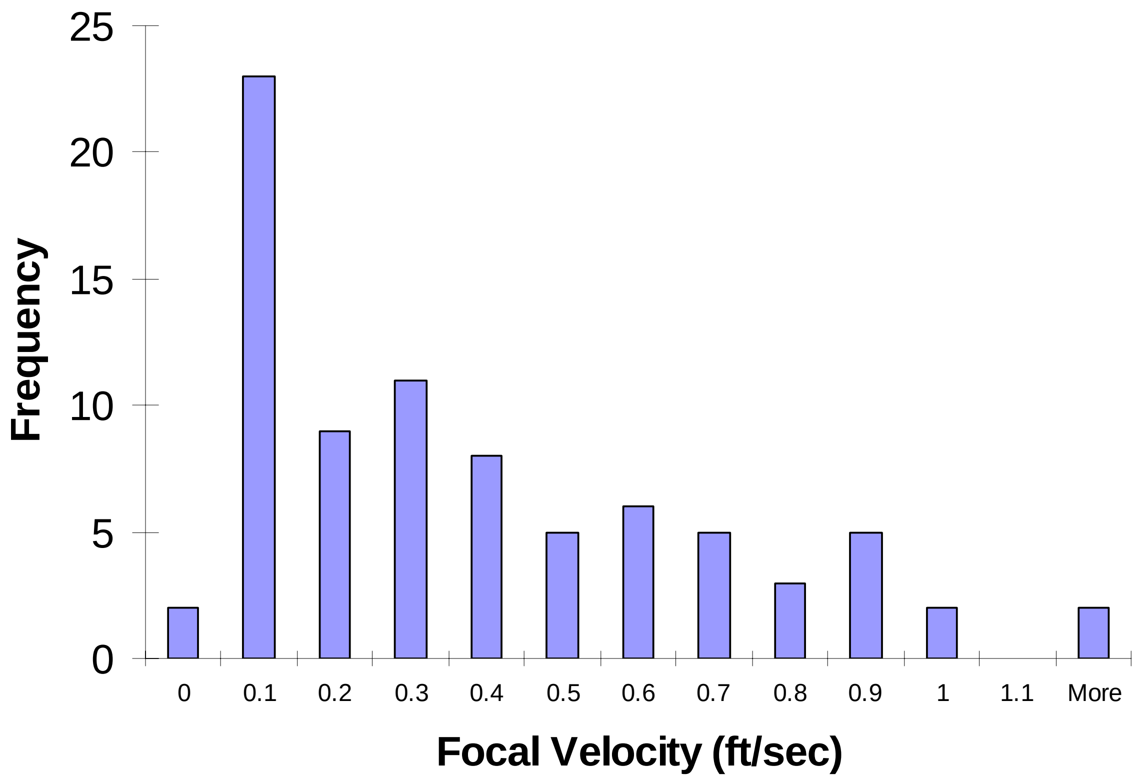


Figure 13 Map of 2006 Tom Martin Creek thermal refugia waters edge and locations of juvenile coho. Arrows in refugia indicate eddy. Black oval indicates highest numbers (cell P8).

Table 12 Temperatures and fish counts on July 26, 2006 at two fish count cells at the Beaver Creek refuge.

Time	K River temp ºC	Fish Temp ºC	# 0+ coho	Fish density #/sq m	Depth (ft)
Beaver Creek cell 12a					
700	-	-	0	0.0	-
900	23.8	20.6	3	0.5	3.2
1100	23.7	21.3	7	1.3	3.1
1300	-	-	0	0.0	-
1500	24.7	23.4	2	0.4	2.9
1700	25.2	23.7	4	0.7	3.6
1900	25.3	23.8	5	0.9	4.6
Beaver Creek cell 13a					
700	24.3	21.1	14	2.5	3.5
900	23.8	20.5	8	1.4	3.3
1100	23.7	21.0	6	1.1	3.9
1300	24.1	22.6	17	3.0	3.4
1500	24.7	23.3	16	2.9	4.5
1700	25.2	23.8	5	0.9	3.7
1900	25.3	23.4	3	0.5	3.5
Beaver Creek combined cells 12a and 13a					
700	24.3	21.1	14	1.3	3.5
900	23.8	20.6	11	1.0	3.3
1100	23.7	21.2	13	1.2	3.5
1300	24.1	22.6	17	1.5	3.4
1500	24.7	23.4	18	1.6	3.7
1700	25.2	23.8	9	0.8	3.7
1900	25.3	23.6	8	0.7	4.1

Figures 14 and 15 are pooled coho observation data taken from Beaver Creek and Tom Martin Creek refugia and Tom Martin Creek (Tables 8 and 10) that show coho frequency histograms for focal velocity and total depth. Examination of these figures indicates that most juvenile coho utilized focal velocities of about 0.1-0.2 ft/sec and 2-3 ft deep water (Figure 14 top). Further analysis was done using nonparametric tolerance limits to calculate juvenile coho habitat suitability criteria (HSC) for 81 non-repeat observations (i.e., one observation contains one or more coho). Bovee (1986) recommended that at least 150 data points where one or more fish are observed are typically needed to construct a reasonably smooth frequency histogram. Thus, our data set is not very robust. Results showed highest suitability index (SI=1.0) for mean column velocities ranged between 0.4 and 0.8 ft/sec (Figure 14) and depth ranged between 2.4 and 3.5 ft (Figure 15). In comparison, envelope HSCs developed by Hardy et al. (2006) indicated that juvenile coho mostly utilized mean column velocities of about 0.3-0.6 ft/sec and depth about 1.5-2.5 ft.



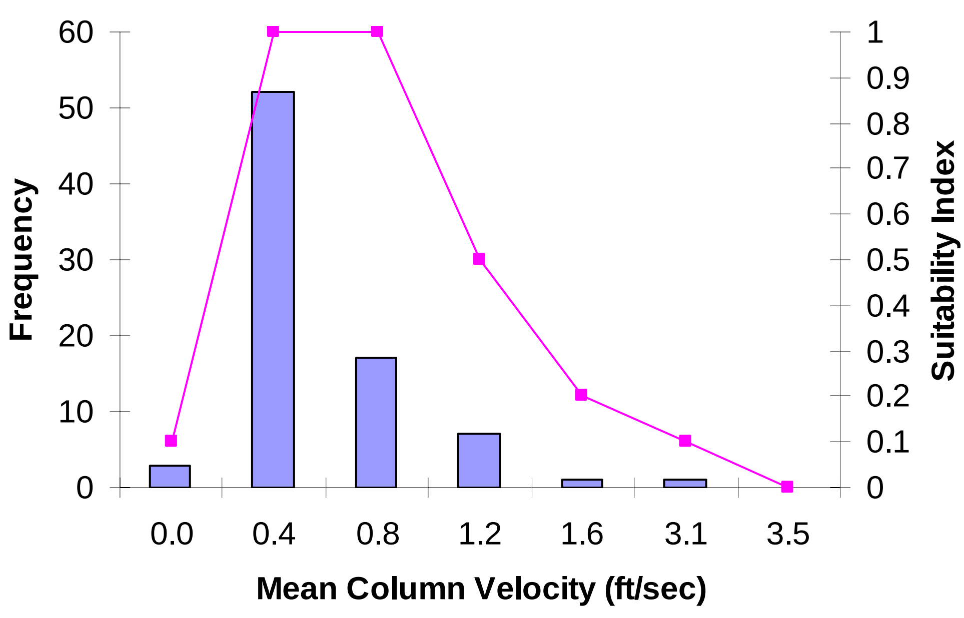


Figure 14 Frequency histogram of juvenile coho salmon focal velocities measured where coho were observed (top) and mean column velocities (bottom) in Beaver Creek and Tom Martin Creek thermal refugia and Tom Martin Creek, summer 2006 (pooled data).

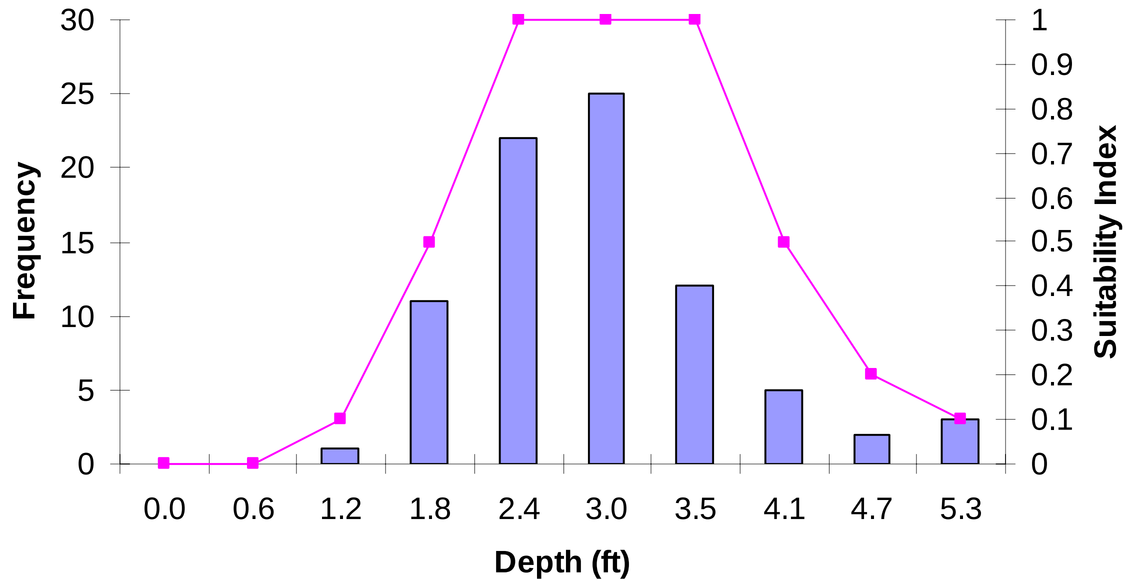


Figure 15 Frequency histogram and suitability index of juvenile coho salmon depths measured where coho were observed in Beaver Creek and Tom Martin Creek thermal refugia and Tom Martin Creek, summer 2006 (pooled data).

Examination of habitat characteristics of specific cells where most coho were located also provided insight into habitat utilization. For example, at the Beaver Creek refuge, most coho were concentrated in fish count cells 12A, 13A, and 14A (Table 8; Figure 12). These cells were next to each other and shared similar habitat characteristics (Table 13). However, the cell in Tom Martin Creek that consistently held the most coho (P8) was shallower with slower water and cooler temperatures than the cells in the Beaver Creek refuge (Table 13). One characteristic common among these cells in Beaver Creek and Tom Martin Creek was an abundance of cover (i.e., overhanging and wood) (Tables 9 and 11). Juvenile coho tend to prefer overhead cover and wood, especially in summer (Moyle 2002; Peters 1996; Hartman 1965). Peters (1996) concluded that the reason why juvenile coho were so tightly associated with wood during summer was to provide refuge cover from predators and not primarily as water velocity refuge.

Table 13 Habitat characteristics of cells where most juvenile coho were concentrated at Beaver Creek refuge and Tom Martin Creek.

Beaver Creek Refuge				
Cell	Depth (ft)	Mean Col Vel (ft/sec)	Focal Vel (ft/sec)	Temp ºC
12A				
Min	2.9	0.0	0.1	17.7
Max	4.6	0.6	0.6	23.8
Avg	3.4	0.3	0.3	21.4
13A				
Min	2.7	0.2	0.2	17.5
Max	4.5	1.0	1.0	23.8
Avg	3.3	0.5	0.6	20.8
14A				
Min	2.4	0.3	0.3	17.4
Max	5.0	1.0	1.1	22.7
Avg	3.7	0.6	0.6	20.6
Tom Martin Creek				
P8				
Min	1.7	0.0	0.0	12.8
Max	2.0	0.1	0.1	16.2
Avg	1.8	0.0	0.1	15.0

Escape cover is one issue that has been addressed in detail in the Klamath River for Chinook salmon fry (Hardy et al. 2006). Escape cover is defined as the riverine component that is used, or that could be used, for protection or concealment when fleeing from predators or a threat. Figure 16 shows 90 percent of juvenile coho were located within 6 feet of escape cover in the Beaver Creek and Tom Martin Creek refugia in 2006.

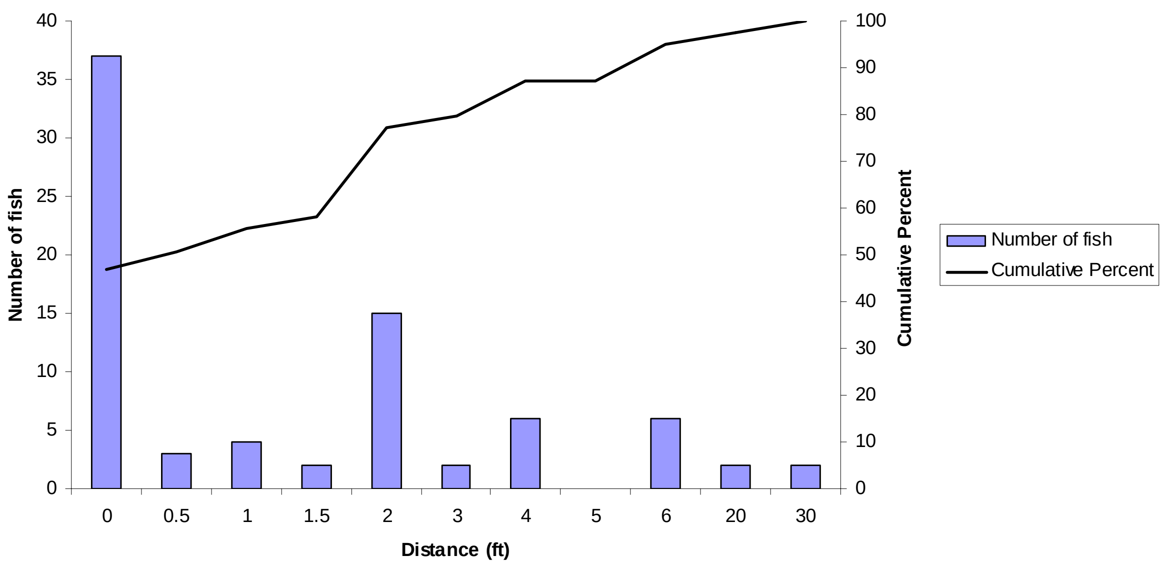


Figure 16 Juvenile coho distance to cover at Beaver Creek and Tom Martin Creek, summer 2006 (pooled data).

Recommendations

Based on results from the past three years of studies at thermal refugia on the Klamath River, the following study is recommended to better understand coho juvenile behavior in these areas:

Tracking movements of juvenile coho during June-early July would help determine at what mainstem temperatures coho start to move into thermal refugia. Tracking in late July – August within thermal refugia would help address the question about the fate of these fish in summer and fall (i.e., do they move into the tributaries, downstream, or do they succumb to high water temperatures). This study could possibly be an addition to the on-going winter study to assess fall-winter habitat utilization by juvenile coho salmon residing in the mainstem Klamath River and lower sections of tributaries. Summer upstream/downstream trapping is feasible in Tom Martin Creek and would give clues when coho move into the creek and possibly a summer survival estimate (Toz Soto, personal communication). Based on previous sampling with minnow traps and snorkeling which yielded no coho in Tom Martin Creek in January, fish may leave this creek and seek better overwinter habitat (Toz Soto, personal communication).

One method of tracking is radio telemetry based on success with this method on juvenile suckers in upper Klamath Lake. However, other trapping and marking methods may be useful, such as fyke nets, minnow trapping, PIT tagging or freeze branding. Added stress during capture and marking during summer conditions would need to be considered with these approaches. Since a weak year-class of young coho is expected in 2007, there will likely be too few wild coho to track. One option would be to test this method in 2007 by radio-tracking 20-30 juvenile coho obtained from the hatchery at IGD and planted into the Beaver Creek and Tom Martin Creek refugia. If radio-telemetry is successful using hatchery fish in 2007, then wild coho could be sampled and implanted with receivers in 2008 during an expected strong year-class. Partnership with the Karuk tribe is suggested because of their close proximity to the study area with oversight by Reclamation biologists. Tracking would involve an intense effort of monitoring which would have to be designed in partnership with the Karuk tribe. Additional sampling using snorkeling is not suggested except to locate transmitters that appear to stationary (e.g., dead fish). In addition to radio-tracking juvenile coho, temperature sensors would be deployed to monitor temperatures hourly within the refugia and the tributaries. Temperatures would also be measured where coho are located to determine if they are following a temperature gradient.

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