Daytime use of the Red Cap Creek thermal refuge by juvenile steelhead and Chinook salmon in the Klamath River, August 2005.

Klamath River Division
Yurok Tribal Fisheries Program
Box 196, Hwy 96, Weitchpec Route
Hoopa, CA 95546

Ryan L. Benson
and
Jamie E. Holt

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INTRODUCTION

The Klamath River, located in northwestern California, once had diverse and abundant anadromous fish runs thought to number in the millions. For countless years the river allowed native people to survive and thrive off abundant anadromous fish runs. Now, all of the anadromous fish species inhabiting the Klamath River are in a state of serious decline (Higgins et al. 1992, NRC 2004), especially those species or stocks which depend on summer fresh water aquatic habitat, such as Chinook salmon(*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), and steelhead (*O. mykiss*).

Poor water quality during the summer months is a major contributing factor in the decline of anadromous fish runs of the Klamath River (Bartholow 2005; NRC 2004). The Klamath River mainstem often reaches daytime maximum temperatures well over 25°C (Yurok Tribal Fisheries Program unpubl. data; Bartholow 2005); well above optimal temperatures for juvenile salmonids (Brett 1952; McCullough 1999; McCullough et al. 2001). In addition, other water quality parameters reach deleterious levels including pH, dissolved oxygen, and un-ionized ammonia (NCRWQCB 2003; Flint et al. 2004; YTEP 2005).

In many watersheds, adult and juvenile salmonids have been observed utilizing areas of cooler water, such as those found at the confluences of cold water tributaries, to escape potentially lethal water temperatures (Kaya et al. 1977; Bilby 1984; Ozaki 1988; Neilson 1994; Belchik 1997; Biro 1998; McCullough1999; Torgersen et al. 1999; Ebersole et al. 2001; Belchik and Turo 2002; Belchik 2003). These areas, known as thermal refugia, are thought to be important, because they allow fish to use mainstem habitats that otherwise would be unavailable to them due to high water temperatures, high pH, or other water quality conditions.

The National Research Council hypothesized that, "increase in [mainstem Klamath River] flows might reduce the size of these refugia by causing more effective mixing of the small amounts of locally derived cool water with much larger amounts of warm water from points upstream." (NRC 2002: pp 24-25). Based on this hypothesis, the National Marine Fisheries Service (NMFS) directed the Bureau of Reclamation (BOR) to conduct evaluations of thermal refugial areas. These studies have taken on two broad topics: the physical characteristics of certain thermal refugial areas, and the biological significance of these areas. The Yurok Tribal Fisheries Program (YTFP) explored the biological significance of this hypothesis by documenting salmonid use of coldwater refugia under different flow conditions from Iron Gate Dam (IGD). The objective was to monitor diurnal changes in salmonid use of Red Cap Creek thermal refuge throughout the hottest summer periods and as mainstem discharge changed. This is study has been ongoing since 2002. This report presents results from 2005 sampling efforts.

MATERIALS and METHODS

Four snorkel surveys were made at the Red Cap Creek thermal refuge, located at river kilometer (RKM) 85.10, in July and August 2005 (Fig. 1). Survey dates were the following: 26 July, 2 August, 10 August, and 18 August. No night dives were conducted. Fish were classified and enumerated by life stage and species according to the following classification: Chinook and coho were classified as 0+, 1+, jack, and adult. Steelhead were classified as 0+, 1+, 2+/half pounder (HP), and adult. All salmonids were separated into two major groups: juveniles and adults. Jacks, 2+/HP and adults were all classified as adults, while 0+, 1+ were classified as juvenile (Table 1).

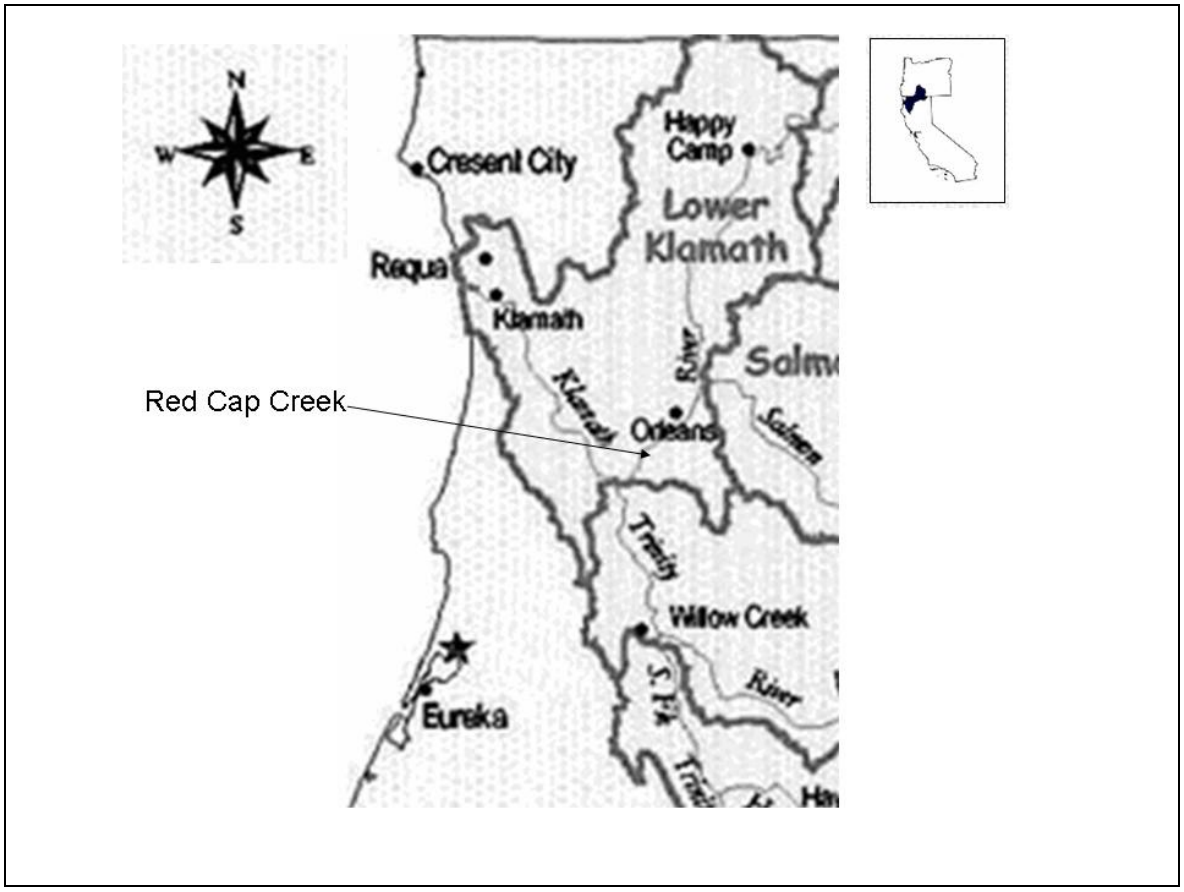

Figure 1. Red Cap Creek thermal refuge study area and its location in the Klamath River Basin, California.

Table 1. Delineation of size classes for salmonids observed in Red Cap Creek thermal refuge.

Species	Life stage	Fork length
steelhead	0+	<15cm
	1+	15-30cm
	HP/2+	30-70cm
	Adult	>70cm
Chinook and coho	0+	<15cm
	1+	15-30cm
	Jack	30-50cm
	Adult	>50cm

After completing each snorkel survey water temperatures were recorded to 0.1 °C with an Oakton Acorn 5 Series temperature meter, calibrated according to company directions before each snorkel sample period. Water temperatures were taken in Red Cap Creek and in the mainstem Klamath River 90 m upstream of the creek confluence. We compiled river flow from United States Geological Survey and California Department of Water Resources gauging stations. Gauge data used for this analysis were compiled from stations upstream of Red Cap Creek (RKM 85.10) at IGD (no. 11516530) (RKM 308.00) and Orleans (no. 11523000) (RKM 95.00).

Fish counts were conducted using a block method. Divers counted fish in blocks or groups and worked their way through the survey area. A counting hierarchy was established to assist divers with counting large blocks or groups of fish in a confined area (Table 2).

Table 2. Counting method for different sized groups of salmonids.

Approximate number of fish	Counting method
<50 fish	observe exact amount
50-100 fish	count fish in 10 fish increments
100-500 fish	count fish in 50 fish increments
500> fish	count fish in 100 fish increments

Horizontal and vertical visibility was measured in arm lengths, with one arm length equaling approximately 3 ft of visibility (Table 3). Visibility was measured out to the shear line, the transition zone between creek and river water, approximately 9 m from shoreline.

Table 3. Classification of visibility measurements in Red Cap Creek refuge.

Visibility classification	Distance
Poor	1-3'
Fair	3-6'
Good	6' >

Fish locations were also documented at a finer scale. The thermal refugial area was partitioned into four different sections: 1) lower refuge, 2) middle refuge, 3) plume of creek, 4) upper refuge (Figure 2). The total number of salmonids in each section along with the number of each species and size class was recorded for each of the four sections in the thermal refuge.

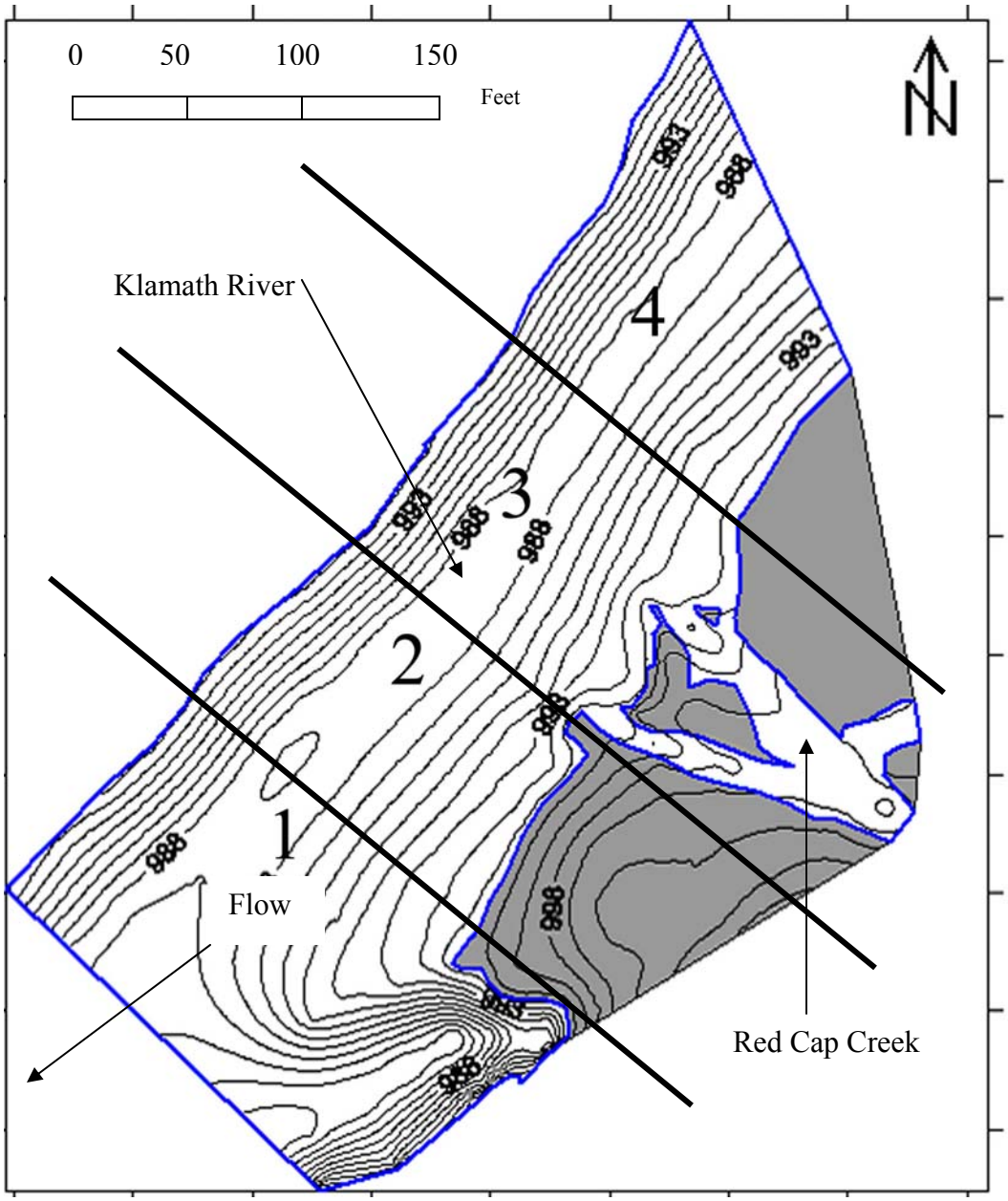

Figure 2. Site map for the Red Cap Creek (RKM 85.1) thermal refuge study area delineated into dive areas: 1) lower refuge; 2) middle refuge; 3) plume of creek; 4) upper refuge. Isobath intervals are 1 foot.

RESULTS

Survey Period One

During the first survey period on 26 July, 2005, the total number of Chinook and steelhead observed during the morning hours (8:00 and 10:00) progressively increased, then decreased slightly by 12:00. During the afternoon and evening hours overall fish usage plateaued with approximately 1,000 salmonids utilizing the refuge (Table 4).

Table 4. Water temperatures and total steelhead and Chinook salmon observed in the Red Cap Creek thermal refuge on 26 July, 2005.

Steelhead							
Time	Creek temp (˚C)	River temp (˚C)	Area 1	Area 2	Area 3	Area 4	Total
8:00	16.1	22.9	25	20	0	120	165
10:00	16.9	22.9	22	21	192	16	256
12:00	18.8	23.4	17	52	66	21	156
14:00	19.5	24.0	7	21	179	0	207
16:00	19.5	24.4	0	0	374	0	374
17:15	19.1	24.4	0	0	415	0	415
Chinook							
Time	Creek temp (˚C)	River temp (˚C)	Area 1	Area 2	Area 3	Area 4	Total
8:00	16.1	22.9	5	0	85	120	210
10:00	16.9	22.9	5	65	155	0	225
12:00	18.8	23.4	0	50	200	0	250
14:00	19.5	24.0	0	0	425	0	425
16:00	19.5	24.4	0	0	670	0	670
17:15	19.1	24.4	0	0	610	0	610

Flow below IGD was 925 cfs on 26 July during survey period one. Flow at the Orleans gauge was 2,465 cfs. Mean daily water temperatures were 23.7ºC for the mainstem Klamath River and 18.3ºC for Red Cap Creek. The refuge offered good visibility of 8-9 ft. throughout sample period 1.

Fish were actively feeding throughout the refugial area during the morning hours. During the afternoon and evening hours (16:00-17:15) salmonids were condensed towards the immediate plume of the creek (section 3, Fig. 2).

Survey Period Two

The second survey period occurred on 2 August, 2005. Over the course of the morning snorkel observations (8:00, 10:00, and 12:00) we observed an increase in the

number of Chinook and steelhead within the thermal refuge. During the afternoon and evening dives (12:00 to 17:40), overall fish usage plateaued with approximately 650 to 750 salmonids in the refuge (Table 5).

Table 5. Total steelhead and Chinook salmon observed in the Red Cap Creek thermal refuge on 2 August, 2005.

Steelhead							
Time	Creek temp (˚C)	River temp (˚C)	Area 1	Area 2	Area 3	Area 4	Total
8:00	17.2	23.2	8	19	249	2	278
10:00	17.3	23.2	27	23	306	6	362
12:00	18.5	24.0	4	15	363	3	385
14:00	19.9	24.6	3	11	342	2	358
16:00	20.6	25.0	3	15	342	1	361
17:40	20.9	24.9	6	8	328	7	349
Chinook							
Time	Creek temp (˚C)	River temp (˚C)	Area 1	Area 2	Area 3	Area 4	Total
8:00	17.2	23.2	17	5	7	0	29
10:00	17.3	23.2	53	6	15	0	74
12:00	18.5	24.0	11	1	250	0	262
14:00	19.9	24.6	0	0	300	0	300
16:00	20.6	25.0	1	0	350	0	351
17:40	20.9	24.9	0	0	300	1	301

Flow of the mainstem Klamath River was 1026 cfs below IGD and 2,330 cfs at Orleans. Air temperature recorded at the start of the snorkel survey (8:00) was 16.3ºC. Air temperature recorded at the conclusion of the observation period was 33.9ºC. Maximum daytime air temperature was 35.0ºC at 14:00. The mean daily Klamath River mainstem temperature was 24.2ºC and the mean daily Red Cap Creek temperature was 19.1ºC, recorded between 8:00 to 17:40. Visibility was good in the refugial plume and fair outside of the creek influence.

Fish were observed actively feeding throughout the study area during the morning dives (8:00 and 10:00). During the morning surveys we observed Chinook actively feeding on top of the water column and steelhead actively feeding on the bottom portion of the water column. Throughout the morning dives, Chinook and steelhead remained segregated. During the afternoon snorkel observations (14:00 to 17:40) both Chinook and steelhead were mixed within the immediate plume of Red Cap Creek .

Survey Period Three

The third survey period occurred on 10 August, 2005. Total salmonid numbers were somewhat higher at 8:00, dropped slightly at 10:00, then gradually increased until 16:00 (Table 6). Numbers peaked during the 16:00 dive, with a maximum of 726. Generally, more steelhead were present than Chinook salmon, with Chinook counts averaging approximately 50% less than steelhead counts throughout the survey period, particularly late in the day.

Table 6. Total steelhead and Chinook salmon observed in the Red Cap Creek thermal refuge on 10 August, 2005.

Steelhead							
Time	Creek temp (˚C)	River temp (˚C)	Area 1	Area 2	Area 3	Area 4	Total
8:00	16.8	22.8	30	31	230	24	315
10:00	17.2	23.1	19	20	247	4	290
12:00	18.0	23.6	10	31	332	5	378
14:00	19.5	25.5	9	14	403	3	429
16:00	20.0	25.7	3	15	486	2	506
17:40	20.5	24.9	5	20	445	2	472
Chinook							
Time	Creek temp (˚C)	River temp (˚C)	Area 1	Area 2	Area 3	Area 4	Total
8:00	16.8	22.8	38	42	110	3	193
10:00	17.2	23.1	39	45	105	1	190
12:00	18.0	23.6	15	13	180	0	208
14:00	19.5	25.5	0	0	205	0	205
16:00	20.0	25.7	0	0	220	0	220
17:40	20.5	24.9	0	0	200	0	200

Flow of the mainstem Klamath River was 1,010 cfs below IGD and 2,161 cfs at Orleans. The average air temperature was 29.2ºC. The mean daily Klamath River mainstem temperature was 24.3ºC and the mean daily Red Cap Creek temperature was 18.7ºC, recorded between 8:00 to 17:40. Generally, visibility was fair to good in the direct refugial plume but was poor outside the immediate creek influence and in the mainstem. Lower visibility was likely due to high turbidity and the green coloration of the river, possibly due to elevated levels of algae in the river.

Fish were noted as actively feeding throughout the morning (8:00) snorkel survey. Once again snorkelers observed that Chinook were on the upper portion of the water column and steelhead remained toward the bottom of the water column during the earlier (8:00 and 10:00) observations. During the later observations salmonids were observed intermixing and utilizing the immediate plume of Red Cap Creek.

Survey Period Four

The fourth and final sample period was on 18 August, 2005. Salmonid presence remained relatively stable throughout the day, with total salmonid counts ranging from 547 to 660 (Table 7). Chinook salmon numbers were slightly less than steelhead presence, with Chinook counts averaging 31% less than steelhead counts throughout the day. Highest fish usage was observed during the 16:00 and 17:00 dives, with total number of fish present equaling 652 and 660, respectively.

Table 7. Total steelhead and Chinook salmon observed in the Red Cap Creek thermal refuge on 18 August, 2005.

Steelhead							
Time	Creek temp (˚C)	River temp (˚C)	Area 1	Area 2	Area 3	Area 4	Total
8:00	17.0	22.6	35	21	264	5	325
10:00	17.1	22.8	26	65	282	8	381
12:00	18.9	23.0	7	26	279	13	325
14:00	19.4	24.1	11	6	362	16	395
16:00	20.8	24.7	10	8	334	17	369
17:00	20.3	24.6	8	11	307	16	342
Chinook							
Time	Creek temp (˚C)	River temp (˚C)	Area 1	Area 2	Area 3	Area 4	Total
8:00	17.0	22.6	35	40	160	6	241
10:00	17.1	22.8	25	30	175	6	236
12:00	18.9	23.0	6	17	195	4	222
14:00	19.4	24.1	3	0	250	4	257
16:00	20.8	24.7	0	0	290	1	291
17:00	20.3	24.6	0	0	225	3	228

Flow of the mainstem Klamath River was 989 cfs below IGD and 2,044 cfs at Orleans. The average air temperature was 27.3ºC. The mean daily Klamath River mainstem temperature was 23.6ºC and the mean daily Red Cap Creek temperature was 18.9ºC, recorded between 8:00 to 17:00. Visibility was fair in the refuge including the direct creek plume and mixing zone while poor everywhere else. Visibility was poorest during sample period four compared to all other sample periods.

Flow releases from IGD generally decreased over the duration of the study, with the exception of the first and second survey periods, in which flow increased 11% (Table 8). Flow at Orleans decreased 5-7% each survey period (Table 8). In contrast, IGD flows in 2004 increased during the study. Flow at Orleans generally increased, with the exception of the first and second survey periods, where flow decreased 3% (Table 8).

Table 8. Summary of flows at IGD and Orleans and the relative change between survey periods at the Red Cap Creek thermal refuge, 2005. Flow summary for 2004 have been included for comparison.

Survey date	IGD flow (cfs)	% change	Orleans flow (cfs)	% change
26-Jul-05	925		2,465	
2-Aug-05	1,026	+ 11	2,330	- 5
10-Aug-05	1,010	- 2	2,161	- 7
18-Aug-05	989	- 2	2,044	- 5
10-Aug-04	615		1,417	
12-Aug-04	615	0	1,375	- 3
24-Aug-04	896	+ 46	1,517	+ 10
30-Aug-04	911	+ 2	1,744	+ 15

DISCUSSION

Steelhead and Chinook salmon use of the Red Cap Creek thermal refuge was correlated with mainstem Klamath River temperatures during the study period. Typically, the months July and August encompass the hottest time of the year in the Klamath Basin. Salmonid presence in the refuge paralleled diurnal fluctuations in river temperature. Water temperatures have shown to be a strong determinant of fish utilization (Belchik 2003; Belchik & Turo 2002). No coho salmon were observed throughout the duration of the study, which is consistent with previous years (Belchik 2003; Belchik & Turo 2002).

Total salmonid and juvenile salmonid abundance in the Red Cap Creek thermal refuge exhibited a pattern of increased fish utilization corresponding with elevated mainstem Klamath River temperatures (Fig. 3a). This pattern was similar in 2004, with the exception of the first sample period, 10 August, 2004 (Fig. 3b), when salmonid abundance was greatest during the morning dives and river temperature was lower (salmonid abundance versus mainstem temperature for 2004 is included for comparison (Fig. 3b)). Salmonid abundance in the Red Cap Creek thermal refuge ranged from 215 to 2,400 for all survey periods in 2003 (Holt et al. 2003).

Fig. 3(a)

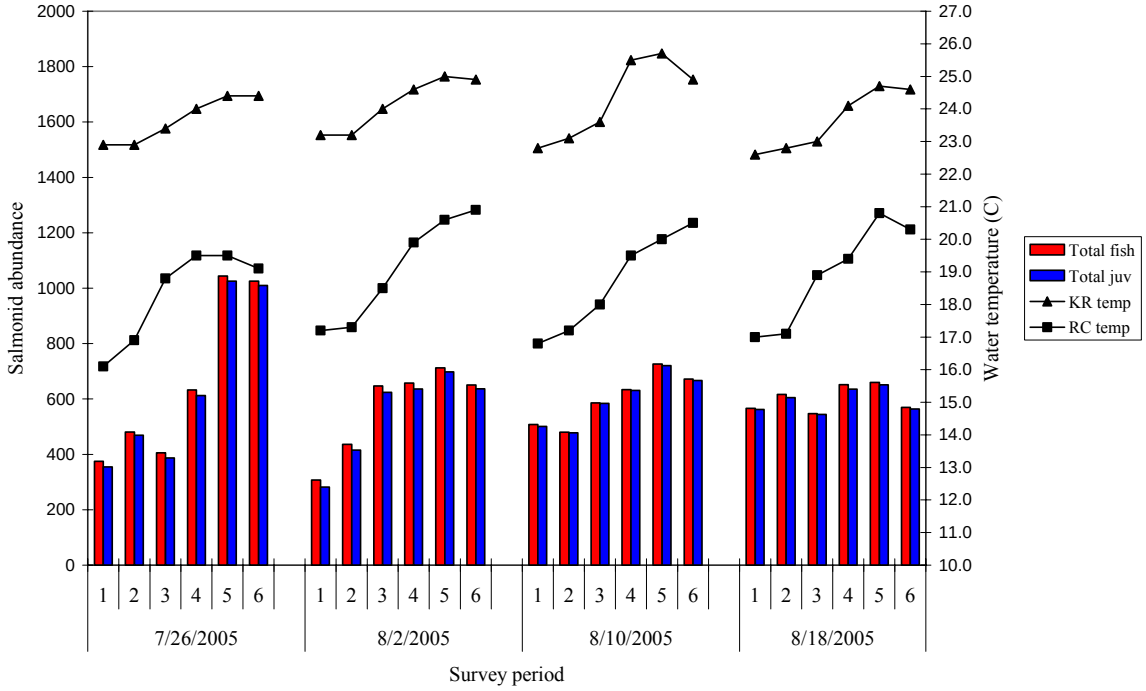

Fig. 3(b)

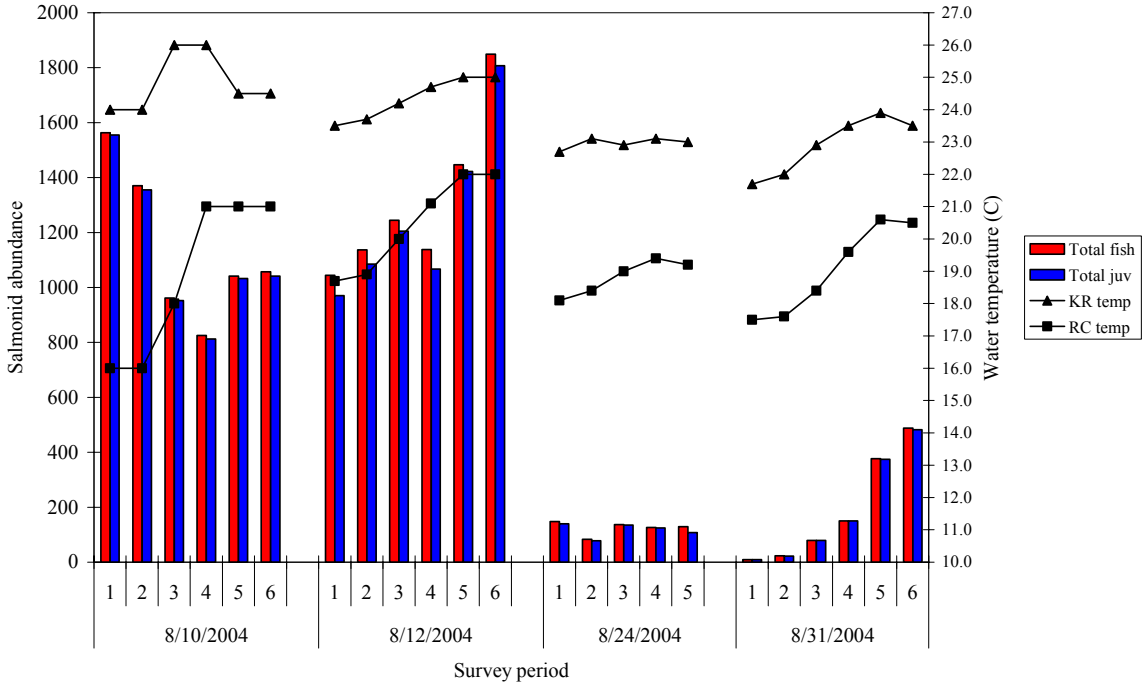

Figure 3. Total salmonid and juvenile salmonid abundance relative to Klamath River and Red Cap Creek temperature at Red Cap Creek thermal refuge in 2005 (a) and 2004 (b). Data for 2004 from Belchik et al. (in press).

These results are comparable to observations conducted in 2004. However, a cold storm system moved into the area in late August 2004, resulting in lower ambient air temperatures and reduced insolation and thus, lower water temperatures (Belchik et al. in press). Lower mainstem river temperatures resulted in lower presence of both steelhead and Chinook.

Data from 2004 and 2005 provides an example of different river temperature scenarios. The thermal history for the mainstem Klamath River illustrates that during the 2005 study period, temperatures consistently remained above 23°C, whereas two cooling trends in 2004 resulted in temperatures below this threshold (Fig. 4). Weather and ambient air temperatures in 2005 remained relatively hot and stable during the study period, without the influence of a cold weather system such as occurred in 2004. As a result, patterns of salmonid refuge use remained stable throughout the month of August. In contrast, refuge use in 2004 dropped significantly when river temperature dropped below the 23°C (Belchik et al. in press).

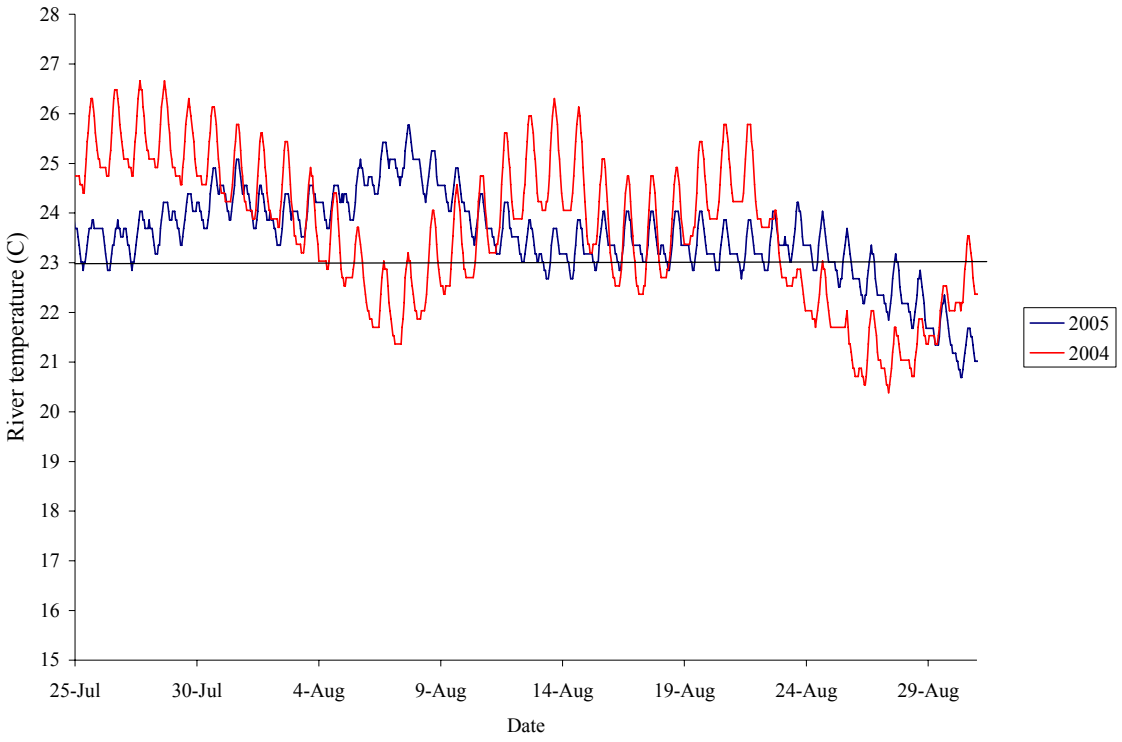

Figure 4. Thermograph for the Klamath River upstream of Red Cap Creek during the 2004 and 2005 study period. The horizontal line represents the 23°C temperature threshold.

Published values for optimal temperature ranges for juvenile Chinook and steelhead growth is 15 -20ºC (McCullough et al. 2001), but salmonids in the Klamath River are often observed leaving a refugial area and utilizing the mainstem at temperatures up to 22ºC. When mainstem Klamath temperatures reach and surpass 23ºC fish usage in the refugial areas climbs sharply (Belchik and Turo 2002; Belchik 2003).

A scatter plot of salmonid abundance versus mainstem river temperature demonstrates a pattern of increased fish abundance in the thermal refuge as temperature increases (Fig. 5). Data from 2004 and 2005 indicate a temperature threshold range of 22.5 ºC to 23ºC. Above this threshold, salmonid abundance dramatically increases (Fig. 5).

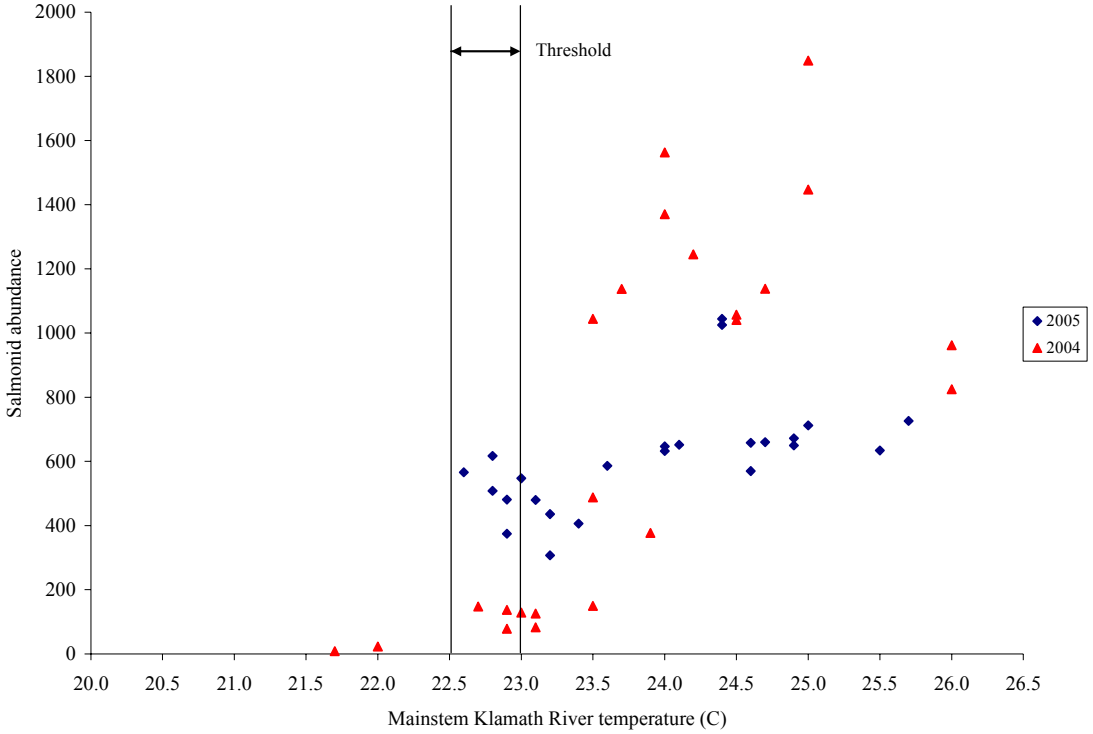

Figure 5. Relationship between mainstem Klamath River instantaneous temperature and salmonid abundance at Red Cap Creek thermal refuge, 2004 and 2005. The vertical bar represents a 22.5 - 23°C temperature threshold range based on YTFP unpublished data.

Juvenile salmonid behavior appears to be sensitive to minor changes in temperature. For example, behavioral observations show that juvenile steelhead and Chinook remained vertically segregated with Chinook on top in the morning hours when mainstem temperatures were below 23°C. As the day progressed and river temperatures increased, juvenile steelhead and Chinook tended to crowd together closer to the inflow of the creek plume, where temperatures were coolest. Salmonids of all species crowded together as water temperature increased. In addition, fish were observed feeding more in the morning and tended to cease feeding and concentrate at the plume inflow when mainstem temperatures ranged from 23.6°C to 25°C. When temperatures reach this range, fish are no longer feeding and are consuming energy reserves. Thus, from a bioenergetic standpoint, it is critical to avoid the high mainstem temperatures (Brett et al. 1982)

Our data confirms that there is no direct relationship between salmonid abundance at the Red Cap Creek thermal refuge and mainstem Klamath River flows (Fig. 6).

Observations in 2004 indicate highly variable salmonid abundance under the same flow conditions due to the overriding influence of temperature. For example, low fish abundance in the refuge was temperature driven via cooler ambient air and water temperature. Observations from 2005 suggest equivalent salmonid abundance under different flow scenarios (Fig. 6). Mean salmonid abundance was not significantly different when flow was 2,044 cfs versus 2,465 cfs, a 17% change (paired t-test, P ($\alpha_{0.05}$) = 0.32). Salmonid abundance displayed a higher range of variance at increased flows.

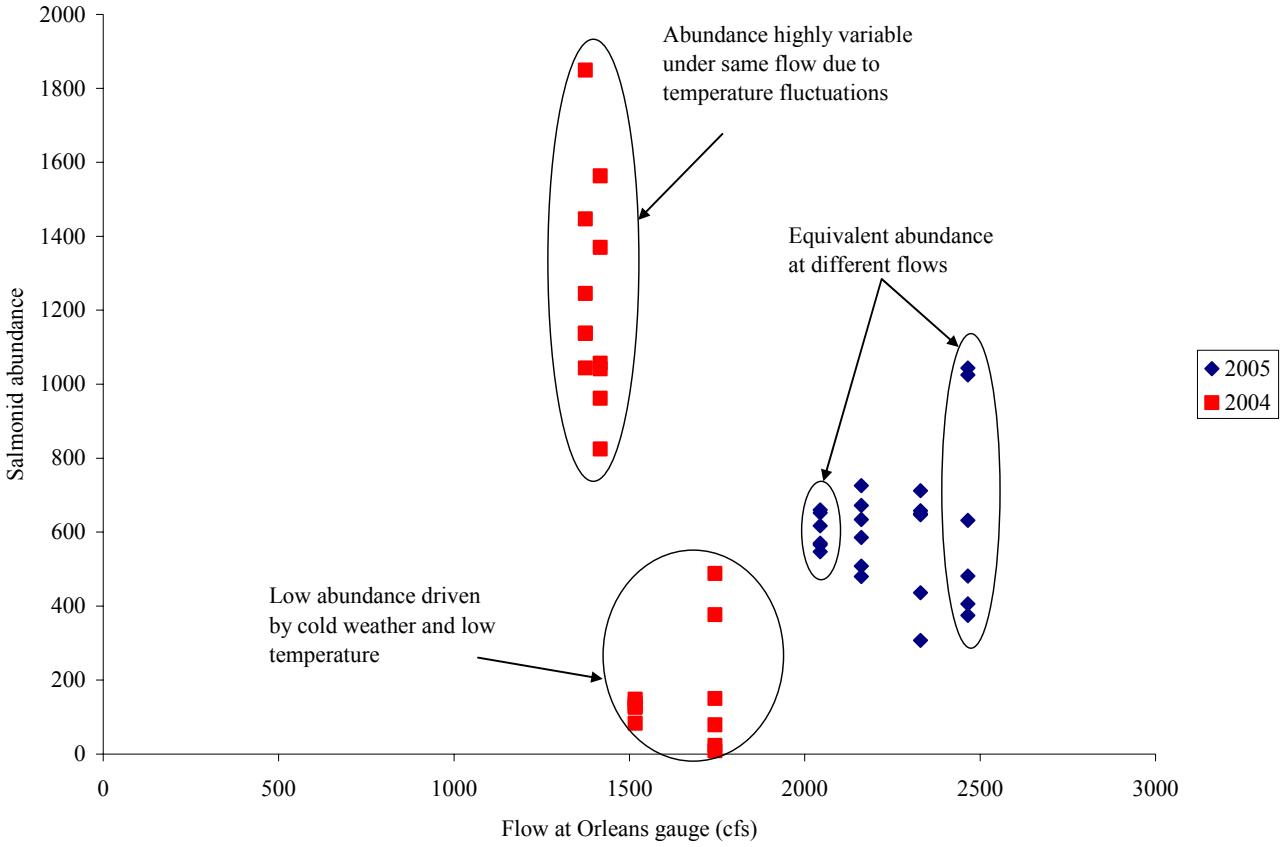

Figure 6. Relationship between flow at Orleans vs. salmonid abundance at Red Cap Creek thermal refuge, 2004 and 2005.

Our data does not support the NRC hypotheses that increases in mainstem Klamath River flows may reduce the size of refugia and harm juveniles by forcing them into the warmer mainstem (NRC 2002). If these hypotheses were true, the data would indicate a negative relationship between mainstem flow and salmonid abundance, but the results indicate no such relationship (Fig. 6). In contrast, observations at Red Cap Creek thermal refuge show that salmonid use is temperature dependent. Although the change in physical attributes of thermal refugia in response to changes in mainstem flows was beyond the scope of this study, our results show there is no decrease in the biological effectiveness (as measured by salmonid abundance) of thermal refugia as mainstem Klamath River flows increase, even if the size of the refugia decreased.

Changes in flows in 2005 were large enough and within the range of reasonably possible releases to result in changes to the physical nature of the refuge (Deas et al. 2006). However, we observed no significant change in abundance at the Red Cap Creek refuge with a 17.1% change in flow at Orleans.

In summary, thermal refugia are critical to the survival of salmonids by providing an area of significantly lower temperatures during the summer months when mainstem Klamath River temperatures exceed their thermal tolerances. Meteorological conditions, as influenced by water volume and discharge dynamics, govern mainstem temperatures (Sinokort and Stefan 1993) and thus salmonid use of thermal refugia. The biological function of Red Cap Creek refuge was not directly affected by varying flows from IGD, even if the physical size of the refuge was decreased. Observed increases in flow were not high enough to "wash out" the Red Cap refuge, however, under reasonably possible flow release scenarios from IGD, such an occurrence is unlikely. Even though reducing the physical size (surface area) of thermal refugia via higher flows does not affect the biological function of refugia, in contrast, increased IGD flow may facilitate access to other cold-water influences that would otherwise be inaccessible under lower flows. For example, cold-water springs in the vicinity of Red Cap and Beaver creeks could provide thermal refuge for salmonids if the river stage was high enough to reach them (A. Corum, Karuk Dept. of Natural Resources, personal communication; YTFP, unpublished data). In conclusion, increased mainstem Klamath River flows do not negatively affect the biological function of thermal refugia and may potentially increase access at some sites.

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