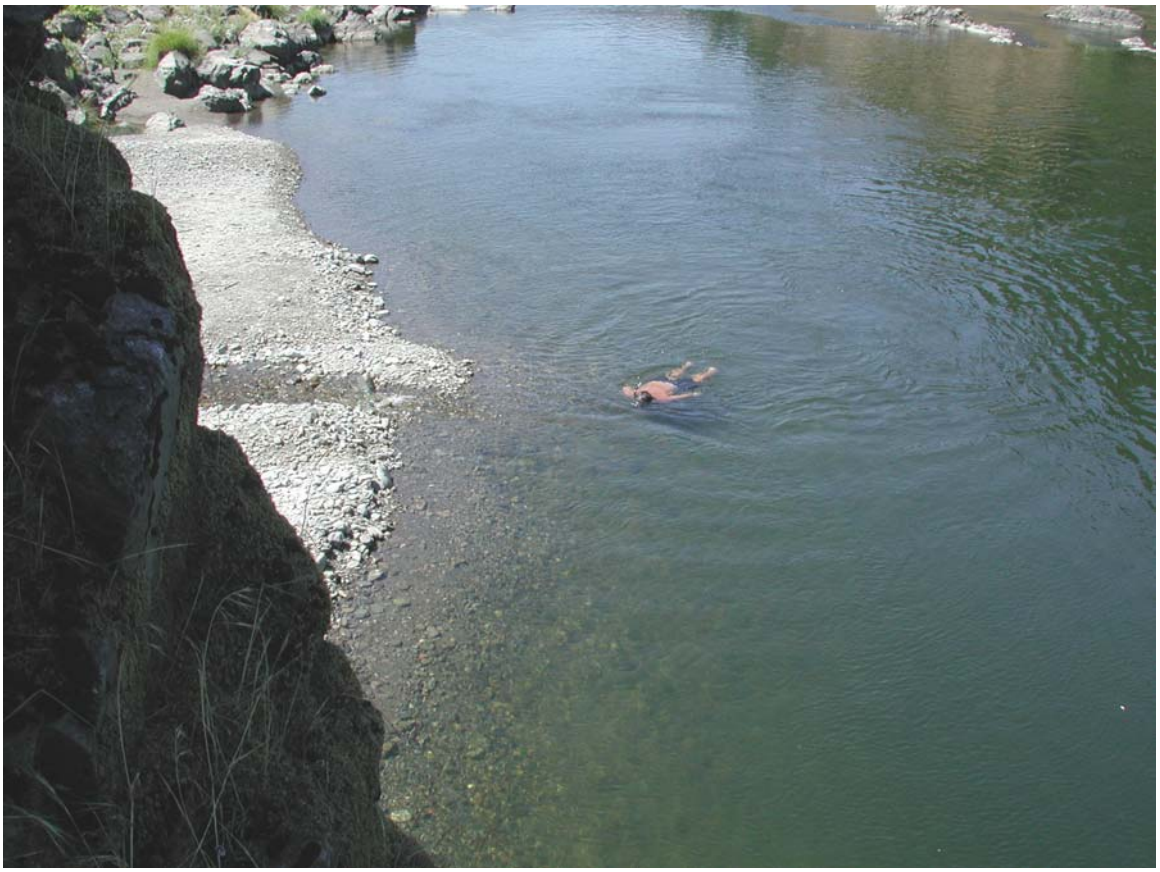
Use of Thermal Refugial Areas on the Klamath River by Juvenile Salmonids; Summer 1998



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Abstract

During the summer of 1998, the Yurok Tribal Fisheries Program observed and documented salmonid use of thermal refugial areas located near the mouths of cool-water tributaries in the Klamath River from Iron Gate Dam to Bluff Creek. Juvenile Chinook salmon and juvenile steelhead were observed making extensive use of these areas during the summer months. No coho were observed using these areas, despite searching, and crew training. 24 hour observations revealed that juvenile fish leave refugial areas and make extensive use of nearby mainstem areas, presumably to take advantage of the greater food resources located in the mainstem Klamath. Physical measurements revealed a great diversity in size of refugial areas; from 4 m^2 to 1750 m^2, and refugial areas showed a great deal of variability with regard to habitat complexity. When flow releases at Iron Gate Dam were increased from 1140 to 1390 cfs, the refugial area located at the mouth of Indian Creek was reduced in aerial extent and volume, but still appeared to be functioning as a viable refugial area.

Introduction

The Klamath River, located in northwestern California, once had diverse abundant anadromous fish runs thought to number in the millions. Now, all of the anadromous fish species inhabiting the Klamath River are in a state of serious decline (Higgins et al 1992, NRC 2003), especially those species or stocks which depend on summer fresh water aquatic habitat, such as coho salmon, steelhead, or spring chinook.

In the Klamath River, poor water quality conditions during the summer season have been recognized as a major contributing factor to the decline of anadromous fish runs (Bartholow 1995, NRC 2003). The Klamath River mainstem often reaches daytime maximum temperatures well over 25°C (Yurok Tribal Fisheries Program unpubl. data, Bartholow 1995); well above optimal temperatures for juvenile salmonids (Brett 1952). 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 1978, Bilby 1984, Ozaki 1988, Neilson 1994, Belchik 1997, Biro 1998, Torgersen et al 1999, Ebersole et al. 2001, Ebersole et al. 2003). These areas, known as thermal refugia, are thought to be important, because they allow fish to utilize mainstem habitats that otherwise would be unavailable to them due to high water temperatures.

In 1996, the Yurok Tribal Fisheries Program searched the mainstem Klamath for areas of cool water that might provide refuge from high water temperatures for juvenile salmonids in the area from Iron Gate Dam, (the upper limit of current anadromous migration), down to Seiad Valley approximately 60 mi. downstream (Belchik 1997). In that survey, it was found that the major areas of cold water occur at cold water tributary mouths, and that there is apparently little or no thermal refuge provided by 1) through gravel flow, 2) groundwater contributions, 3) thermal stratification of pools, or 4) shaded riparian areas.

In the 1996 thermal refugia survey, it was observed that juvenile fish did indeed concentrate in areas of cool water inflow during July, August and September. That study also showed that the cold tributary inputs provide thermal diversity to otherwise warm Klamath River mainstem water temperatures. Given that the species in the Klamath Basin that are showing the most depressed populations levels are those that depend in some way on summertime freshwater habitats (Weitkamp 1995), these areas of cool water likely play a key role in the functioning of the Klamath aquatic ecosystem during times of warmer water temperatures (Belchik 1997, NRC 2003).

Until this study, the distribution and abundance of various species of anadromous salmonids within these areas on the Klamath River remained unknown. Furthermore, it was unknown how that distribution and abundance changed with time on both seasonal and daily time scales. Finally, the physical attributes of these areas had not been quantified or investigated. Answering those questions was the focus of this study.

Materials and Methods

Based on the previous work done by Belchik (1997), this study focused on acquiring data on salmonid use and physical characteristics of major cold water tributary confluences in the Klamath River mainstem from Iron Gate Dam (river mile 190) to Bluff Creek (river mile 45) (Figures 1 and 2). This focus was chosen as a result of the 1996 surveys which showed that tributary confluences are the major cool water refugial areas in the mainstem Klamath.

Data was collected from all major cold water tributary confluences above the confluence of the Trinity River with the exception of Clear Creek and the mouth of the Salmon River where no data was collected out of respect for Karuk Tribe cultural and ceremonial use of those areas. Data was also not collected at tributary confluences downstream from the Trinity River due to lack of road access and logistical concerns. Major cold water tributaries in this unsampled area include Pine, Pecwan, Blue and Hunter Creeks. Fish usage observations were conducted from July 1 to September 16, 1998. The sampling areas, dates, and types of data collected at each area are summarized in Table 1. In addition to sampling major sites (the larger cold water tributaries), we sampled selected smaller creeks throughout the season.

Types of data collected included: general data collection, fish abundance and habitat use observations, and physical measurements of thermal refugial areas, including length, widths, depths, substrate size, and water velocities.

<u>General Data Collection:</u> Weather conditions were reported for each site, including air temperature and general weather conditions. Air temperature was taken by suspending a thermometer in a shaded area for at least 15 minutes, and sky conditions were noted by observation. Also noted was the time of day, and the estimated discharge of the cool water into the mainstem.

<u>Fish Observations:</u> At each of these sites, fish numbers were estimated by visual observation, usually once per week per site during the afternoon hours, while the mainstem temperature was at or near its peak. Reported fish numbers are those of visible fish in the clearer water afforded by the clear water inflow from the tributary. Turbidity and poor visibility precluded visual observations from the Klamath River mainstem. However, observations from the Trinity, which is generally very clear, verified that juvenile salmonids utilizing these refugial areas hold within the area of clearer, colder water.

Fish numbers were reported for: steelhead (young-of-the-year (YOY), juvenile, “half-pounders”, and adults), chinook (juveniles and adults), coho (juvenile), lamprey (eyed juveniles, adults, and ammocetes), and also made qualitative observations of other species such as suckers and speckled dace.

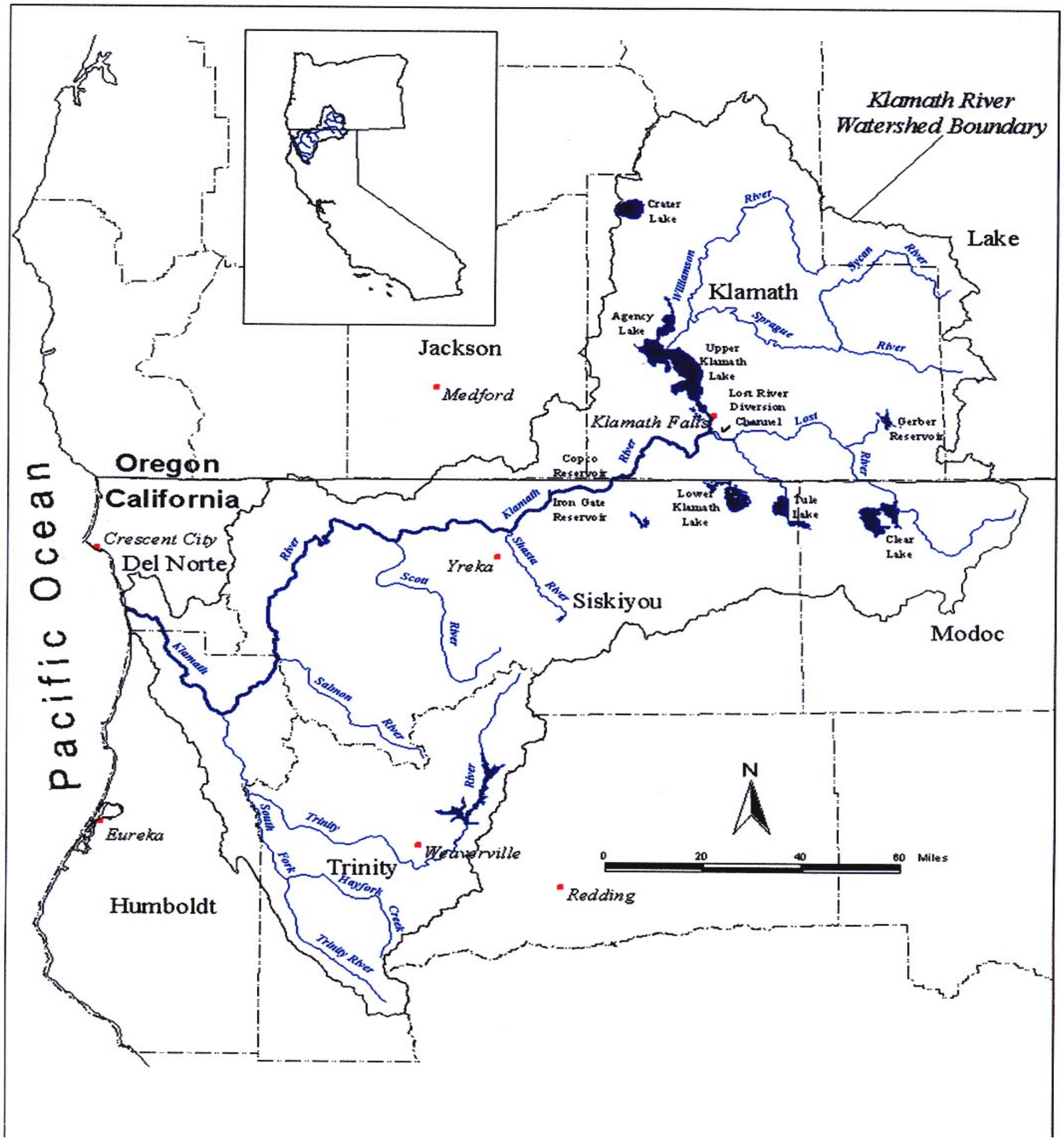

Figure 1: Site location map for the Klamath River Basin.

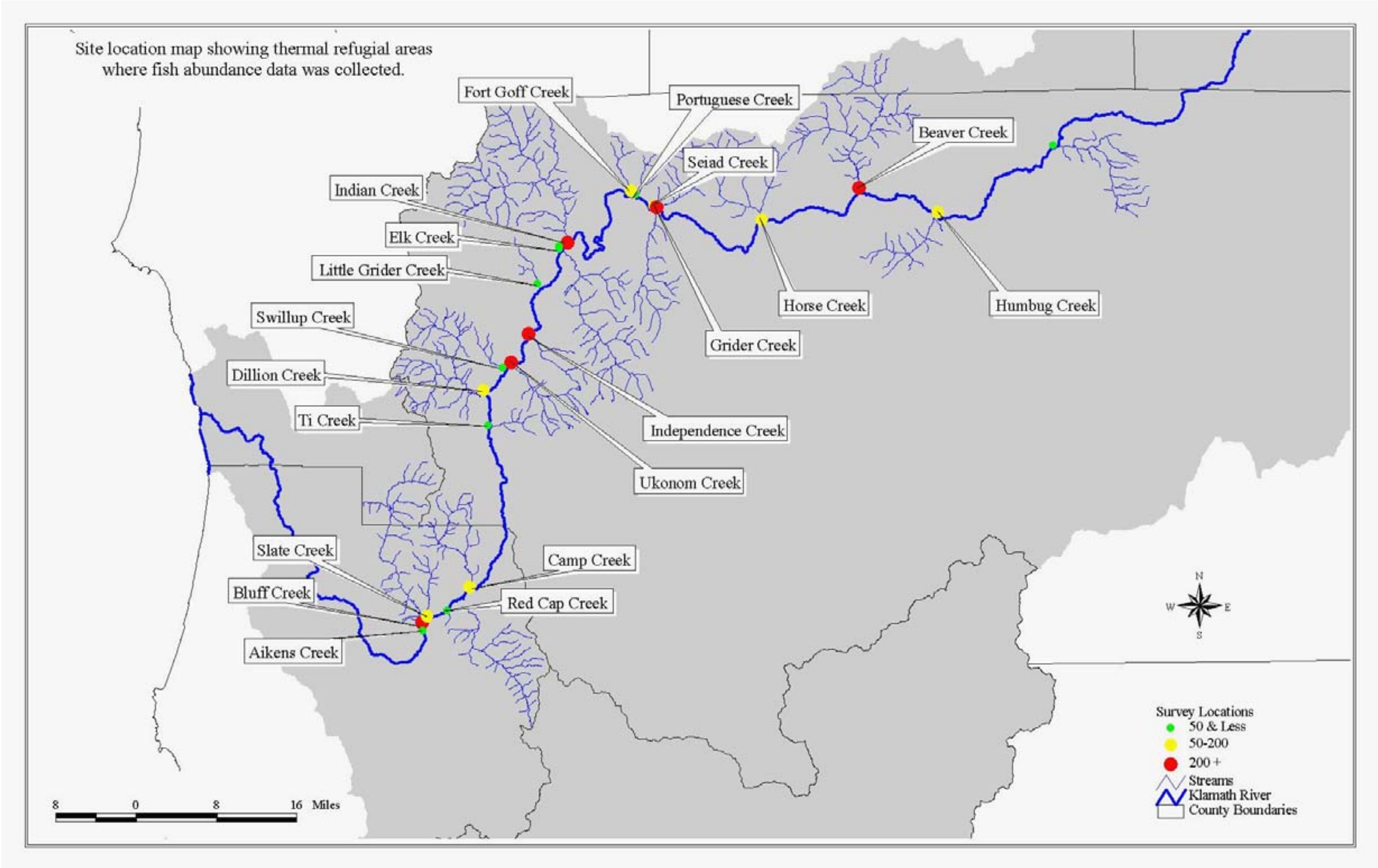

Figure 2: Map showing location of thermal refugial area sample sites. Survey locations are color coded by the maximum number of salmonids observed at each site.

Table 1: Size categories for juvenile salmonid observations.

Juvenile Salmonid Species and Lifestage Definitions	
Species and Lifestage	Length Criteria
steelhead, YOY	<50mm
steelhead, juvenile	51mm – 300mm
steelhead "half-pounder"	301mm – 500mm
steelhead adult	>500mm
chinook juvenile	≤300mm
chinook adult	>300mm
coho juvenile	>300mm

Because each site was physically unique, it was impossible to use a single snorkel observation methodology that would work for every site. Therefore, the actual methods of counting varied depending on the size and configuration of each site. At smaller sites, each swimmer would count all the fish in the entire refugial area from the downstream end working upstream, and then individual counters would all report the number of fish they saw. At the larger sites, such as Beaver, Indian, Elk, Ukonom, and Bluff Creeks, swimmers would swim upstream parallel to each other, each counting the fish to their left or right (depending on which side of the river the tributary came into), and only count fish in their lane. Each observer would then report the number of fish they saw, and the numbers were added together for the total. If fish moved between lanes communication between observers was used to prevent double counting. At all sites, multiple swimmers were used to make fish observations.

At the Indian Creek site, fish abundance observations were made every two hours for a 24 hour period. This 24 hour observation was performed a total of three times at this site. Indian Creek was selected for these observations due to ease of access and abundance of salmonids. Night observations were made by swimmers as two 500 watt quartz halogen lights were positioned to light up the refugial area. The person holding the lights followed the swimmers as they swam, and the lights were turned off between observations. Fish counts were done as described above for the larger sites. Prior to performing these surveys, a diver entered the water in the dark, and then the lights were switched on to observe whether the fish had a flee response that could bias the results. No such behavior was noted.

Physical Measurements: Observers measured temperature using handheld thermometers. Each thermometer was calibrated at the beginning of the field season to an ASTM traceable calibration mercury thermometer. The thermometers were submersed in the water for at least two minutes prior to reading. Incoming cool water temperature was measured above any possible influence from the mainstem Klamath, and mainstem Klamath temperatures were measured well above any tributary confluence. Temperatures were taken to the nearest 0.5°C.

The lengths, widths, and depths of the thermal refugial areas were measured using measuring tapes and wading staffs. Because the edge of the refugial area often was often dynamic and turbulent, the outward edge of the refugial area was determined by visual inspection, or by feeling for the warmer Klamath mainstem water. For some of the areas (Table 1), we performed physical measurements before and after flow releases from Iron Gate Dam increased from 900 cubic feet per second (cfs), to 1300 cfs.

Results

Seasonal and Spatial Variation in Thermal Refugia Usage by Salmonids

A total of 158 snorkel observation dives were made at 24 different creek mouths from July 2 through September 16, 1998 (Table 2). Snorkel observations were usually made during the middle of the day when thermal refugia use was the highest. Fish numbers varied from zero to several thousand per refugial site. In general, fish numbers in refugial areas increased throughout the summer, with low numbers reported during the early sampling efforts (Table 3, Figures 3-14). Because of its size, Table 3 with complete dive results and data results for all sampling efforts can be found at the end of the document.

Table 2: Sample date summary for 1998 Thermal Refugia Study.

Key: f=fish observations, Q=tributary flow measurement, p=physical measurements, h=fish habitat use measurements, 24=24 hour fish observations

dates	Bogus	Humbug	Beaver	Horse	Grider	Seiad	Portuguese	Ft. Goff	China	Indian	Little Grider	Elk	Oak Flat	Independence	Ukonom	Swillup	Dillon	Ti	Rock	Camp	Red Cap	Slate	Bluff	Aikens
6/23/1998																							f	
7/1/1998										f														
7/2/1998															f						f			
7/6/1998										f				f	f		f							
7/7/1998	f		F	f		f																		
7/8/1998		f										f												
7/9/1998																		f			f	f	f	
7/14/1998					f	f		f		f		f		f										
7/15/1998	f	f	F	f			f																	
7/16/1998										f				f	f		f							
7/17/1998																		f		f	f	f	f	f
7/20/1998																	f							
7/21/1998				f	f	f		f(2)																
7/22/1998										f				f										
7/23/1998																			f	f	f	f	f	
7/28/1998										f				f	f		f							
7/29/1998	f	f	F	f	f	f																		
7/30/1998							f	f	f					f			f							
7/31/1998																		f		f	f	f	f	
8/3/1998										f					f									
8/4/1998	f	f	F	f	f																			
8/5/1998												f					f	f		f	f	f	f	
8/10/1998										f		f						f		f	f	f	f	
8/11/1998	f	f,Q	f,Q	f																				
8/12/1998					f	f	f	f						f,Q,24	f		f							
8/17/1998																				f,p	f,p	f,p	f	
8/18/1998					f,p	f,p		f,p				f,p			f,p		f,p							
8/19/1998			f,p							f,p,24														
8/20/1998											f		f,p			f		f,p			f		f	f
8/25/1998			f,p	f,p	f,p	f,p																		
8/26/1998	f	f						f,p							f,p		f,p							
8/27/1998										f,p,24														
8/31/1998																					f,p	f,p	f,p	

Key: f=fish observations, Q=tributary flow measurement, p=physical measurements, h=fish habitat use measurements, 24=24 hour fish observations

dates	Bogus	Humbug	Beaver	Horse	Grider	Seiad	Portuguese	Ft. Goff	China	Indian	Little Grider	Elk	Oak Flat	Independence	Ukonom	Swillup	Dillon	Ti	Rock	Camp	Red Cap	Slate	Bluff	Aikens
9/1/1998														f,p	f		f	f,p		f,p				
9/2/1998	f	f*	F	f	f	f		f		f		f,p												
9/8/1998	f		F,p,h																		f	f,p	f,p	
9/9/1998				f,p	f,p					f,p,h, 24					f,p		f,p	f,p		f,p				
9/10/1998						f,p								f,p,h										
9/14/1998																					f,h	f	f,h	
9/15/1998										f		f		f	f,h		f	f		f				
9/16/1998			F	f	f	f		f																

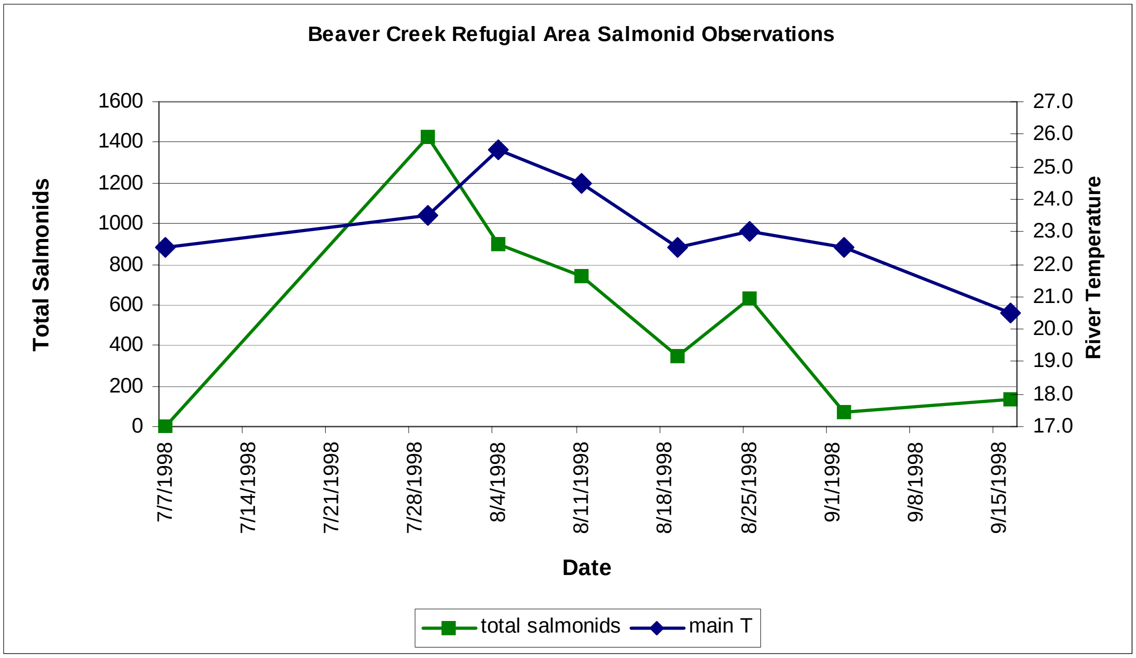

Figure 3: Salmonid use and river temperature at Beaver Creek, 1998.

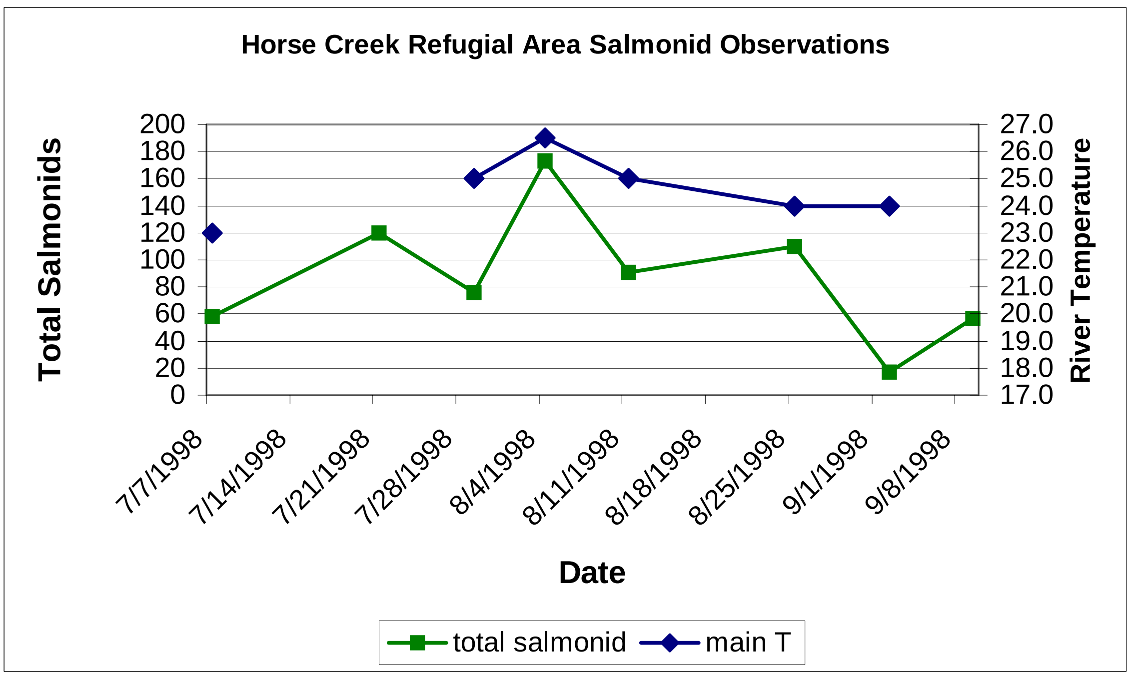

Figure 4: Salmonid use and river temperature at Horse Creek, 1998.

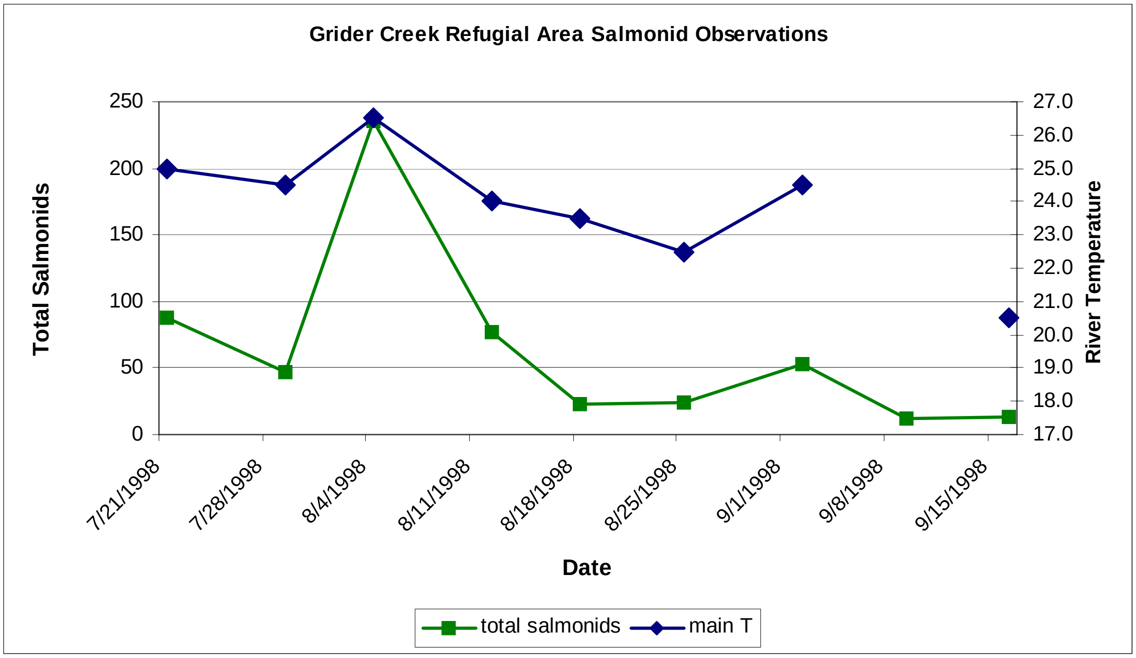

Figure 5: Salmonid use and river temperature at Grider Creek, 1998.

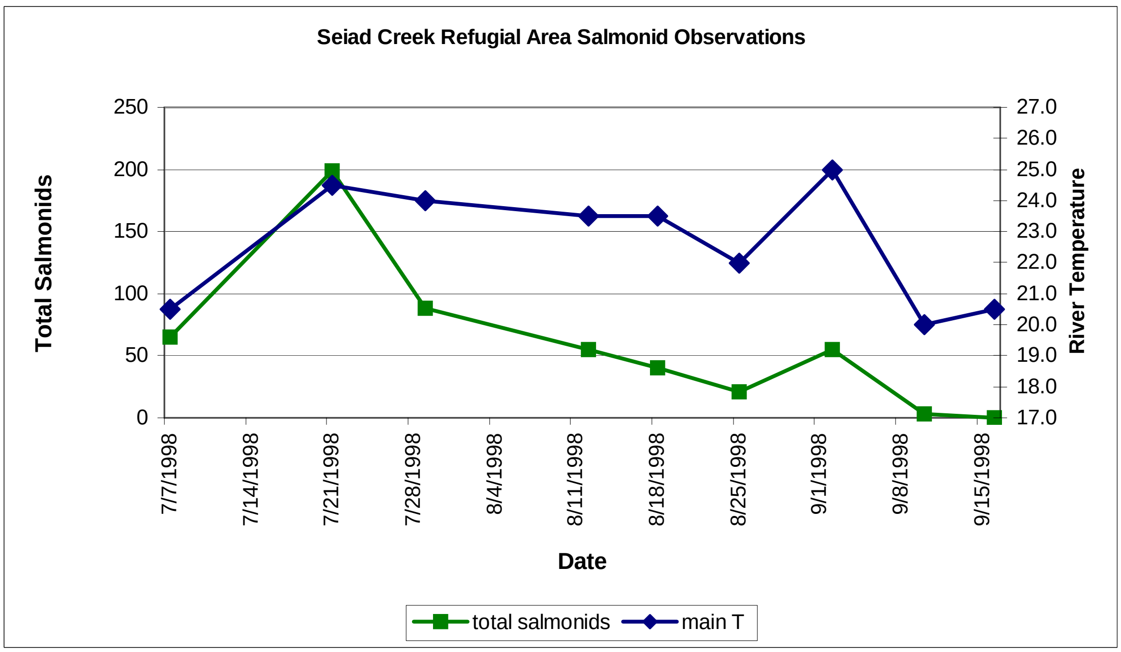

Figure 6: Salmonid use and river temperature at Seiad Creek, 1998.

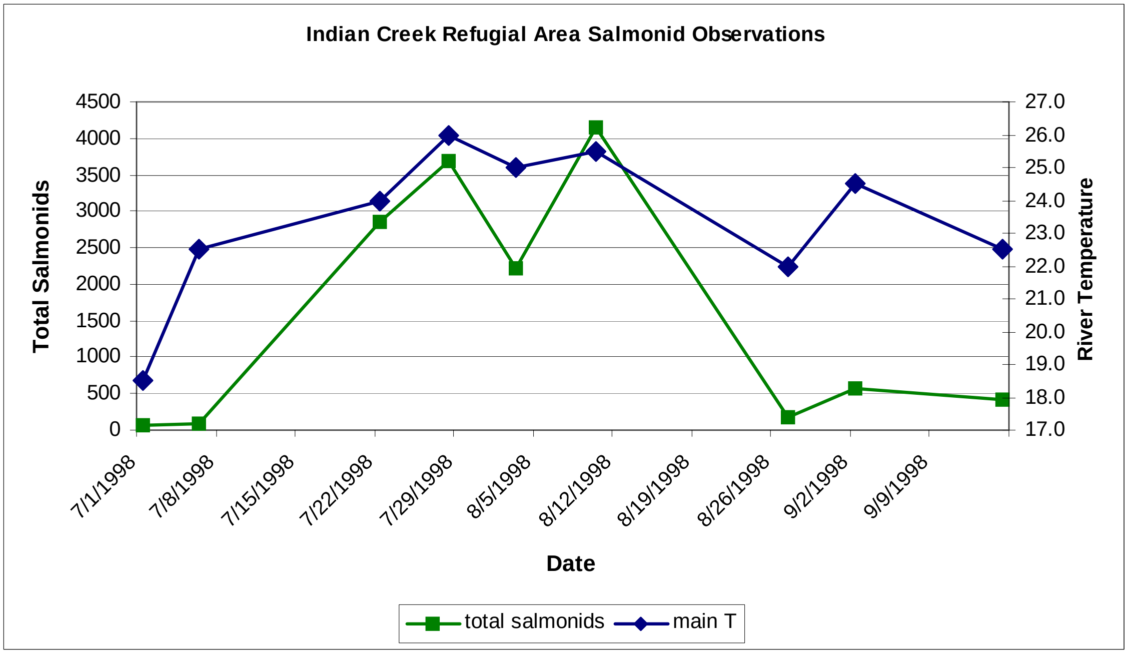

Figure 7: Salmonid use and river temperature at Indian Creek, 1998.

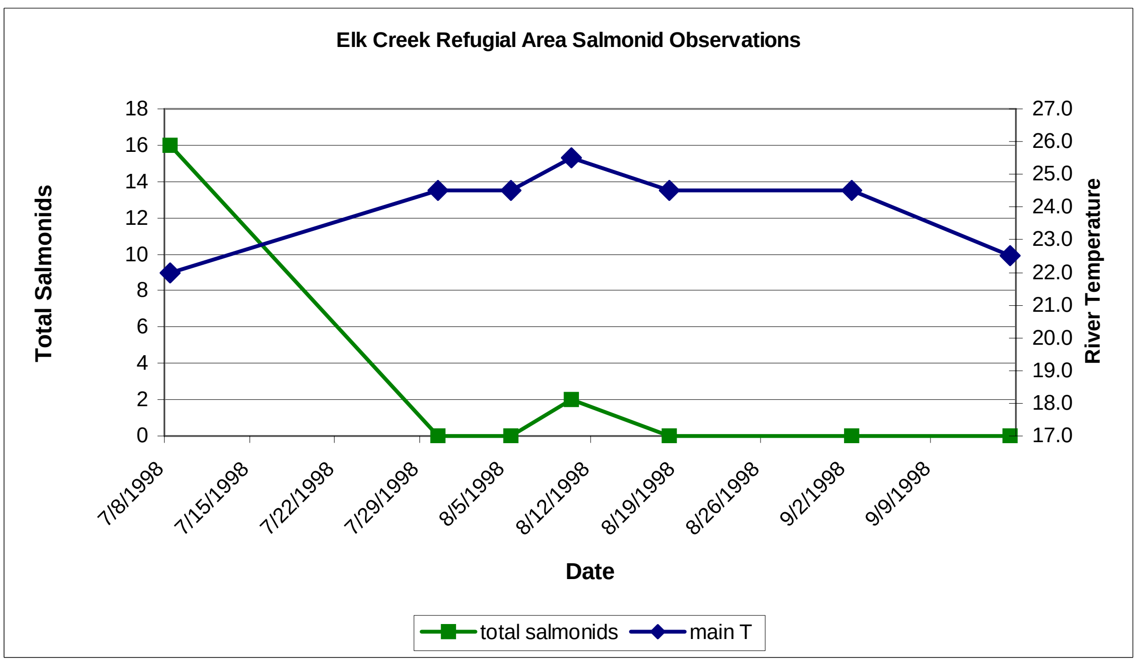

Figure 8: Salmonid use and river temperature at Elk Creek, 1998.

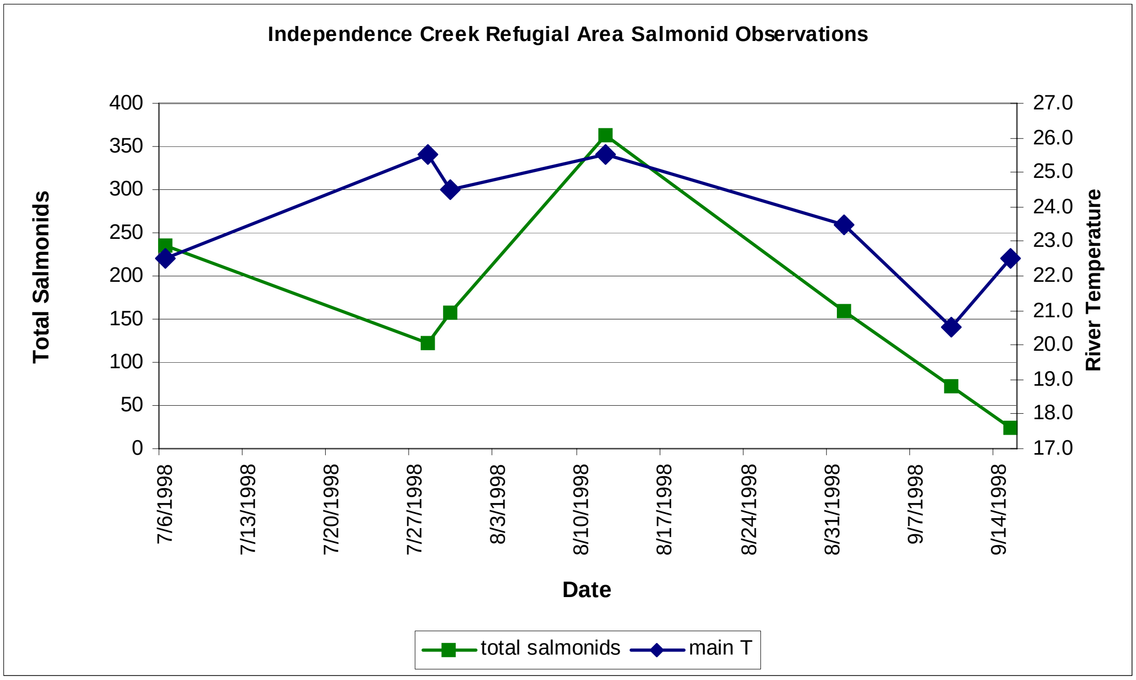

Figure 9: Salmonid use and river temperature at Independence Creek, 1998.

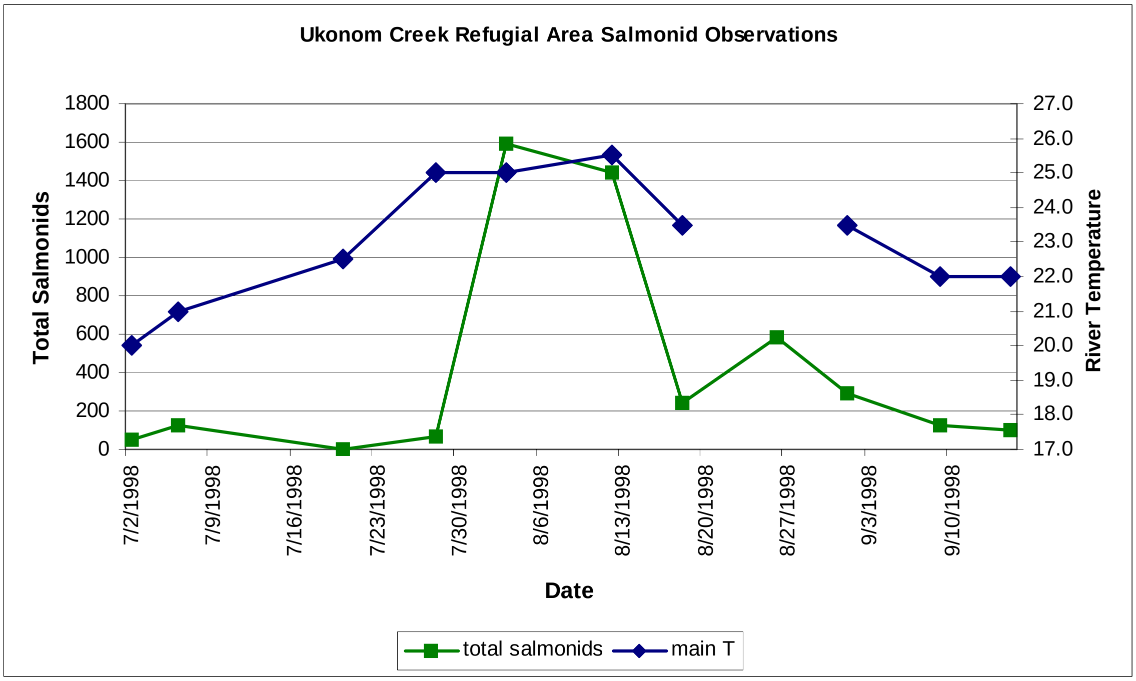

Figure 10: Salmonid use and river temperature at Ukonom Creek, 1998.

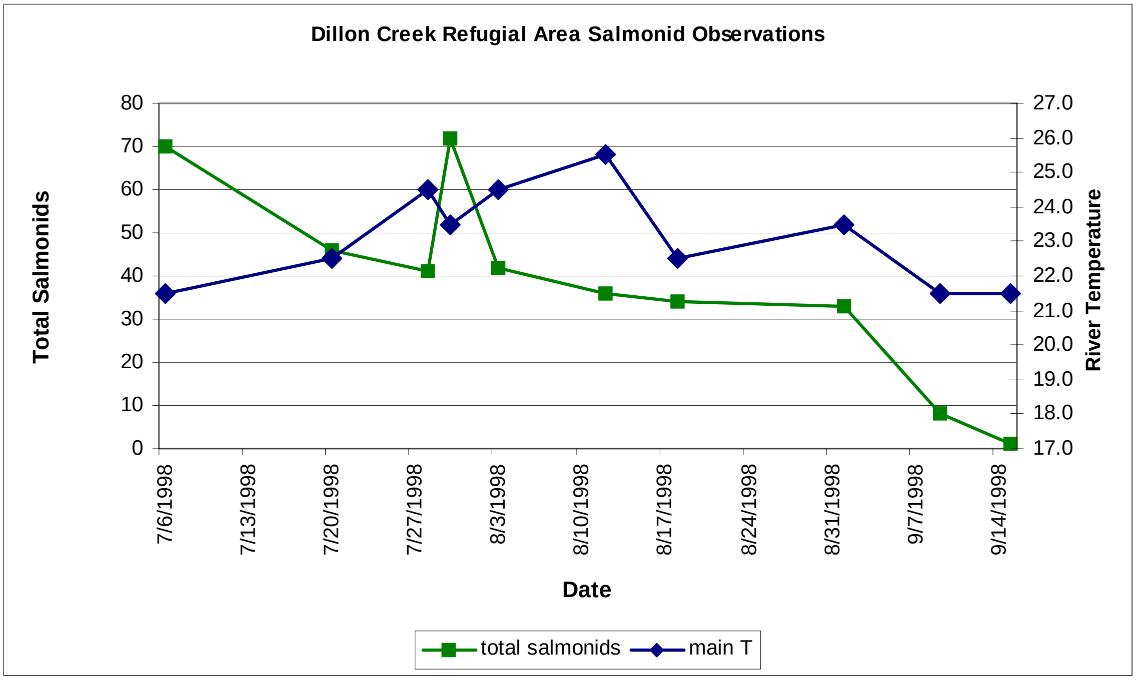

Figure 11: Salmonid use and river temperature at Dillon Creek, 1998.

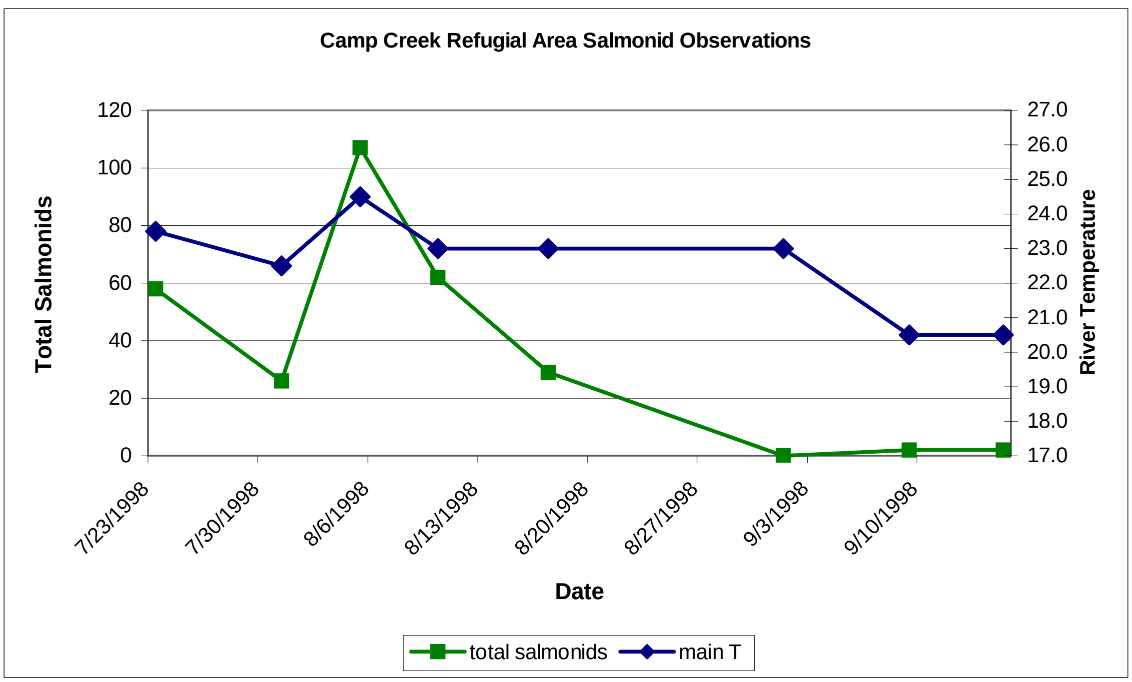

Figure 12: Salmonid use and river temperature at Camp Creek, 1998.

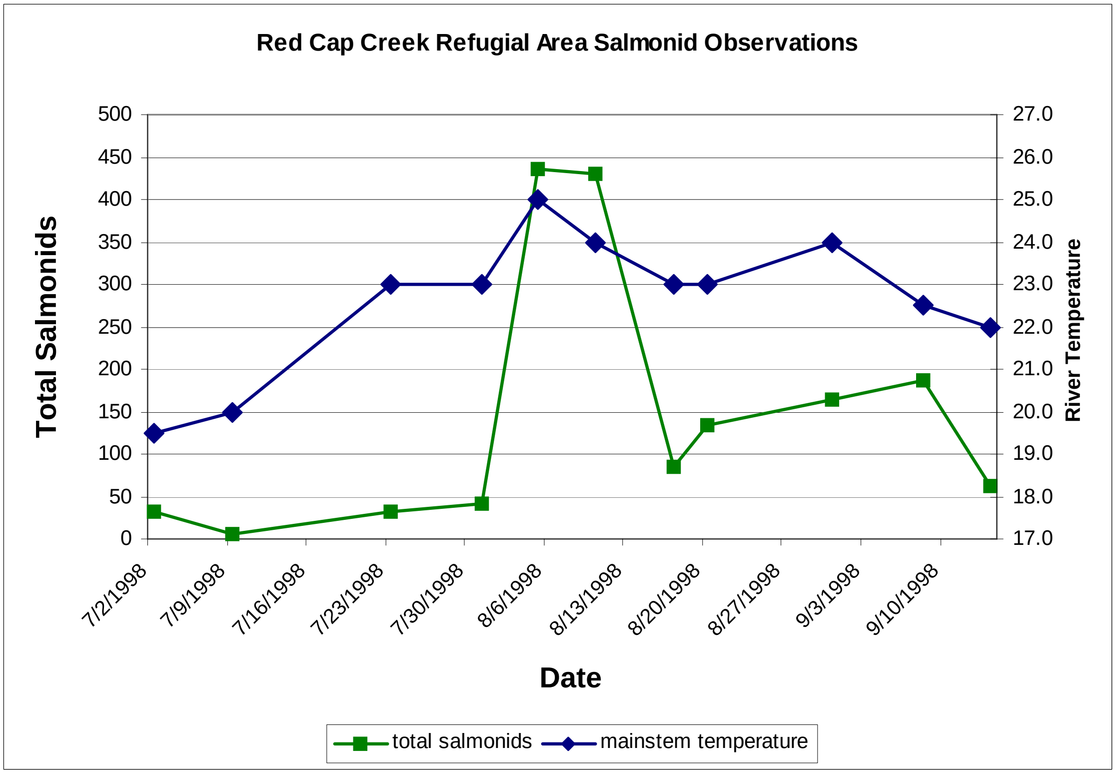

Figure 13: Salmonid use and river temperature at Red Cap Creek, 1998.

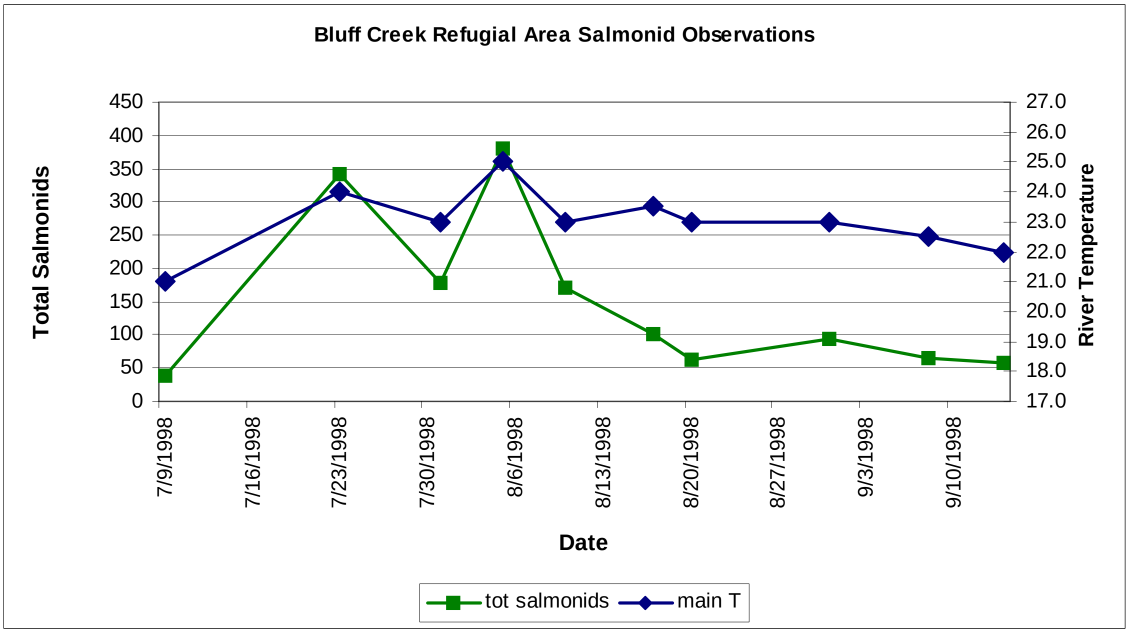

Figure 14: Salmonid use and river temperature at Bluff Creek, 1998.

Results (continued)

Figures 3-14 show the seasonal use of refugial areas of the “major” refugial areas. Major refugial areas are defined as those which had maximum fish observation numbers over 200 fish, or are a major contributor of cold water to the Klamath River. For example, Elk Creek was included even though fish numbers were low because Elk Creek is a major cold water tributary, and observations from subsequent years have showed much higher fish usage at that location. Complete results can be found in Table 3, located at the end of this report.

The date of maximum salmonid concentration in the refugial areas showed no correlation with river mile (Figure 15).

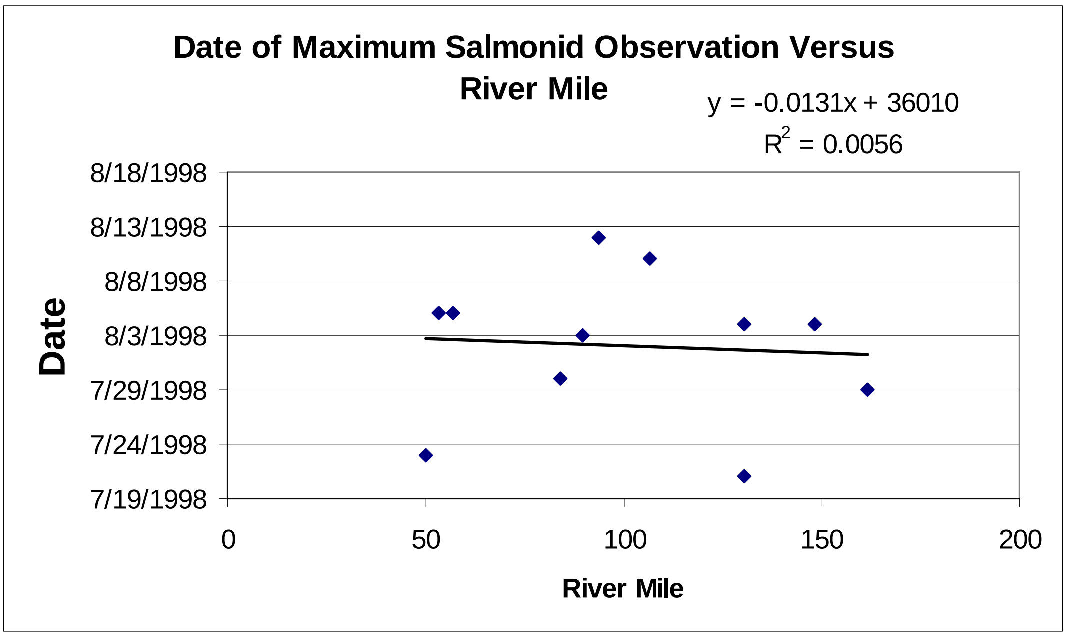

Figure 15: Date of maximum salmonid observation at major refugia areas versus river mile.

Utilization of refugial areas increased dramatically when mainstem river temperatures exceeded 23°C (Figure 16, 17). No observations of over 500 fish were made when mainstem temperatures were under 23°C (Figure 16, 17).

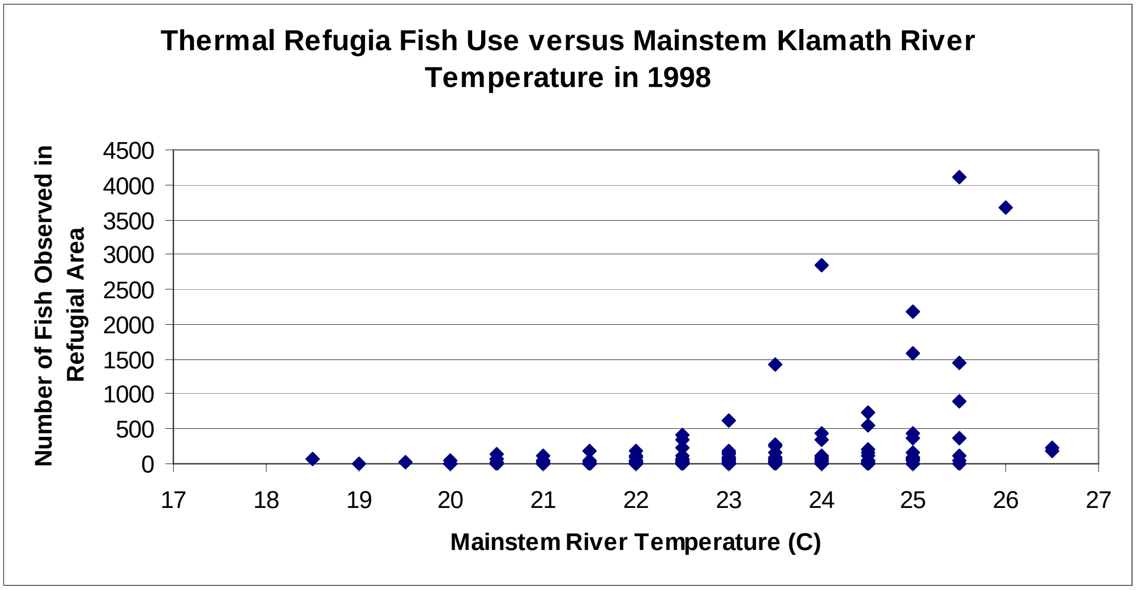

Figure 16: Observed fish abundance at all refugia sites plotted against mainstem river temperature.

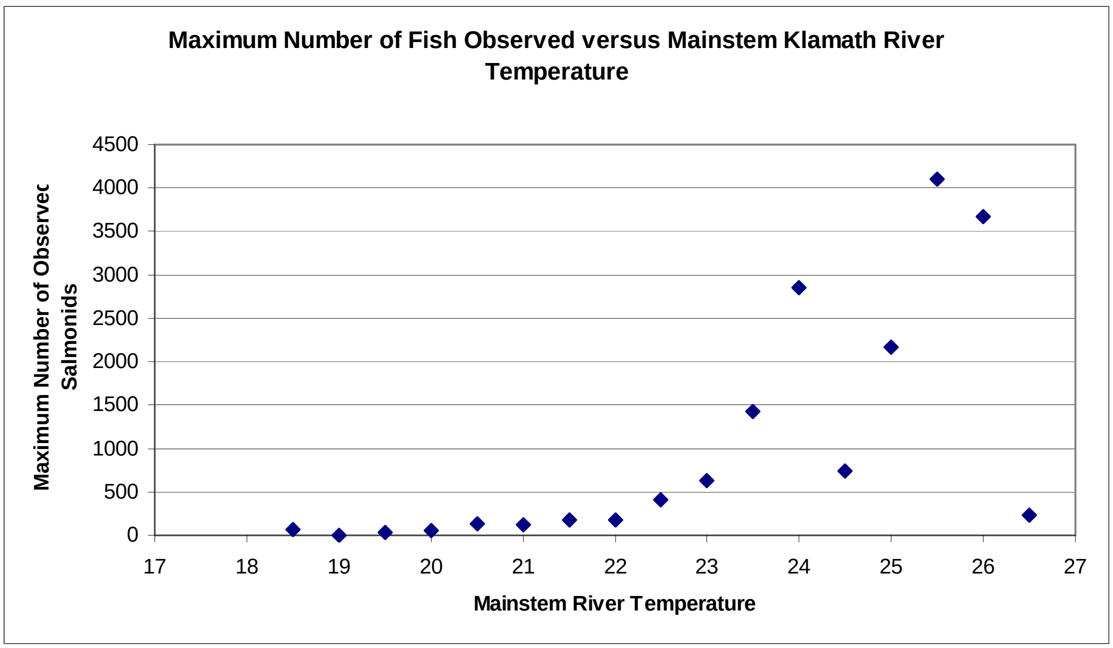

Figure 17: Same graph as Figure 15, but only showing maximum observed fish numbers for all dives at any given river temperature.

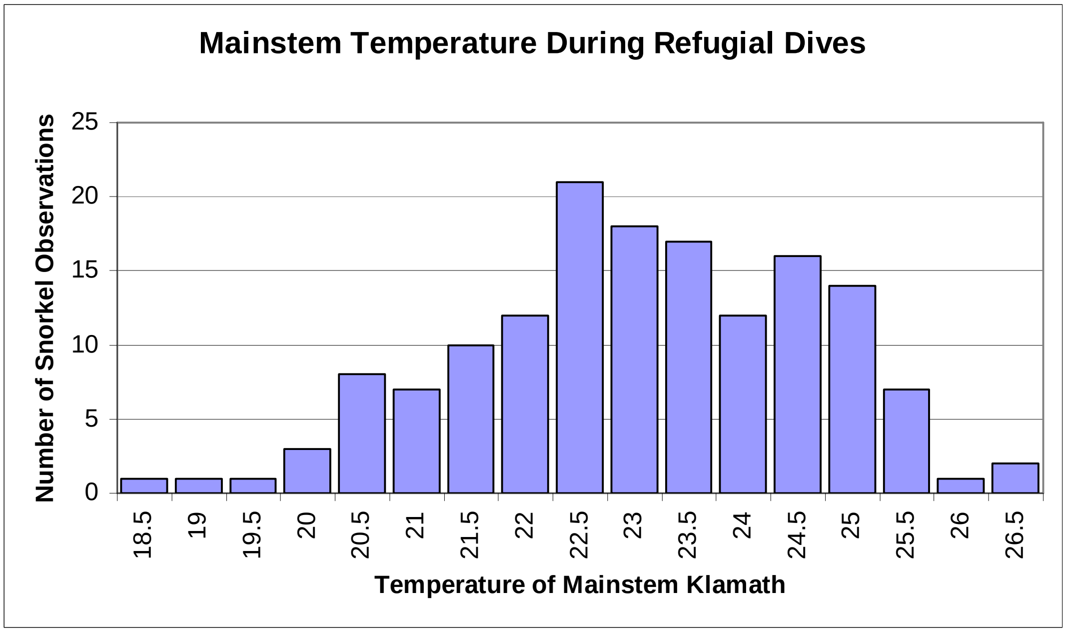

Figure 18: Frequency distribution of snorkel observations at various mainstem temperatures.

Fish distribution did not appear to be strongly related to the temperature differential between the cold water input and the mainstem Klamath River. Instead, it appeared to mimic the frequency distribution of the observations themselves (Figures 19 and 20). For example, with regard to mainstem river temperature, no observations of over 500 fish in any refugial areas were made when the mainstem Klamath was below 23°C (Figures 16, 17). With the temperature differential, however, over 500 fish were observed at a wide range of differentials, from 1.5 to 7.5°C (Figure 19)

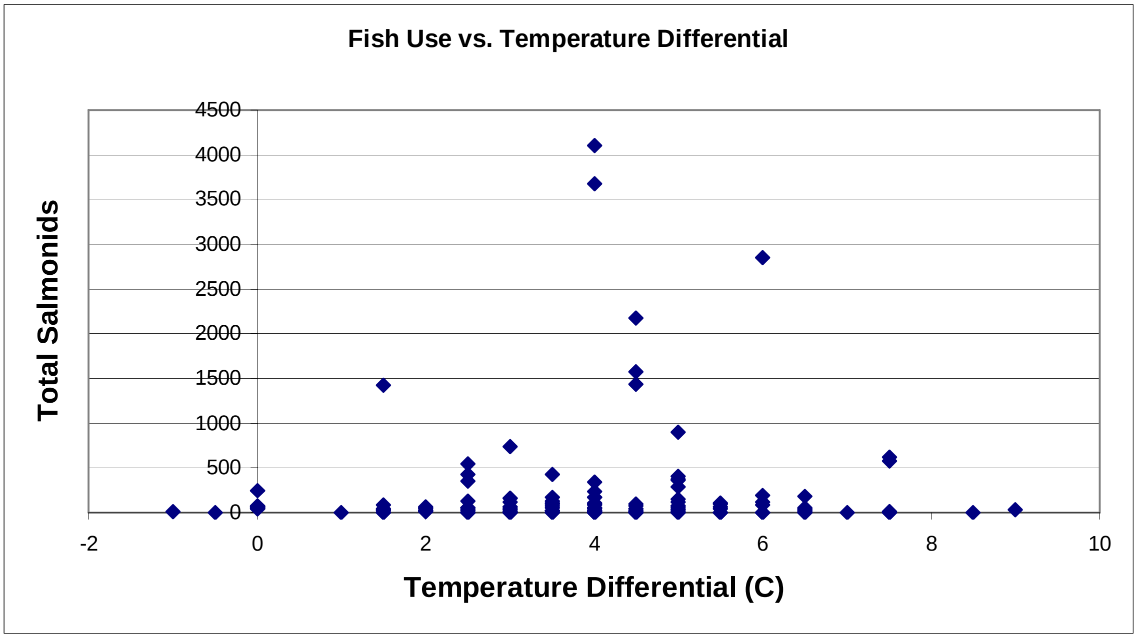

Figure 19: Fish use versus temperature difference between cold water input and the mainstem Klamath River.

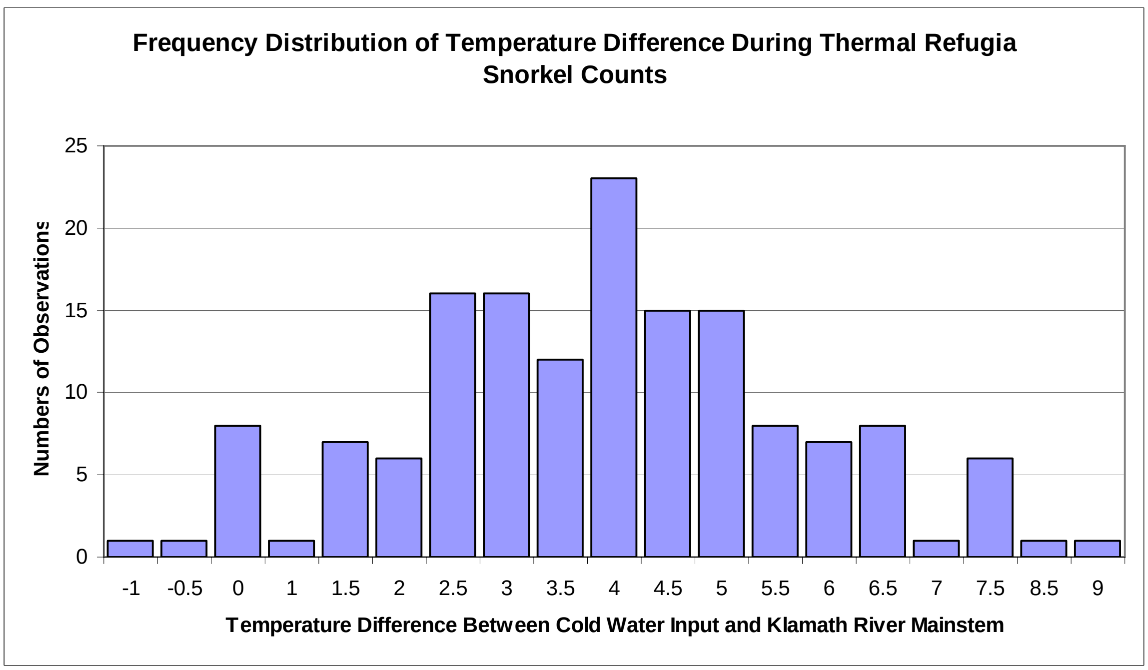

Figure 20: Frequency distribution of snorkel counts at various temperature differentials. Temperature differential is defined as the difference (°C) between the cold water input and the mainstem Klamath.

24 Hour Observations

Fish usage of Indian Creek refugial area dropped sharply toward dawn on both sample dates (Figures 21, 22). In fact, on the September 9 and 10 observations, juvenile Chinook numbers dropped to zero just prior to daybreak (Figure 22). On both days, juvenile salmonids were observed at dawn in the mainstem Klamath River exhibiting surface feeding behavior. Fish numbers were lower during the dark hours (Figures 21, 22), but that could have been due to more difficult observational conditions when snorkeling using artificial lighting.

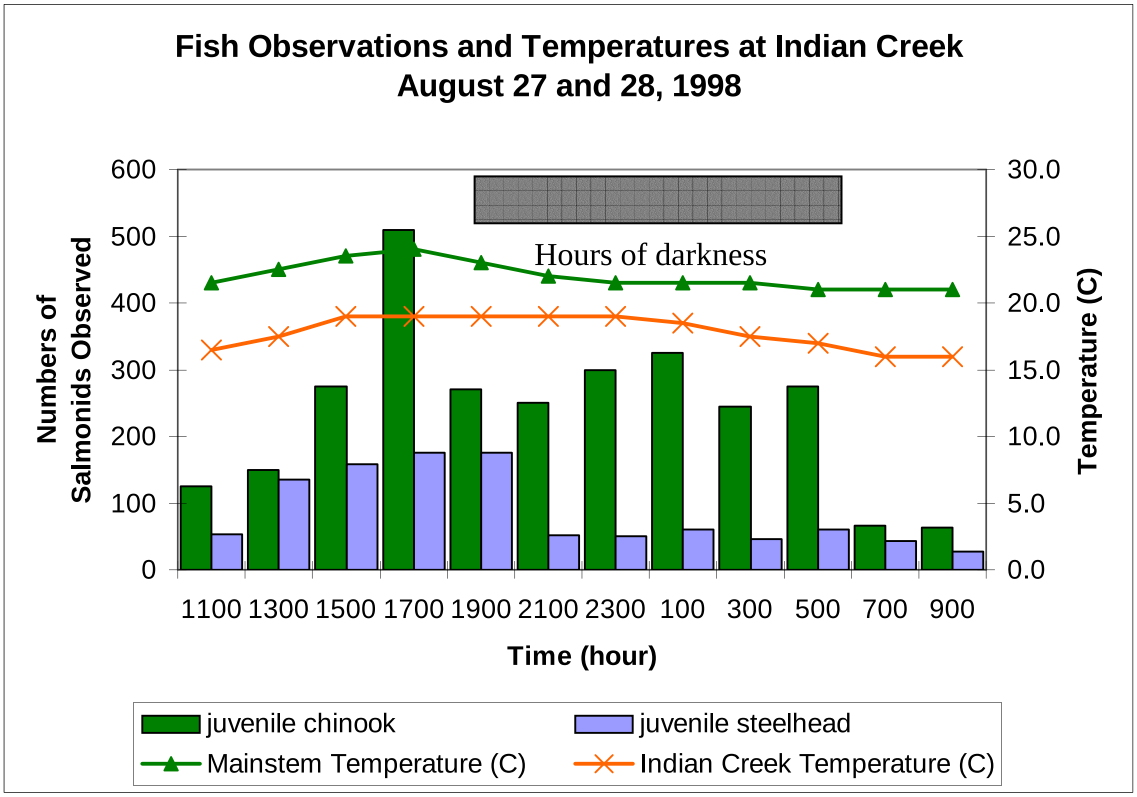

Figure 21: 24 Hour observations of thermal refugia usage by juvenile Chinook and steelhead on August 27-28, 1998. Klamath River and Indian Creek temperatures are also shown.

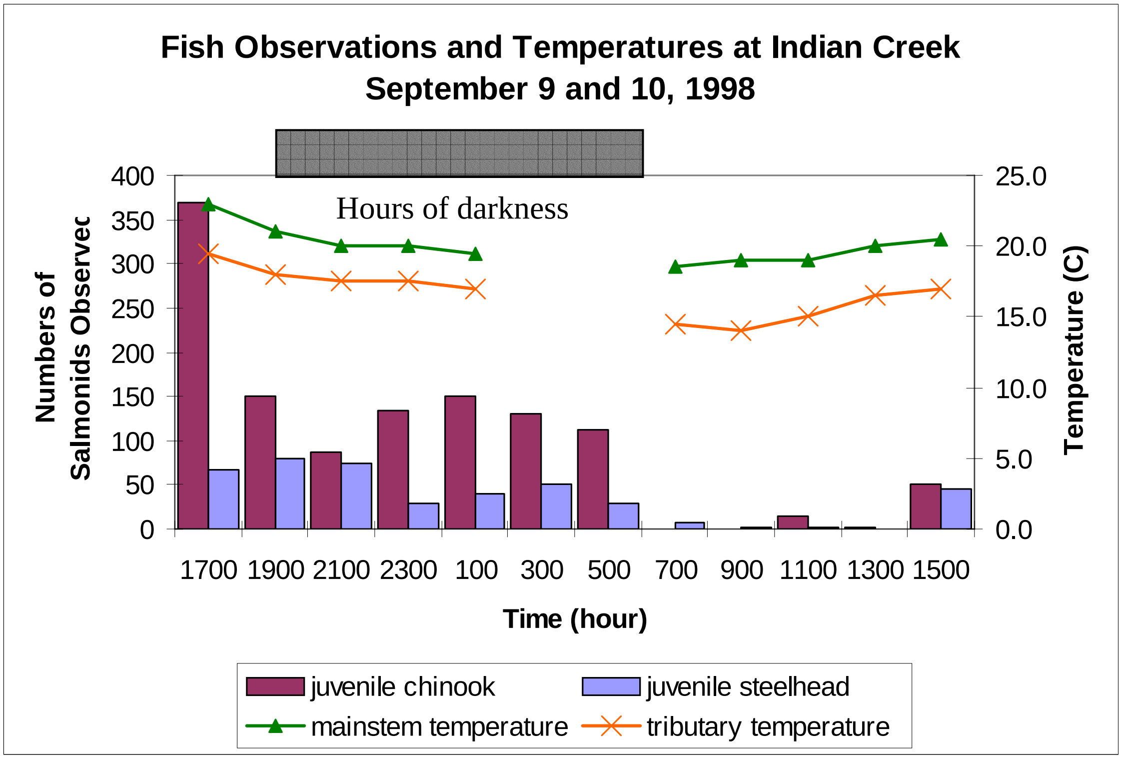

Figure 22: 24 Hour observations of thermal refugia usage by juvenile Chinook and steelhead on September 9-10, 1998. Klamath River and Indian Creek temperatures are also shown.

Physical Measurement of Refugial Areas

The aerial extent of measured refugial areas varied from 4 m^2 at Seiad Creek to 1750 m^2 at Ukonom Creek (Table 4, Figure 23). Volume measurements were taken at several locations, and varied from 75 m^3 at Horse Creek to 494 m^3 at Indian Creek (Table 4). In some locations, repeat measurements were made, and these are presented in Table 4.

Table 4: Locations and measurements of the physical size of refugial areas on the Klamath River mainstem in 1998. Certain refugial areas had volumes measured, and for those, the average depth was presented. Areas and volumes are in square and cubic meters respectively. Average depth is in meters.

Location	Date	Area	Volume	Avg Depth
Beaver	8/19/98	984		
Beaver	8/25/98	855	311	0.36
Bluff	8/17/98	412		
Elk	8/18/98	182		
Fort Goff	8/18/98	26		
Grider	8/18/98	117		
Grider	8/25/98	130		

Location	Date	Area	Volume	Avg Depth
Horse	8/25/98	250	75	0.30
Indian	8/19/98	1099		
Indian	8/27/98	1046	494	0.47
Indian	9/10/98	678	342	0.50
Seiad	8/18/98	4		
Slate	8/17/98	418		
Ti	8/20/98	77		
Ukonom	8/18/98	1750		

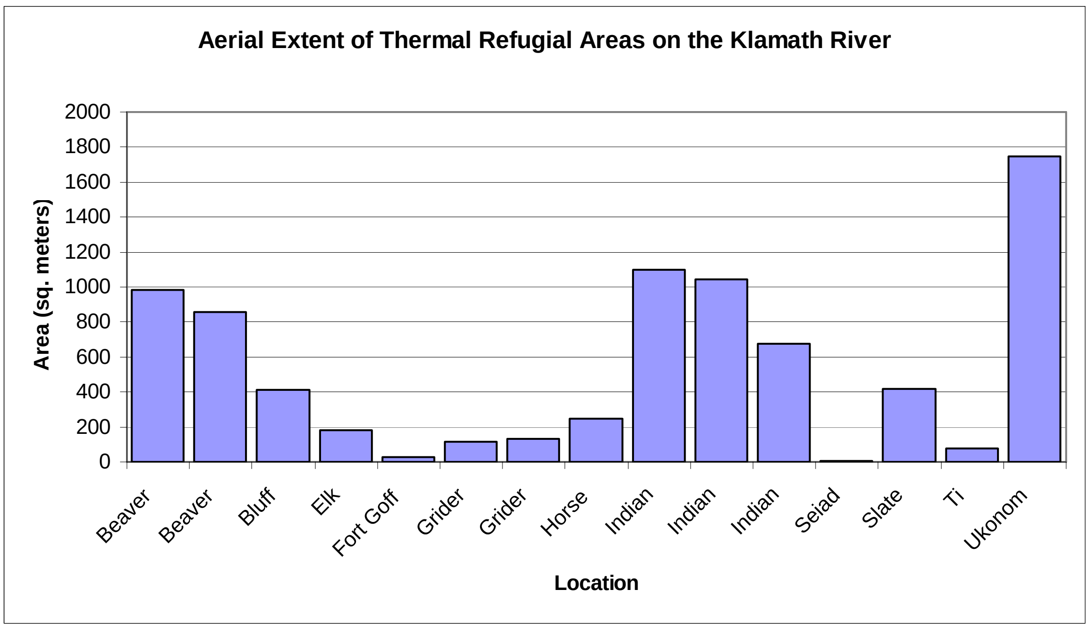

Figure 23: Aerial extent of selected refugial areas on the Klamath River in 1998. Repeat measurements are presented here, hence the repetition of place names. Furthermore, it should be noted that the final Indian Creek measurement was taken after a flow change at Iron Gate Dam, which affected the size of the refugia area.

Survey data was used to make a three-dimensional representation of the Indian Creek thermal refugial area, which highlights the complexity of these habitats (Figure 24).

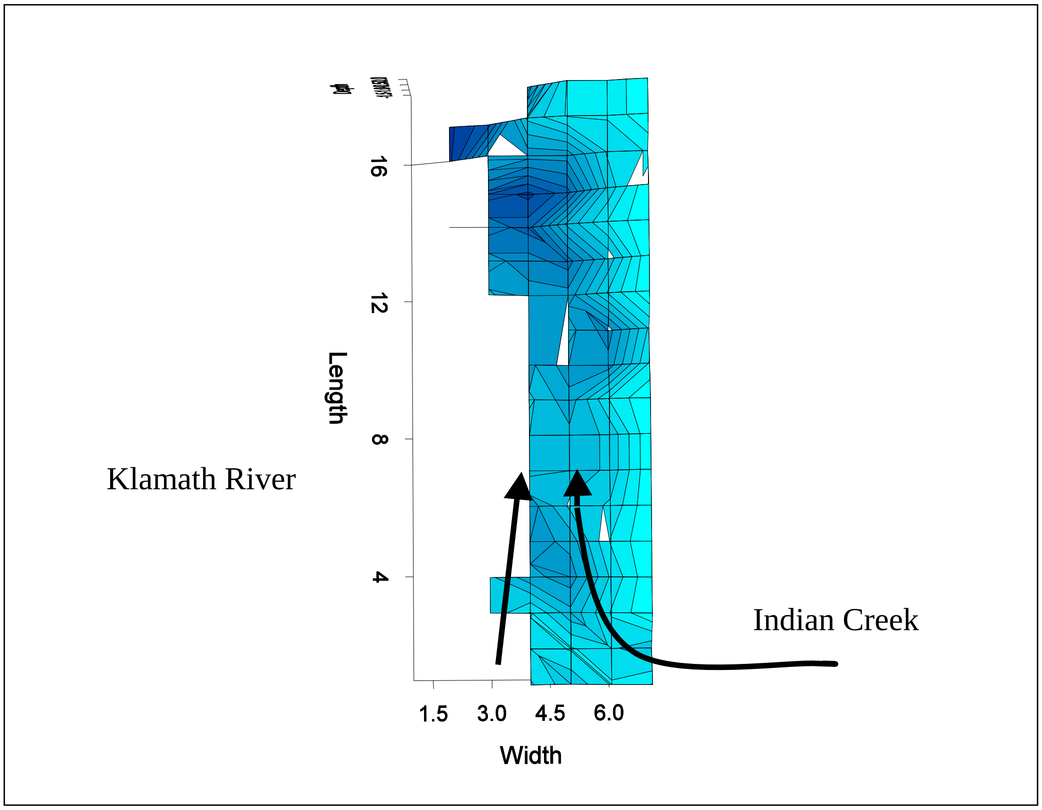

Figure 24: Three dimensional representation of Indian Creek refugial area on September 10, 1998, created using survey data. Curved arrow indicates creek inflow, other arrow is river flow direction. Length is expressed in multiples of five meters (i.e. refugial area is 85 meters long), and width is expressed in increments of two meters. Depth contours are approximately 0.2 meters.

On September 1, 1998, flows at Iron Gate Dam, located approximately 84 miles upstream from the Indian Creek refugial area were increased from 1120 cfs to 1390 cfs (Figure 25). Because there had been no precipitation and therefore tributary input was relatively constant, measurements of the physical characteristics of refugial areas were repeated to see if they were affected by the flow increase (Figure 26). Finally, maximum observed fish numbers for refugial areas was plotted against aerial extent (Figure 27).

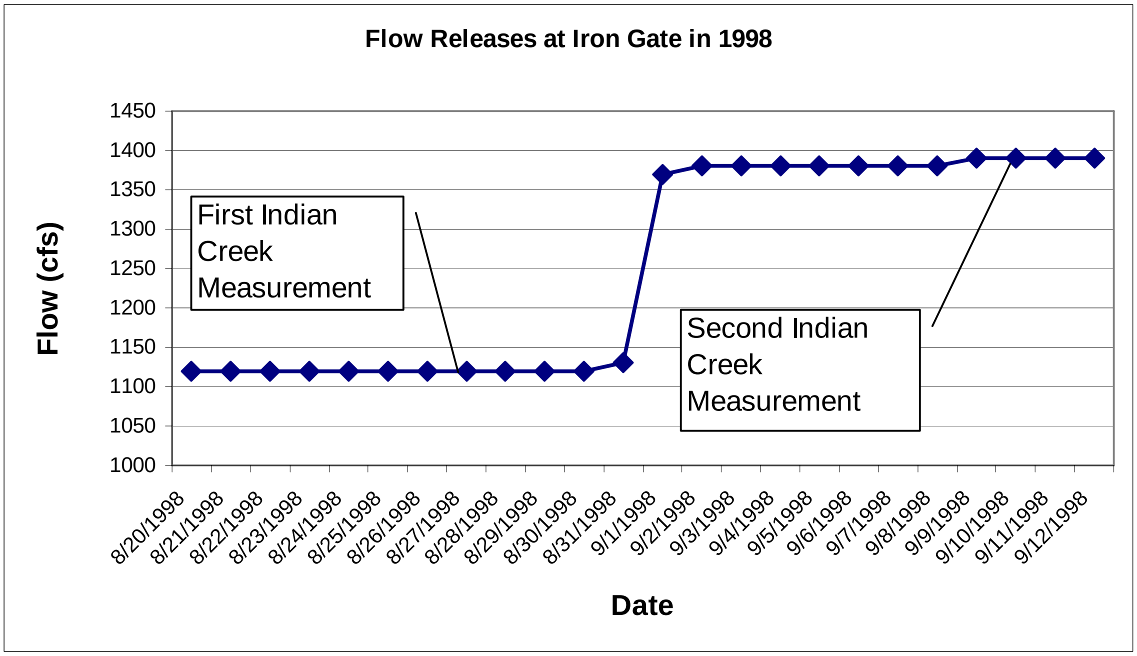

Figure 25: Flow releases from Iron Gate Dam during two measurements of physical size of Indian Creek Refugial area.

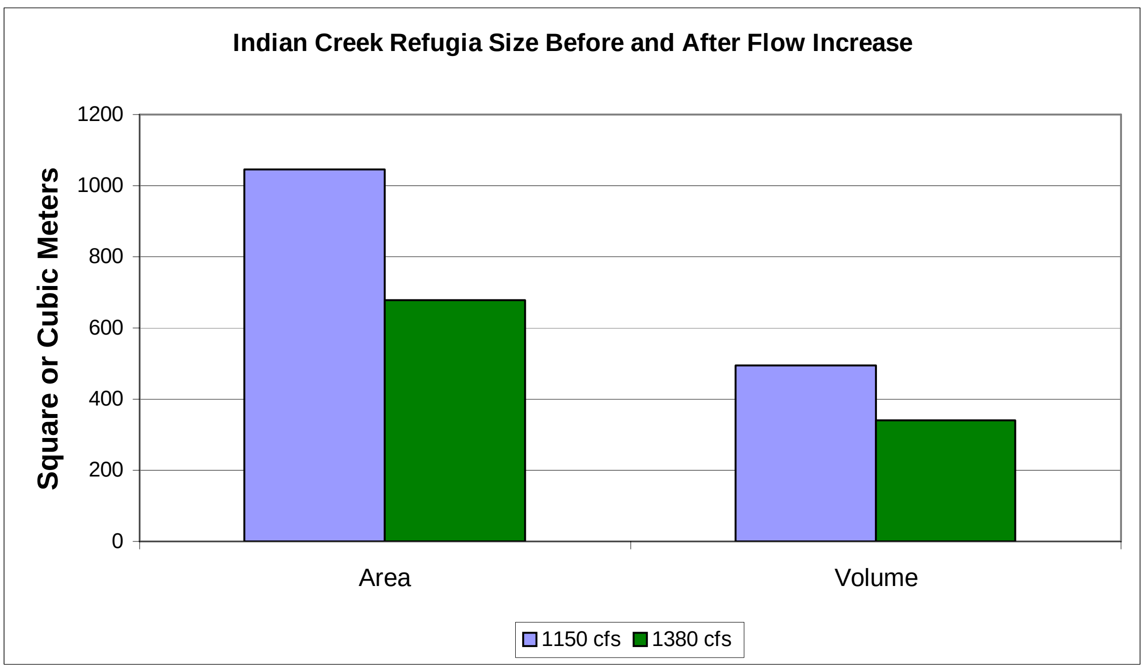

Figure 26: Indian Creek refugial area and volume before and after a flow increase at Iron Gate Dam.

Fish numbers did appear to be somewhat correlated with the size of thermal refugia areas. For example, in no cases during the 1998 surveys were more than 500 salmonids observed in any refugial areas when refugial aerial extent was less than 400 m^2 (Figure 27).

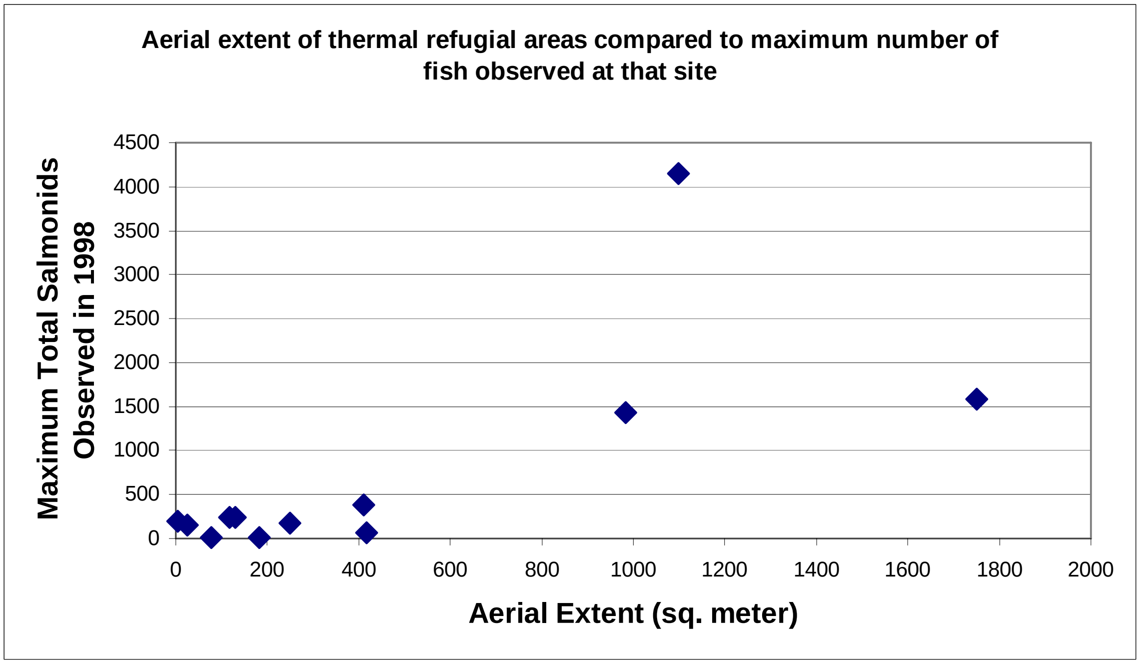

Figure 27: Aerial extent of refugial areas versus maximum numbers of fish observed at that site.

Discussion

The use of thermal refugial areas by fish has been documented by other researchers in a wide variety of systems (Kaya 1978, Bilby 1984, Ozaki 1988, Neilson 1994, Belchik 1997, Biro 1998, Ebersole et al. 2001, Ebersole et al. 2003). Ebersole et al. (2003) noted an increase in salmonid production for both Chinook salmon and rainbow trout in stream reaches that had thermal diversity including thermal refugial areas.

Unlike the results from other thermal refugia research (Ebersole et al, 2001), it appears that all, or nearly all juvenile salmonids on the Klamath utilize thermal refugia areas during the time of maximum daily water temperatures. Evidence in support of this conclusion includes observations that 1) few or no salmonids are seen in the mainstem Klamath away from refugia areas during daylight hours the summer months, and 2) observation of Trinity River (see Figure 1 for location) refugial areas, which show little or no use of nearby mainstem habitats.

In August of 1998, it appeared that at least 10,000 juvenile salmonids were utilizing refugial areas on the Klamath in, with a smaller amount doing so on the Trinity. It is likely that the actual number was closer to 20,000 to 50,000 juvenile salmonids. This estimate was obtained by adding the maximum numbers of fish at all the refugial areas together (approximately 10,000), noting that many areas were not sampled (i.e. Clear Creek, Salmon River, Blue Creek, etc), and also noting that observers probably tend to underestimate refugial area fish abundance due to visibility, and fish avoidance behavior. The Blue Creek refugial area alone has been observed to harbor nearly 5,000 juveniles and 2,000-4,000 adult salmonids (Yurok Tribal Fisheries Program unpublished data 2001-2003), and this location was not included in the 1998 observations.

These observations of fish use of refugial areas confirm the importance of these areas, but also underscore the connection between mainstem Klamath River habitats and tributaries. This concept is echoed by the findings of the NRC (2003), which emphasized restoration of cold water tributaries as a key in coho recovery efforts. Although salmonids do crowd into these areas during the hot daytime hours, the 24 hour observations indicate a heavy reliance on nearby mainstem Klamath River habitats (Figures 21 and 22). It appears that the fish are using these areas of cooler water as “shelter” from high water temperatures during daylight hours and then utilize the abundant food resources of the Klamath River during the morning hours when mainstem temperatures are lower.

Salmonids residing in thermal refugial areas have a choice of temperatures in which to station themselves. Because of this, their choice of their immediate thermal environment gives important information regarding their thermal preferences and tolerances that would be very difficult to obtain through controlled laboratory experiments. Juvenile salmonids observed in this study consistently showed a preference for cooler water when mainstem temperatures reached 22.5-23°C (Figure 16, 17). This is consistent with the work of Li et al. 1993 (as cited in Ebersole at al 2001); and Nielsen et al. 1994, but not consistent with the work of Ebersole 2001, who noted that thermal refugia use began at a wide range of temperatures from 18°C to 25°C. Ebersole’s work, however, concentrated on rainbow trout use of small (<50m^2) refugial areas in northeast Oregon that held dozens, not thousands, of salmonids. By contrast, the refugial areas on the Klamath are large (often over 1000 m^2), and the numbers of salmonids utilizing them often numbered in the thousands.

The data shows that increased flow releases from Iron Gate Dam did have a measurable effect on the size of Indian Creek refugial area (Figure 26). In other systems, flow increases have been shown to reduce the holding effectiveness of refugial areas (Orciari and Landers 1995), but the magnitude of flow increase in that study was far greater than occurred on the Klamath. Furthermore, the data relating refugial area to maximum numbers of holding salmonids suggests that beyond a certain area, fish are not space limited in Klamath River thermal refugial areas. Figure 27 shows the relationship between the size of refugial areas (m^2) and the maximum numbers of fish holding in different refugial areas. From Figure 27, one can see that smaller sized (i.e. <400 m^2) refugial areas were never observed to have over 500 juvenile salmonids in them. The larger refugial areas (only three were measured that were larger than 400 m^2), had considerable variation in the maximum numbers of fish observed. For this reason, it appears that the maximum numbers of fish observed in the larger refugial areas may not be limited by the physical size of the refugial areas, but rather may be limited by other factors, such as fish population size, cover, food resources, predation or other factors.

1998 was marked by a huge snowpack, a late spring, and a prolonged snowmelt runoff. Because of that, the Klamath River mainstem was high and cool into early July, which is somewhat unusual. Without these sustained high, cool flows, it is probable that refugia use would have been heavier in late June and early July than is indicated by these results which show August as the primary month of refugia use.

Because anadromous fish use thermal refugia areas extensively, and refugial areas provide these fish with an opportunity to exist where temperature would otherwise preclude occupation, maintenance and restoration of these areas could provide measurable benefits to Chinook salmon and steelhead trout (Sedell 1990, Ebersole 2003). Loss of access to refugia areas may be the reason for the extensive loss of anadromous fish in the vicinity of Iron Gate Dam (NRC 2003). Prior to the construction of the dam in 1962, anadromous fish had access to several significant thermal refugial areas, including Jenny and Fall Creeks. After the dam was constructed, the nearest significant refugial area is now located at Beaver Creek, almost 20 miles downstream from Iron Gate Dam. Several years after the construction of the dam, spring-run Chinook salmon ceased to return to that area of the river, leaving the Salmon River stocks located over 100 miles downstream as the last significant spring-run Chinook location. Similarly, steelhead returns to Iron Gate Hatchery have been low (KRBFTF 1991).

Additional work regarding salmonid use of thermal refugia is currently being conducted by the Yurok Tribal Fisheries Program, the Karuk Department of Natural Resources, and the Bureau of Reclamation, which includes tagging of juvenile fish to ascertain population sizes and residency time, temperature-sensitive radio telemetry of adult Chinook salmon and steelhead, food availability, aerial temperature measurements using infra-red cameras, and extensive measurements of refugia size at different mainstem Klamath River flows.

Additional recommended research:

1. Careful and detailed temperature monitoring of key cold water inputs and the Klamath mainstem adjacent to these areas is needed. Tidbits or other temperature recorders should be placed near thermal refugial areas. This will facilitate the behavior based temperature tolerance.
2. A mark-recapture study to determine the residence time for these fish in these areas is recommended. This will also enable researchers to look for these fish in lower tributary areas. Careful handling will be required to pull this off without causing excessive mortality.
3. Continuation of weekly and seasonal observations, especially focusing on early morning hours, as well as afternoon peak usage is recommended.
4. A focus on Blue Creek by conducting regular fish abundance monitoring is recommended, as it has been recently discovered that thousands of adults utilize this area as a holding and staging area during the summer and early fall. Blue Creek is also a special area of concern because the adult salmon fish kill of 2002

was concentrated in this area. The health of these summer holding adult fish should be investigated early on before the fall run comes in.

5. Monitoring thermal refugia usage on lower Trinity River tributaries is recommended. The clarity of the Trinity River will enable investigators to examine fish usage in the nearby mainstem river, and will provide important clues on Klamath River fish usage of mainstem habitats.

Finally, it appears that the numbers of adult and juvenile salmonids that utilize these areas could be greatly enhanced by the introduction of overhead and instream cover. The simple introduction of cut brush that is intended to wash away in winter high flows would be inexpensive and effective, as we regularly observed that thermal refugial areas with high quality cover elements held more salmonids than did other areas. Care would need to be taken at certain locations, however, as these are popular swimming areas, and certain tributary mouths are culturally important to the Karuk Tribe of California.

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Literature Cited

Bartholow, J. M. 1995. Review and analysis of Klamath River water temperatures as a factor in the decline of anadromous salmonids with recommendations for mitigation. Pages 1-25 *in* Compilation of Phase I (Reports for the Klamath River Basin, May 1995, by the River Systems Management Section, Nat. Biol. Serv., Ft. Collins, CO.

Belchik, M. R. 1997. Summer Locations and Salmonid Use of Cool Water Areas in the Klamath River; Iron Gate Dam to Seiad Creek, 1996. Yurok Tribal Fisheries Program Technical Report. 13 pp.

Brett J.R. 1952. Temperature tolerance in young Pactfic salmon, genus *Onchorhynchus* sp. Journal of the Fisheries Research Board of Canada 9: 265–323.

Bilby, R.E. 1984. Characteristics and frequency of cool-water areas in a western Washington stream. J. Freshw. Ecol. 2: 593–602.

Biro, P.A. 1998. Staying cool: behavioral thermoregulation during summer by young-of-year brook trout in a lake. Transactions of the American Fisheries Society 127: 212–222.

Ebersole, J.L., Liss, W.J., and Frissell, C.A. 2001. Relationship between stream temperature, thermal refugia and rainbow trout *Oncorhynchus mykiss* abundance in arid-land streams in the north-western United States. Ecol. Freshw. Fish, 10: 1–10.

Ebersole, J.L., Liss, W.J., and Frissell, C.A. 2003. Thermal heterogeneity, stream channel morphology, and salmonid abundance in northeastern Oregon streams. Can. J. Fish. Aquat. Sci. 60: 1266–1280

Higgins, P.T., S. Dobush, and D. Fuller. 1992. Factors in Northern California Threatening Stocks with Extinction. Humboldt Chapter of American Fisheries Society. Arcata, CA. 25pp.

Kaya, C.M., Caddying, L.R. & Burkhalter, D.E. 1977. Use of a cold-water refuge by rainbow and brown trout in a geothermally heated stream. Progressive Fish Culturist 39: 37–39.

Klamath River Basin Fisheries Task Force 1991. Long Range Plan for the Klamath River Basin Conservation Area Fishery Restoration Program

Li, H.W., Pearsons, T.N., Tait, C.K., Li, J.L. & Gaither, R. 1993. Approaches to evaluate habitat improvement programs in streams of the John Day Basin. Completion Report, Oregon Cooperative Fishery Research Unit, Oregon State Uni-versity, Corvallis, Oregon. (as cited in Ebersole at al 2001)

Nielsen, J.L., Lisle, T.E. & Ozaki, V. 1994. Thermally stratified pools and their use by steelhead in northern California streams. Transactions of the American Fisheries Society 123:613–626.

NRC 2003. Endangered and Threatened Fishes of the Klamath River Basin; Causes of the Decline and Strategies for Recovery NRC Press, October 2003.

Orciari, R.D., and D. F. Landers 1995. A Preliminary Assessment on the Effects of Water Releases from the Falls Village Hydrofacility upon Cold-water Refuges in the Housatonic River, Cornwall-Sharon, Connecticut. Connecticut Department of Environmental Protection; Fisheries Division. Technical Report. 25 pp.

Ozaki, V.L. 1988. Geomorphic and hydrologic conditions for cold pool formation on Redwood Creek, California. Redwood National Park Research and Development Technical Report 24. 57 pp.

Sedell, J.R., Reeves, G.H., Hauer, F.H., Stanford, J.A. & Hawkins, C.P. 1990. Role of refugia in recovery from disturbance: modern fragmented and disconnected river systems. Environmental Management 14: 711–724.

Torgersen, C.E., Price, D.M., Li, H.W. & McIntoch, B.A. 1999. Multiscale thermal refugia and stream habitat associations of chinook salmon in northeastern Oregon. Ecological Applications 9: 301–319.

Weitkamp, L.A., T.C. Wainwright, G.J.Bryant, et al. 1995. Status Review of Coho Salmon from Washington, Oregon, and California. U.S. Dep. Commer., NOAA Tech Memo. NMFS-NWFSC-24. 240 pp.

Table 3: Data from all snorkel observations in 1998. Data is ordered by upstream site to downstream site, and then by date. "main T" is the water temperature of the mainstem Klamath upstream from the sample site. "creek T" is the temperature of the cooler water entering the refugia site. "T diff" is the difference between those two temperatures. "std YOY", "sdt juv" and "half pound" are steelhead young-of-year, steelhead juvenile, and steelhead half pounder respectively. Data is organized by location from upstream to downstream, then by date.

date	time	site	river mile	air T	main T	creek T	T diff	std yoy	std juv	half pound	std adult	chin juv	chin adult	unid salm	tot salmonids
7/7/1998	1830	bogus	190.2	26.5	22.0	22.0	0.0	2	0		0	10	0	0	12
7/29/1998	1120	bogus	190.2	26.5	23.5	19.5	4.0	0	3	0	0	0	0	0	3
8/4/1998	1230	bogus	190.2	30.5	24.0	22.5	1.5	2	0	0	0	0	0	0	2
8/11/1998	1230	bogus	190.2	32.0	23.0	21.5	1.5	18	0	0	0	0	0	0	18
8/26/1998	1110	bogus	190.2	28.0	22.5	18.0	4.5	7	0	0	0	0	0	0	7
9/2/1998	1150	bogus	190.2	31.5	22.0	18.5	3.5	3	0	0	0	0	0	0	3
9/8/1998	1530	bogus	190.2					2	15	0	0	0	0	0	17
7/8/1998	1040	humbug	171.8	28.0	21.5	16.5	5.0	0	4		0	175	0	0	179
7/29/1998	1400	humbug	171.8	28.5	23.5	23.5	0.0	2	0	0	0	30	0	0	32
8/4/1998	1350	humbug	171.8	31.5	24.5	24.5	0.0	3	0	0	0	2	0	0	5
8/11/1998	1410	humbug	171.8	34.5	24.0	24.5	-0.5	0	0	0	0	0	0	0	0
8/26/1998	1230	humbug	171.8	28.0	21.5	22.5	-1.0	0	0	0	0	0	0	0	0
9/2/1998	1310	humbug	171.8	33.5	22.0			0	0	0	0	0	0	0	0
7/7/1998	1600	beaver	161.7	32.5	22.5	17.5	5.0	0	0		0	3	0	0	3
7/29/1998	1430	beaver	161.7	33.0	23.5	20.5	3.0	0	175	1	1	1250	0	0	1427
8/4/1998	1400	beaver	161.7	35.5	25.5	21.5	4.0	20	382	0	0	500	0	0	902
8/11/1998	1545	beaver	161.7	34.5	24.5	21.5	3.0	90	275	0	1	375	0	0	741
8/19/1998	1300	beaver	161.7	29.0	22.5	18.0	4.5	171	80	0	0	98	0	0	349
8/25/1998	1710	beaver	161.7	30.5	23.0	19.0	4.0	235	90	2	0	300	0	0	627
9/2/1998	1420	beaver	161.7		22.5	20.5	2.0	56	11	0	0	0	0	0	67
9/8/1998	1650	beaver	161.7				0.0	52	25	0	0	20	0	0	97
9/16/1998	1715	beaver	161.7	27.0	20.5	17.5	3.0	97	33	0	0	6	0	0	136
7/7/1998	1500	horse	148.2	34.5	23.0	17.0	6.0	0	3		0	55	0	0	58
7/21/1998	1735	horse	148.2	34.0		18.0		0	50		0	70	0	0	120
7/29/1998	1630	horse	148.2	28.5	25.0	19.0	6.0	0	43	0	0	33	0	0	76
8/4/1998	1615	horse	148.2		26.5	19.5	7.0	0	85	0	0	88	0	0	173
8/11/1998	1810	horse	148.2	29.0	25.0	19.0	6.0	30	33	0	0	28	0	0	91
8/25/1998	1530	horse	148.2	29.0	24.0	19.0	5.0	60	20	0	0	30	0	0	110
9/2/1998	1520	horse	148.2	29.5	24.0	20.5	3.5	15	2	0	0	0	0	0	17

date	time	site	river mile	air T	main T	creek T	T diff	std yoy	std juv	half pound	std adult	chin juv	chin adult	unid salm	tot salmonids
9/9/1998	1315	horse	148.2				0.0	40	16	0	0	1	0	0	57
9/16/1998	1550	horse	148.2	31.5	21.5	17.5	4.0	21	7	0	0	0	0	0	28
7/21/1998	1845	grider	130.6	26.0	25.0	21.0	4.0	0	46		0	42	0	0	88
7/29/1998	1815	grider	130.6	29.5	24.5	21.5	3.0	6	31	2	1	7	0	0	47
8/4/1998	1730	grider	130.6	36.5	26.5	23.5	3.0	35	125	1	0	75	0	0	236
8/12/1998	1200	grider	130.6	35.0	24.0	20.0	4.0	13	43	0	0	21	0	0	77
8/18/1998	1820	grider	130.6	30.5	23.5	19.5	4.0	8	15	0	0	0	0	0	23
8/25/1998	1250	grider	130.6		22.5	20.0	2.5	15	9	0	0	0	0	0	24
9/2/1998	1600	grider	130.6	39.5	24.5	23.0	1.5	41	12	0	0	0	0	0	53
9/9/1998	1500	grider	130.6				0.0	4	8	0	0	0	0	0	12
9/16/1998	1300	grider	130.6	32.5	20.5	19.0	1.5	9	3	0	0	1	0	0	13
7/7/1998	1140	seiad	130.5	24.0	20.5	19.0	1.5	0	6		0	59	0	0	65
7/21/1998	1915	seiad	130.5		24.5	20.5	4.0	0	23		0	175	0	1	199
7/29/1998	1730	seiad	130.5	24.5	24.0	21.5	2.5	0	0	0	0	88	0	0	88
8/12/1998	1230	seiad	130.5	32.5	23.5	20.5	3.0	0	0	0	0	55	0	0	55
8/18/1998	1730	seiad	130.5	25.5	23.5	20.5	3.0	0	0	0	0	40	0	0	40
8/25/1998	1145	seiad	130.5	28.0	22.0	18.5	3.5	0	2	0	0	19	0	0	21
9/2/1998	1700	seiad	130.5	31.5	25.0	22.0	3.0	0	7	0	0	48	0	0	55
9/10/1998	1145	seiad	130.5	23.5	20.0	18.0	2.0	1	0	0	0	2	0	0	3
9/16/1998	1200	seiad	130.5	26.5	20.5	18.5	2.0	0	0	0	0	0	0	0	0
7/30/1998	1100	portuguese	128.1	21.0	21.0	18.5	2.5	3	0	0	0	10	0	0	13
8/12/1998	1300	portuguese	128.1	31.5	24.5	21.0	3.5	4	2	0	0	7	0	0	13
7/22/1998	1100	fort goff	127.3	26.0	23.0	17.5	5.5	0	0		0	0	0	0	0
7/30/1998	1145	fort goff	127.3	21.5	22.5	18.0	4.5	0	0	0	0	0	0	0	0
8/12/1998	1320	fort goff	127.3	32.5	25.0	20.5	4.5	7	7	0	0	138	0	0	152
8/18/1998	1630	fort goff	127.3	29.5	24.0	19.0	5.0	0	0	0	0	0	0	0	0
8/26/1998	1445	fort goff	127.3	34.0	23.0	18.0	5.0	1	0	0	0	0	0	0	1
9/2/1998	1740	fort goff	127.3		24.5	19.5	5.0	3	0	0	0	0	0	0	3
9/16/1998	1130	fort goff	127.3	21.5	20.5	16.5	4.0	1	0	0	0	0	0	0	1
7/1/1998	1144	indian	106.8	20.0	18.5	14.5	4.0	0	11		0	54	0	2	67
7/6/1998	1730	indian	106.8		22.5	20.0	2.5	0	12		0	65	0	0	77
7/22/1998	1300	indian	106.8		24.0	18.0	6.0	0	100		0	2750	0	0	2850
7/28/1998	1630	indian	106.8	33.5	26.0	22.5	3.5	0	425	20	0	3250	0	0	3695
8/3/1998	1330	indian	106.8	38.0	25.0	19.5	5.5	0	90	35	2	2080	0	0	2207

date	time	site	river mile	air T	main T	creek T	T diff	std yoy	std juv	half pound	std adult	chin juv	chin adult	unid salm	tot salmonids
8/10/1998	1810	indian	106.8	34.0	25.5	21.5	4.0	0	600	45	5	3500	0	0	4150
8/27/1998	1100	indian	106.8	26.0	22.0	17.0	5.0	2	53	4	1	125	0	0	185
9/2/1998	1800	indian	106.8	30.5	24.5	20.5	4.0	5	165	13	3	380	0	0	566
9/15/1998	1700	indian	106.8	28.0	22.5	18.5	4.0	17	37	3	3	350	0	0	410
8/20/1998	955	little grider	106.1	25.5	21.5	16.0	5.5	0	0	0	0	0	0	0	0
7/8/1998	1510	elk	105.9	37.0	22.0	19.5	2.5	0	2		0	14	0	0	16
7/30/1998	1230	elk	105.9	28.5	24.5	20.0	4.5	0	0	0	0	0	0	0	0
8/5/1998	1130	elk	105.9	26.0	24.5	20.0	4.5	0	0	0	0	0	0	0	0
8/10/1998	1745	elk	105.9		25.5	21.5	4.0	0	1	0	0	1	0	0	2
8/18/1998	1530	elk	105.9		24.5	20.5	4.0	0	0	0	0	0	0	0	0
9/2/1998	1830	elk	105.9		24.5	20.5	4.0	0	0	0	0	0	0	0	0
9/15/1998	1730	elk	105.9	31.0	22.5	18.5	4.0	0	0	0	0	0	0	0	0
8/20/1998	1050	oak flat	100.4	25.5	21.0	15.0	6.0	30	9	0	0	5	0	0	44
7/6/1998	1530	independence	93.9		22.5	19.5	3.0	0	99		0	137	0	0	236
7/28/1998	1530	independence	93.9	35.0	25.5	21.5	4.0	0	35	0	0	87	0	0	122
7/30/1998	1515	independence	93.9	31.0	24.5	19.5	5.0	0	48	0	0	110	0	0	158
8/12/1998	1745	independence	93.9	34.0	25.5	20.5	5.0	35	50	0	3	275	0	0	363
9/1/1998	1800	independence	93.9	33.5	23.5	19.0	4.5	60	58	2	0	40	0	0	160
9/10/1998	1630	independence	93.9		20.5	15.5	5.0	32	20	0	0	20	0	0	72
9/15/1998	1620	independence	93.9	28.5	22.5	17.5	5.0	9	8	0	0	7	0	0	24
7/2/1998	1300	ukonom	89.6		20.0	15.0	5.0	0	25		0	25	0		50
7/6/1998	1330	ukonom	89.6	28.0	21.0	16.5	4.5	0	77		0	49	0	0	126
7/20/1998	1330	ukonom	89.6	32.0	22.5	18.5	4.0								0
7/28/1998	1300	ukonom	89.6	29.0	25.0	18.5	6.5	0	58	1	1	9	0	0	69
8/3/1998	1730	ukonom	89.6		25.0	18.5	6.5	0	225	0	13	1350	0	0	1588
8/12/1998	1800	ukonom	89.6	30.5	25.5	19.5	6.0	75	238	0	5	1125	0	0	1443
8/18/1998	1215	ukonom	89.6		23.5	14.5	9.0	64	68	0	1	110	0	0	243
8/26/1998	1630	ukonom	89.6	30.5			0.0	67	132	3	1	383	0	0	586
9/1/1998	1600	ukonom	89.6	33.5	23.5	17.0	6.5	62	90	2	4	132	1	0	291
9/9/1998	1500	ukonom	89.6	26.5	22.0	16.0	6.0	44	53	0	1	25	1	0	124
9/15/1998	1445	ukonom	89.6	34.5	22.0	15.5	6.5	33	25	1	0	43	0	0	102
8/20/1998	1200	swillup	88.2	26.0	21.5	15.0	6.5	1	0	0	0	0	0	0	1
7/6/1998	1100	dillon	84.1		21.5	19.0	2.5	0	40		30	0	0	0	70
7/20/1998	1130	dillon	84.1	31.0	22.5	18.5	4.0	0	35		0	11	0	0	46

date	time	site	river mile	air T	main T	creek T	T diff	std yoy	std juv	half pound	std adult	chin juv	chin adult	unid salm	tot salmonids
7/28/1998	1100	dillon	84.1	25.5	24.5	21.5	3.0	0	6	0	0	35	0	0	41
7/30/1998	1615	dillon	84.1	27.0	23.5	22.0	1.5	0	33	1	0	38	0	0	72
8/3/1998	1245	dillon	84.1	28.0	24.5	21.5	3.0	2	7	0	0	33	0	0	42
8/12/1998	1530	dillon	84.1	33.5	25.5	23.0	2.5	8	15	0	0	13	0	0	36
8/18/1998	1100	dillon	84.1	26.5	22.5	18.5	4.0	8	11	0	0	15	0	0	34
8/26/1998	1820	dillon	84.1				0.0								0
9/1/1998	1420	dillon	84.1	31.0	23.5	20.0	3.5	20	7	0	0	5	1	0	33
9/9/1998	1345	dillon	84.1	26.5	21.5	20.0	1.5	7	1	0	0	0	0	0	8
9/15/1998	1315	dillon	84.1	33.0	21.5	17.5	4.0	1	0	0	0	0	0	0	1
7/9/1998	920	ti	79.6	22.0	21.0	13.5	7.5	0	0		0	9	0	0	9
7/31/1998	1100	ti	79.6	26.0	22.5	15.0	7.5	0	1	0	0	0	0	0	1
8/5/1998	1340	ti	79.6	28.5	25.0	17.5	7.5	0	0	0	0	1	0	0	1
8/10/1998	1620	ti	79.6	32.5	25.0	16.5	8.5	0	0	0	0	1	0	1	2
8/20/1998	1310	ti	79.6	26.0	22.5	15.0	7.5	0	0	0	0	0	0	0	0
9/1/1998	1300	ti	79.6	32.5	23.5	16.0	7.5	0	0	0	0	0	1	0	1
9/9/1998	1210	ti	79.6	27.5	22.0	15.5	6.5	0	0	0	0	0	0	0	0
9/15/1998	1230	ti	79.6	32.0	21.0	15.5	5.5	0	0	0	0	0	0	0	0
7/23/1998	1320	camp	57.1	36.5	23.5	20.0	3.5	16	4		0	38	0	0	58
7/31/1998	1500	camp	57.1	29.0	22.5	20.5	2.0	12	2	0	1	11	0	0	26
8/5/1998	1615	camp	57.1	31.5	24.5	21.0	3.5	16	7	0	0	84	0	0	107
8/10/1998	1315	camp	57.1	35.5	23.0	19.5	3.5	6	3	0	0	53	0	0	62
8/17/1998	1635	camp	57.1	27.0	23.0	20.0	3.0	13	3	0	0	13	0	0	29
9/1/1998	1130	camp	57.1	30.5	23.0	18.0	5.0	0	0	0	0	0	0	0	0
9/9/1998	1100	camp	57.1		20.5	17.5	3.0	2	0	0	0	0	0	0	2
9/15/1998	1130	camp	57.1	27.5	20.5	17.5	3.0	1	1	0	0	0	0	0	2
7/2/1998	1630	red cap	53.3	27.0	19.5	18.5	1.0	0	26		0	6	0		32
7/9/1998	1130	red cap	53.3		20.0	17.0	3.0		2			3	0	0	5
7/23/1998	1135	red cap	53.3	27.0	23.0	19.5	3.5	0	13		0	20	0	0	33
7/31/1998	1230	red cap	53.3	25.5	23.0	20.5	2.5	0	18	1	0	23	0	0	42
8/5/1998	1500	red cap	53.3	30.0	25.0	22.5	2.5	10	90	3	0	325	7	0	435
8/10/1998	1430	red cap	53.3	28.5	24.0	21.5	2.5	0	100	0	3	325	3	0	431
8/17/1998	1815	red cap	53.3	26.5	23.0	20.5	2.5	17	15	0	1	50	1	0	84
8/20/1998	1445	red cap	53.3	27.0	23.0	20.5	2.5	7	36	0	1	90	0	0	134
8/31/1998	1630	red cap	53.3	29.5	24.0	21.5	2.5	18	15	0	3	28	100	0	164

date	time	site	river mile	air T	main T	creek T	T diff	std yoy	std juv	half pound	std adult	chin juv	chin adult	unid salm	tot salmonids
9/8/1998	1700	red cap	53.3	26.5	22.5	20.0	2.5	4	80	1	2	25	75	0	187
9/14/1998	1715	red cap	53.3		22.0	20.0	2.0	17	25	2	1	15	2	0	62
7/6/1998	835	slate	51.1	21.5	19.0	14.5	4.5								0
7/9/1998	1430	slate	51.1	31.0	21.0	17.5	3.5	0	2		0	8	0	0	10
7/23/1998	1450	slate	51.1	36.5	24.0	18.5	5.5	0	15	1	2	25	1	0	44
7/31/1998	1545	slate	51.1	27.5	23.0	19.0	4.0	2	1	0	0	2	0	0	5
8/5/1998	1700	slate	51.1	29.5	25.0	18.5	6.5	2	5	3	0	50	5	0	65
8/10/1998	1245	slate	51.1	32.0	23.5	17.0	6.5	1	6	0	0	10	0	0	17
8/17/1998	1535	slate	51.1		23.0	18.0	5.0	0	1	0	0	0	0	0	1
8/31/1998	1400	slate	51.1		23.5	19.0	4.5	4	14	0	0	0	0	0	18
9/8/1998	1500	slate	51.1	27.5	22.5	18.0	4.5	7	13	0	0	0	0	0	20
9/14/1998	1530	slate	51.1	32.0	22.0	17.5	4.5	0	0	0	0	0	0	0	0
7/9/1998	1500	bluff	50.3	31.0	21.0	19.0	2.0	5	22		0	12	0	0	39
7/23/1998	1530	bluff	50.3	33.0	24.0	21.0	3.0	0	100	0	1	240	0	0	341
7/31/1998	1630	bluff	50.3	28.5	23.0	20.5	2.5	0	113	0	1	63	0	0	177
8/5/1998	1730	bluff	50.3	28.5	25.0	20.5	4.5	1	200	3	1	175	1	0	381
8/10/1998	1200	bluff	50.3	30.5	23.0	17.5	5.5	0	88	0	2	80	0	0	170
8/17/1998	1400	bluff	50.3	25.0	23.5	19.0	4.5	7	65	0	3	25	1	0	101
8/20/1998	1720	bluff	50.3	26.0	23.0	19.5	3.5	10	35	1	2	15	0	0	63
8/31/1998	1230	bluff	50.3	33.0	23.0	18.5	4.5	9	60	0	0	25	1	0	95
9/8/1998	1215	bluff	50.3	27.5	22.5	17.5	5.0	6	38	1	1	11	7	0	64
9/14/1998	1430	bluff	50.3	30.5	22.0	19.5	2.5	14	30	0	0	12	1	0	57
7/9/1998	1600	aikens	49.6		21.5	16.0	5.5	0	0		0	7	0	0	7
8/20/1998	1620	aikens	49.6	24.5	22.5	15.0	7.5	0		0	0	1	0	0	1