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Basking patterns and thermal regulatory behaviors of western pond turtles (*Clemmys marmorata*) between two thermal regimes in a dammed and undammed Trinity River system.

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Photo of western pond turtle #6002 from the South Fork Trinity River population. 6JUL04

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Abstract—Basking activity of western pond turtles (*Clemmys marmorata*) was studied on two forks of the Trinity River in northern California, the dammed Mainstem Trinity River and the undammed South Fork Trinity River. The thermal regime between these two riverine systems is extreme due to the hypolimnetic release from the Lewiston Dam on the Mainstem Trinity River. Turtles studied on the Mainstem Trinity River were exposed to summer water temperatures that are >10°C lower than the control population on the South Fork Trinity River. We tested the null hypothesis that there would be no difference in thermal regulatory behavior times between the two populations of *C. marmorata*. However, there was a significant difference between the two population's thermal regulatory behavior, with the Mainstem Trinity River population of *C. marmorata* spending more time seeking aquatic thermal refugia and basking than the South Fork Trinity River population (Yates chi-square value = 2368.07, $P = 0.0000$, and t-value = -3.4048, $P = 0.0078$) when compared to the river maximum water temperatures. Individual turtles from the undammed South Fork Trinity River tended to bask for shorter periods of time per day and also utilized aquatic basking behaviors compared to the turtles from the Mainstem Trinity River population.   The artificially colder thermal regime created by the hypolimnetic releases from the Lewiston Dam may be influencing the turtles thermoregulatory behavior on the Mainstem Trinity River and having these animals seeking alternative aquatic thermal refugia.

Key words: Altered thermal regimes; Aquatic thermal refugia; Basking; *Clemmys marmorata*; iBass dataloggers; Thermoregulation; Trinity River; Western pond turtle.

Introduction

Bioenergetics plays an important role in the maintenance of an individual to control its homeostasis. In particular, poikilothermic species rely on behavioral adaptations to assist in thermoregulation (Huey and Kingsolver 1989). One such behavioral adaptation used by freshwater chelonians is basking, or heliothermic use of heat from solar radiation, to warm their body. Changes in normal thermal regulatory behaviors may affect several aspects of general life-history traits. These could include growth patterns, age at maturity, and size at maturity, which in turn could affect age- and size-specific reproductive investments and the size at birth of offspring. Therefore, understanding thermoregulatory requirements of turtles may better elucidate the potential impact on these other key life history traits.

Animals that are challenged by a deviation from the normal environmental parameters that they evolved with may incur chronic stress that could result in lowered fitness. For poikilothermic species, one such stress could be colder thermal regimes, both ambient air temperatures and aquatic temperatures (Stearns and Koella 1986). There were five reactions in life-history traits that could occur in poikilothermic species in relation to cold stress, 1) they could mature later at a smaller size, 2) they could mature later at the same size, 3) they could mature later at a larger size, 4) they could mature earlier at a smaller size, or 5) they could mature at the same age at a smaller size (Stearns and Koella 1986). In an examination of spotted turtles (*Clemmys guttata*) in the northern latitudinal limit of

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their range, researches determined that turtles reached a larger mean adult body size relative body size compared to southern populations and that they reached sexual maturity at a later estimated age (Litzgus and Brooks 1998) and this follows that 3rd pattern of maturing later at a larger size.

Change in body size due to cold stress may have impacts on reproductive success in the form of smaller clutch sizes (# of eggs per nesting season), smaller size of eggs or a combination of the two. In a study on the egg-size relationships of the Mediterranean Gecko (*Hemidactylus turcicus*) that has a fixed clutch size, Selcer (1990) indicates that clutch lipid mass was positively correlated with female snout-vent length (SVL) and carcass mass and that egg mass was positively correlated to both hatchling mass and SVL. In a study of three eastern species of turtles, it was found that there was a structural constraint placed on egg size by the size of the pelvic girdle and that two of the smaller species were unable to maximize the size of their eggs (Congdon and Gibbons 1987). If there is a size difference for western pond turtles as a result of thermoregulatory behaviors constraining size at maturity, there could be a negative impact on the size of the eggs produced in this population. Preliminary analysis of sizes at maturity of western pond turtles between populations on the Mainstem Trinity River and populations on the South Fork Trinity River demonstrates a significant difference with the South Fork Trinity turtle population being larger (Bettaso, Ashton and Welsh, unpublished data). The smaller size of female turtles on the Mainstem Trinity River could have a cascade effect on potential recruitment into the population on the Mainstem Trinity River.

In a study on painted turtles (*Chrysemys picta*) on variation of seasonal temperatures, use of Thermochron iButtons were placed on the external carapace to derive thermoregulatory behaviors of this species (Grayson and Dorcas 2004). These researchers also conducted an experiment to look at the difference between the external Thermochron iButtons readings and the internal temperature of the turtles as measured by cloacal temperatures. They detected only a small difference between the two readings (mean difference = datalogger 0.26 C ± 0.24 SE lower than cloacal temperature) and suggested that external dataloggers could accurately reflect the thermal behaviors of the turtles (Grayson and Dorcas 2004).

The objective of this study was to compare the thermoregulatory behaviors of the western pond turtle between a population from a non-challenged thermal regime (South Fork Trinity River) to a population on a challenged thermal regime (Mainstem Trinity River) by recording temperature habits of this species. The second objective of this study was to test the use of iBass temperature dataloggers affixed to the exterior of a turtle's carapace would approximate the use of difference thermal regimes.

Methods

Western pond turtles were captured in the summer of 2004 by snorkel surveys and had radio-transmitters (PD-2 model, Holohil Systems Ltd.) and temperature dataloggers (iBass model, Alpha Mach Inc.) to track thermal behavior of the turtles. Standard morphometrics were taken on maximum carapace length, minimum carapace length, weight, sex and age by counting annuli (Bury and Germano 2004). The temperature dataloggers were set to record every fifteen minutes for a total of 21.7 days. The length of the radio-transmitters' batteries were either three or six months. Placement of equipment was by attachment to the external carapace towards the rear with waterproof surfing bonding (Dingleberries Surfboard Repair™) or Quiksteel. A total of six turtles were captured on the Trinity River with the first captures date of June 22, 2004 and the last capture date was August 17, 2004, with one additional turtle that had a radio-transmitter placed on it but no temperature datalogger on August 17, 2004 (Appendix A). On the South Fork Trinity River, six turtles were captured and fitted with radio-transmitters and temperature loggers on July 6, 2004. Temperature dataloggers were placed in both the river and in the air in the shade at an area close to were turtles were captured.

Post retrieval of iBass temperature dataloggers, data was downloaded into Excel spreadsheets (Appendix B for temperature profiles of eleven turtles). Overlays of individual turtle external shell temperatures (T_S) were compared to water and ambient air temperatures from each of the two rivers. Data was sorted to represent when turtles were two degrees Celsius higher than the maximum water temperature of the river to determine when the turtle has left the main river channel for either basking in radiate temperature or seeking a warmer aquatic thermal refugia. On the South Fork Trinity River, the maximum river temperature was 26º C. For the Mainstem Trinity River, a threshold temperature was set at 14º C for the maximum river temperature and all data points at 16º C or higher were considered when the turtle was basking by direct solar radiation or was using aquatic thermal refugia. Data for each turtle was split into datapoints as time above the maximum river water temperature ("basking") and datapoints as time spent in the river for each respective river. These datapoints were then used to create a proportional number of time spent "basking" divided by time spent in the river.

Data analysis was performed in NCSS (Hintz 2001). T-test and Yates Chi-square analysis were run on the proportional data.

Results

We successfully recovered all thirteen radio-transmittered turtles in the six days of field visits over three weeks in September 2004. The turtles on the South Fork Trinity River were recaptured on 8, 14, 21 and 29 September, were as the turtles from the Mainstem Trinity River were recaptured on 15 & 16 September. Data from iBass dataloggers was downloaded into excel spreadsheets for the six turtles on the Mainstem and for 5 turtles on the South Fork Trinity River. Data was lost from one logger on a turtle on the South Fork Trinity River.

Temperature data for each turtle was compared to the river temperatures to understand the turtle's behavior based on thermal profiles. The temperature datapoints that were considered "basking" were divided by the total datapoints collected to give a proportion of time spent "basking" for each turtles and the results are presented in Tables 1 & 2. The average amount of time spent "basking" by turtles on the South Fork Trinity River was 21% whereas for turtles on the Mainstem Trinity River was 53% (Figure 1). A t-test on the individual proportions of each turtle comparing between the Mainstem Trinity River population and the South Fork Trinity River population had significantly different use of "basking" (t-value = -3.4048, P = 0.0078). Yates Chi-square test of the proportional data also had significant differences between the time spent basking between the two populations (Yates chi-square value = 2368.07, P = 0.0000).

Table 1. Comparison of time spent "basking" to total time datalogger collected datapoints for the South Fork Trinity River western pond turtles (n=5).

Turtle #	715	716	717	719	6002	Sum
"basking"	706	515	187	660	110	2178
Total logger points	2045	2044	1986	2048	2002	10125
Proportion spent "basking"	0.345232	0.251957	0.094159	0.322266	0.054945	**0.215111**

Table 2. Comparison of time spent "basking" to total time datalogger collected datapoints for the Mainstem Trinity River western pond turtles (n=6).

Turtle #	160	427	5668	5750	5903	5911	Sum
"basking"	428	1464	916	984	1171	1277	6240
Total logger points	1685	1961	1943	2028	1943	2048	11608
Proportion spent "basking"	0.254006	0.746558	0.471436	0.485207	0.602676	0.623535	**0.53756**

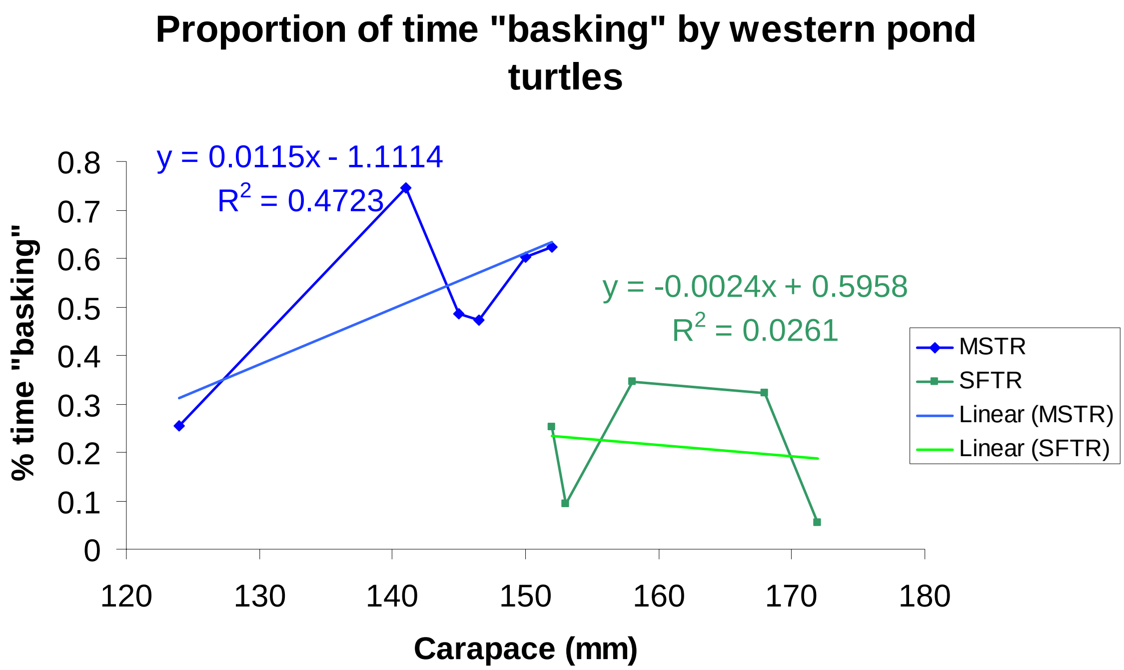

Figure 1. Proportion of time that western pond turtles spent "basking" for the Mainstem Trinity River population and the South Fork Trinity River population. See text for definition of "basking".

Discussion

The thermoregulatory behaviors of the western pond turtles are being interpreted based on examination of their thermal graphs. The term "basking" used in this study covers temperatures that are above the mean maximum daily temperature of the river and therefore include when a turtle is seeking alternative aquatic thermal refugia, such as ponds or wetlands off the main river channels. Examination of individual turtle thermal graphs for a Mainstem Trinity River turtle #5750 (Appendix B) shows that the animal moved from the nocturnal activity in the main channel of the river to a thermal profile that was identical to river conditions on the South Fork Trinity River. That the turtle #5750 moved to an aquatic habitat for five days before returning to the Mainstem river channel, it may be that associated wetland habitat located off the Mainstem channel is preferred habitat and under resource competition.

There are several mechanisms that may be affecting the Mainstem Trinity River turtle population in relation to flow releases from the Lewiston Dam. The duration of the summer flows with a 2000cfs bench until early July does not follow historical hydrographs for the system. The bench flows may prevent use of the Mainstem channel for constant use until the flows are dropped down to 450cfs in mid-July. The decision to

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increase flows in mid-August again could have a negative impact upon the Mainstem Trinity River turtle population if this flow encourages leaving the aquatic resource early for hibernation, or in over-crowding in preferable pond habitats. It may be the lower water temperature from the hypolimnetic releases from the Lewiston Dam could be negatively affecting the Mainstem Trinity River turtle population by changing foraging abilities or efficiencies. These changes may in turn result in abilities of females to supply sufficient lipid reserves to developing ova or decrease the number of ova produced for a clutch. These could have negative impacts on the potential recruitment into the Mainstem Trinity River population if nest failure is occurring due to lack of lipid energy supplies to developing embryos or if there are too few hatchlings in a female clutch to allow for natural mortality of young turtles early in life.

It was observed upon recapturing the turtles at the end of the study by locating them with their radio-transmitters that animals on the South Fork Trinity River were still using the river the second week of September, 2004, where as six of the seven turtles on the Mainstem Trinity River were already out of the river and five of these six were exhibiting over-wintering behaviors. Of the two turtles on the South Fork Trinity River that were recovered in the third and fourth week of September, 2004, one turtle was exhibiting hibernation behavior and the other was found walking, presumably in search of over-wintering habit, over 300 meters from the main channel of the river. The small sample sizes used do not allow for a comparison between the timing of over-wintering behaviors in statistical rigorous manner, but the Mainstem Trinity River turtles may be moving out of foraging habitat earlier than the South Fork Trinity turtles, and this could have added stress of prolonged hibernation cycles. The timing and location of terrestrial hibernaculum of spotted turtles (Clemmys guttata) were found to be important factors of over-winter survival of this species (Litzgus et al. 1999). Further research into these factors for western pond turtles in the Trinity River Basin should be explored.

<u>Management Implications and Considerations</u>

The TRRP is developing restoration efforts that will influence some of the historical floodplains and associated aquatic habitats that the Trinity River in pre-dammed conditions. Creation of backwater ponds that may provide warmer thermal refugia that the western pond turtle can utilize to off-set the current altered thermal regime of the Mainstem Trinity River should be a restoration goal of the TRRP. A difficult challenge will be the ability to create historical aquatic habitat conditions that will benefit western pond turtles, other herpetofauna and other riparian associated wildlife in the Mainstem Trinity River basin without creation of backwater "stranding" pools that may negatively impact salmonid species or facilitate exotic species establishment (e.g. bullfrogs).

Timing and duration of flows from the Lewiston Dam may be having a direct impact on how and when the Mainstem Trinity River turtle population uses the river. In light of the late summer flow releases in August to assist relief of river conditions in the Klamath River below Wetchipec, these flow releases may be acting as a trigger for the Mainstem population to leave the river and seek out over-wintering habitat. This could have

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negative long-term impacts on the condition of these turtles by increasing their hibernation length that would create on over-demand on their body fat reserves. If not resulting in direct mortality, it may prevent sufficient lipid reserves being laid down in maternal ova development, thus affecting the population demographics by lowering recruitment.

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Monty Larson (volunteer) and Damon Goodman (USFWS) provided field assistance in locating turtles with transmitters. Jason Ogawa (USFWS) provided technical assistance with use of iBass temperature loggers, as well as Greg Goldsmith (USFWS) in providing support for software installment and initial analysis.

Literature Cited

Bury, B. and D, Germano. 1998. Annual deposition of scute rings in the western pond turtle, *Clemmys marmorata*. Chelonian Conservation and Biology 3(1):108-109.

Congdon, J. D. and J. W. Gibbons. 1987. Morphological constraint on egg size: a challenge to optimal egg size theory? Proceedings of the National Academy of the Sciences 84:4145-4147.

Grayson, K. L and M. E. Dorcas. 2004. Seasonal temperature variation in the painted turtle (*Chrysemys picta*). Herpetologica 60(3):325-336.

Hintz, J. 2001. NCSS & PASS. Number Cruncher Statistical Systems. Kaysville, Utah. www.ncss.com

Huey, R. B. and J. G. Kingsolver. 1989. Evolution of thermal sensitivity of ectotherm performance. Trends in ecology and evolution 4(5):131-135.

Litzgus, J. D. and R. J. Brooks. 1998. Growth in a cold environment: body size and sexual maturity in a northern population of spotted turtles, *Clemmys guttata*. Canadian Journal of Zoology 76:773-782.

Litzgus, J. D., J. P. Costanzo, R. J. Brooks, and R. E. Lee, Jr. 1999. Phenology and ecology of hibernation in spotted turtles (*Clemmys guttata*) near the northern limit of their range. Canadian Journal of Zoology 77:1348-1357.

Selcer, K. W. 1990. Egg-size relationships in a lizard with fixed clutch size: variation in a population of the Mediterranean gecko. Herpetologica 46(1):15-21.

Stearns, S. C. and J. C. Koella. 1986. The evolution of phenotypic plasticity in life-history traits: predictions of reaction norms for age and size at maturity. Evolution 40(5):893-913.

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APPENDIX A

Notes for iBass loggers used on western pond turtles (*Clemmys marmorata*) in 2004.

Table 1. South Fork Trinity Turtles from 2004.

	702	**715**	**716**
Released @	10:20 7JUL04	10:20 7JUL04	10:20 7JUL04
Excel spreadsheet	FAILED	715 SFTR	716 SFTR
With data cut to:	iBASS	10:53 7JUL04	10:50 7JUL04
Datapoints	FAILED	2045	2044
Range	iBASS	19.5 – 40º C	19.8 – 26.4º C
Retrieved on:	21SEPT04	14SEPT04	14SEPT04

	717	**719**	**6002**
Released @	10:20 7JUL04	10:20 7JUL04	10:20 7JUL04
Excel spreadsheet	717 SFTR	719 SFTR	6002 SFTR
With data cut to:	10:50 7JUL04	10:46 7JUL04	10:57 7JUL04
Datapoints	1986	2048	2002
Range	19.1 – 26.4º C	14.5 – 36.5º C	19.4 – 26.4º C
Retrieved on:	29SEPT04	14SEPT04	8SEPT04

Table 2. Mainstem Trinity River turtles from 2004.

	160	**427**	**5668**
Released @	10:09 23JUN04	15:55 5AUG04	16:40 18AUG04
Excel spreadsheet	160 TR	427 TR	6558 TR
With data cut to:	No data cut	17:28 5AUG04	17:10 18AUG04
Datapoints	1685	1961	1943
Range	9.5 - 42º C	11 – 31.5º C	7.5 - 38º C
Retrieved on:	15SEPT04	15SEPT04	16SEPT04

	5750	**5903**	**5911**
Released @	15:00 8JUL04	16:40 18AUG04	18:30 18AUG04
Excel spreadsheet	5750 TR	5903 TR	5911 TR
With data cut to:	15:29 8JUL04	17:11 18AUG04	No data cut
Datapoints	2028	1943	2048
Range	10 - 39º C	7 – 35.5º C	10.5 – 37.5º C
Retrieved on:	15SEPT04	15SEPT04	15SEPT04

External shell temperature (T_s) ranges for MSTR turtles are: 7 - 42º C.
External shell temperature (T_s) ranges for SFTR turtles are: 14.5 - 40º C.

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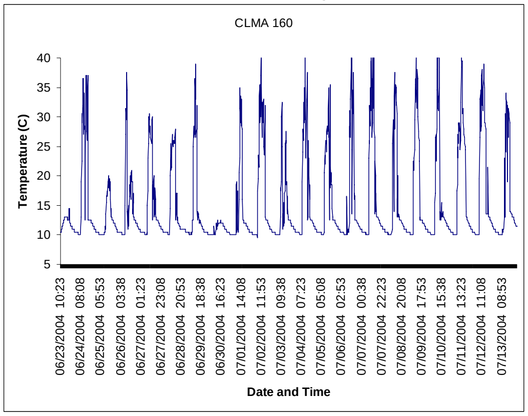
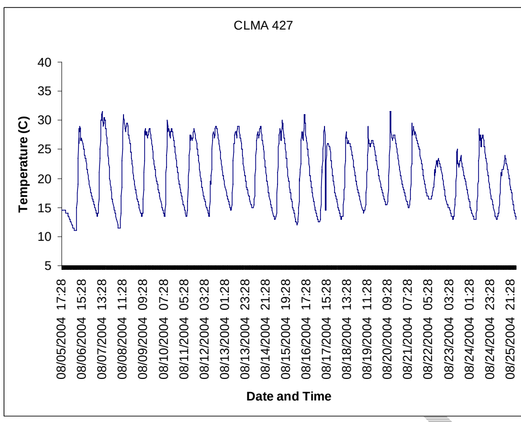
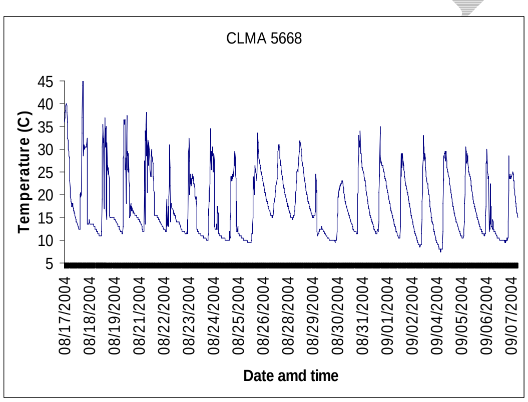
APPENDIX B.

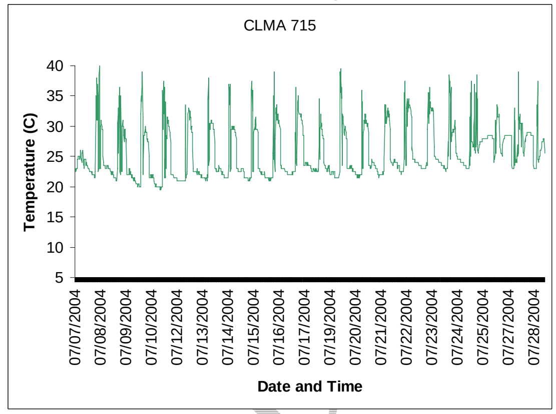
Mainstem Trinity River

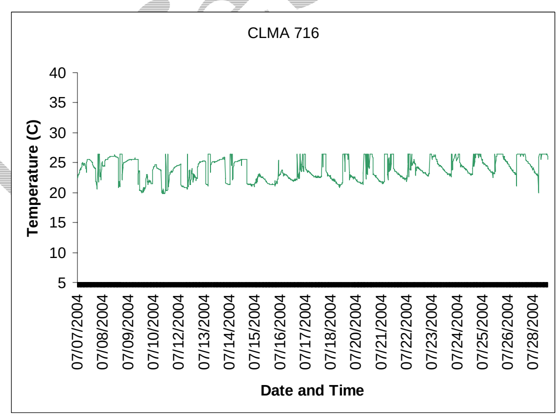


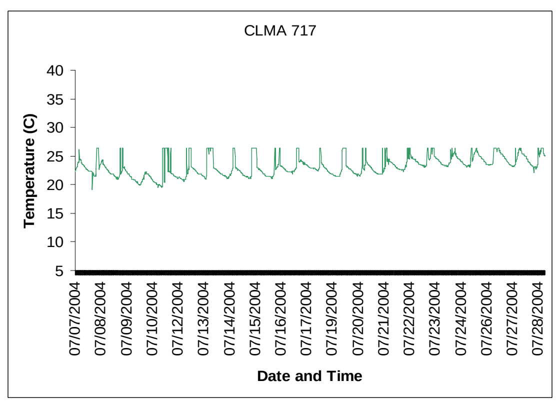




South Fork Trinity River







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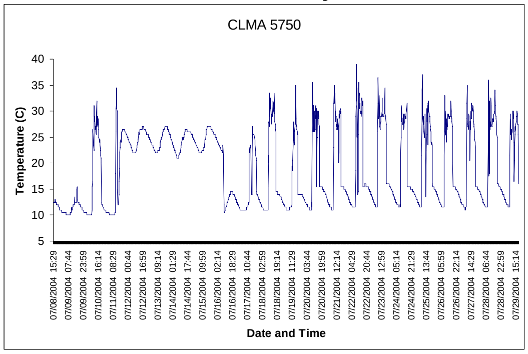
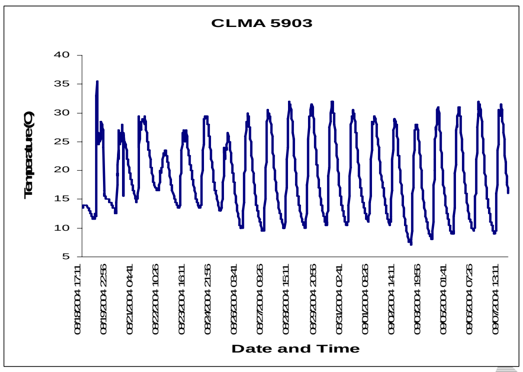
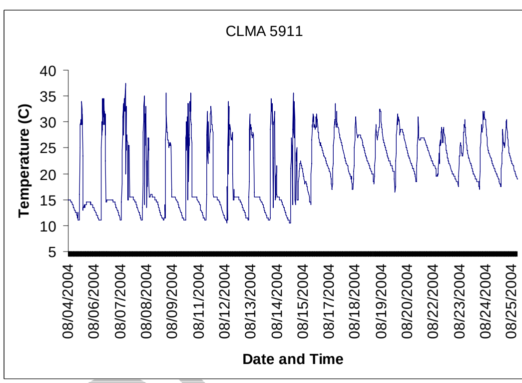
Mainstem Trinity River







South Fork Trinity River