Adult Chinook Migration in the Klamath River Basin:

2003 Radio Telemetry Study Final Report

Radio listening station at Blue Creek 2003. Photo by author.

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ABSTRACT

The maintenance and recovery of Chinook salmon populations in the Klamath River Basin (KRB) depends on ensuring sufficient success in all phases of their life cycle, including the spawning migration. The details of adult Chinook spawning migration behavior in the KRB are unknown, and a massive epizootic fish kill in the lower Klamath River during September of 2002 greatly increased concerns over this phase of the Chinook life cycle. Thus the Yurok Tribal Fisheries Program initiated a collaborative research project with the overarching goal of comprehensively determining adult Chinook migration behavior in the KRB throughout the spectrum of run timing. This research project relied primarily on a combination of temperature-sensitive radio tags, external archival temperature tags, and monitoring of environmental conditions such as temperature and flow. A total of 120 adult Chinook were tagged from 5/8/2003 to 10/8/2003 in the lower Klamath River and its estuary, of which 39 (termed migrants) provided enough data to examine migration behavior for specific stocks or run timing groups. The stock/run timing migrant groups that emerged based on the fates of these migrants were spring Chinook (n=11), summer Chinook (n=6), Klamath fall Chinook (n=10), and Trinity fall Chinook (n=12). Each of these groups had relatively distinctive movement timing and patterns. Behavioral thermoregulation via cold-water thermal refuges was an important tactic used both prior to emergence from the estuary and while migrating enroute. The most used thermal refuges where the estuarine salt wedge and the associated nearshore ocean, and the Blue Hole refuge complex at the confluence of Blue Creek with the lower Klamath River. Tagged Chinook behavior observed in 2003 was consistent with a thermal migration inhibition threshold occurring when mean daily temperatures ≥22ºC, higher than the 21ºC threshold commonly referenced in relevant literature. Thermal stress occurs at temperatures lower than the migration inhibition threshold, and spring Chinook that did not migrate above high gradient reaches (e.g. Burnt Ranch Gorge) before the onset of acutely stressful high water temperatures (≥20ºC) had a substantially lower probability of survival. Summer Chinook migrants, apparently comprised of Trinity River ‘spring’ Chinook, relied on enroute thermal refuges and weather-induced cooling events to reach spawning areas in the upper Trinity River. As part of an effort to prevent a repeat of the 2002 fish kill, a pulse of water was released from Lewiston Dam on the Trinity River from 8/24/2003 to 9/16/2003. It was expected that this pulse of water would trigger the upriver movement of adult Chinook from the lower Klamath River, thus decreasing fish densities and thereby reducing the risk of an epizootic outbreak. This did not appear to occur, as upriver movement of fall run Chinook primarily did not occur until September 2nd, which coincided with a sharply declining temperature trend throughout the lower KRB as is common in early September due to consistent seasonal cooling. Also coinciding with upriver movement of fall run Chinook was the arrival of a 12% increase in flows from Iron Gate Dam on September 2nd. The role of this flow increase is unclear, but the correlation in timing suggests it could have provided an added migratory stimulus for Klamath fall Chinook. This research project will continue and results from the 2003 study year will be included in a peer reviewed publication at a later date.

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Klamath River estuary during the summer of 2003. Photo by author.

1.0 Introduction

Accomplishing protection and restoration goals for Pacific salmon and steelhead populations will require, in part, a coherent understanding of salmonid life histories and their interactions with environmental variability (Mangle 1994). In a review of salmon recovery policies on the Columbia River, the Independent Scientific Group concluded that in order to recover declining stocks, policies needed to be guided by a foundational "salmon life history ecosystem concept", which would involve restoration of habitats for all life history stages including migration (Williams et al. 1999). This holds equally true for other salmon producing river basins.

The adult in-river spawning migration is one salmon life history stage that has received relatively little research attention in comparison to other stages, especially in relation to increased environmental variability and adversity, from both natural and human-induced causes (Rand et al. 2004). Understanding the spawning migration life history component and its interaction with environmental conditions and variability requires understanding how salmon life histories have evolved. There is an extensive body of literature on life history theory (see reviews by Stearns 1980; Roff 2002), including specifically for fish and salmonid migrations (see reviews by Legget 1985; Dodson 1997). A central assumption of life history theory is that natural selection produces traits that are adaptations for fitness (Roff 2002). Thus variations in life history traits are a product of evolution that optimize reproductive success (Gross 1984). Examples of life history traits in salmonids include age and size at maturity, fecundity, egg size, and migration timing. These traits did not evolve independently from one another; rather they form location-specific coadapted complexes that represent a compromise of trade-offs between trait costs and benefits (Roff 2002).

Migration is a response to temporally (seasonal) and spatially (ocean vs. freshwater) variable habitats, which, when coupled with reliable environmental cues, serves to reduce the costs of environmental variability on reproductive success (Legget 1985; Dingle 1996). Evidence supports the hypothesis that the timing of salmon migration has adapted to the long term average conditions (e.g. temperature, flow, and migration distance) experienced by populations (Gilhousen 1990; Quinn et al. 1997;

Hodgson and Quinn 2002), and is timed to allow for a spawning date that will result in offspring emergence during the window of time most favorable to growth and survival (Bye 1984; Brannon 1987). Hodgson and Quinn (2002) undertook a regional examination of adult sockeye (*Oncorhynchus nerka*) migration timing and found that in the absence of adverse environmental conditions (defined as water temperatures >19°C) sockeye timed their migration to arrive on the spawning grounds about one month prior to spawning. In the face of adverse environmental conditions adult sockeye timed their migration to avoid high summer water temperatures by migrating before (spring) or after (fall) the onset of high temperatures (Hodgson and Quinn 2002).

This pattern would be expected to hold true for other salmonid species due to the same selective pressures, which appears to be the case with spring and fall run Chinook (*Oncorhynchus tshawytscha*). In general spring Chinook run timing avoids the predictable period of high water temperatures in the summer and is also widely believed to allow them reach headwater spawning areas which require higher flows to access but requires foregoing ocean feeding opportunities. With fall Chinook, in general, their run timing avoids high water temperatures and also allows for continued ocean feeding and growth during the summer. The problem with this tidy story are the outliers such as summer run Chinook.

In the Klamath River Basin (KRB) of northern California and southern Oregon (Figure 1) for example, Chinook historically (Snyder 1931) and presently enter the river throughout the year including the hot summer months of July and August when river temperatures typically exceed 20°C. Understanding whether the run timing of KRB Chinook violates the hypothesis advanced by Hodgson and Quinn (2002) requires an evaluation of the historical environmental conditions (e.g. lotic thermal regime) under which they evolved. It may be that water temperatures were historically not as high during the summer in the KRB, indeed data from the last several decades shows trends of increasing water temperatures throughout the Pacific Northwest (Beschta et al. 1987; Bartholow 1995; Quinn and Adams 1996), including the KRB specifically (Bartholow 1995). Since run-timing in salmonids has been shown to be under considerable genetic control (Gharrett et al. 1987; Stewart et al. 2002), it could be that run-timing has not yet genetically shifted in adaptation to the new conditions, especially given the maturation constraints of salmon (Quinn and Adams 1996). Another possible explanation is that behavioral flexibility within the summer run timing strategy compensates for the adverse environmental conditions.

Individuals within a run timing strategy will employ a range of flexible behavioral tactics (Potts and Wooton 1984) in the face of annual and inter-annual variations from the long-term average conditions that they are presumably adapted to. These behavioral tactics serve to reduce the variance of environmental conditions actually experienced and the risks associated with adverse conditions (Legget 1985). One form of this is the fine-tuning of run timing to annual variability; indeed run-timing has been show to be influenced by environmental conditions (e.g. temperature and flow) (Banks 1969; Jonsson 1991; Smith et al. 1994; Quinn and Adams 1996; Trepanier et al. 1996; Quinn et al. 1997; Hodgson 2000). Run timing is fine tuned (in part) on an annual basis by delaying or advancing freshwater entry. Salmon have been shown to delay freshwater entry by holding in the estuaries of their natal rivers (Gilhousen 1960; Brawn 1982; Potter 1988), which presumably allows them to undergo the process of osmotic transformation, ensure time for homing mechanisms to work, and monitor the river for optimal or adequate migratory conditions, while using passive tidal transport and thermal stratification to conserve energy (Groot et al. 1975; Aprahamian et al. 1998). Telemetry and archival temperature tag data from our 2002 telemetry study in the KRB suggest that adult Chinook use the salt wedge of the Klamath River estuary as a thermal refuge habitat prior to fresh water migration. While there are advantages to such behavior, Wertheimer (1984) showed that gamete viability was poor when advanced maturation occurred in high salinity water among chum and coho salmon, thus holding in estuaries may present a compromise between the need to delay until after adverse riverine conditions have ceased and the need for continued maturation in a low salinity environment.

Once salmon enter the river from the estuary and commence their fresh water spawning migration, adjustments of travel rates is another behavioral tactic that is employed. Bernatchez and Dodson (1987) concluded that only salmon stocks with exceptionally long or difficult migrations that exhaust energy reserves conform to theoretical optimums of swimming speed, thus most stocks have a sufficient energy cushion, which combined with energy saving swimming behaviors (Hinch and Rand

2000), allows for some level of energetic flexibility with swim speeds and hence travel rates. This flexibility can be used to reduce the duration of travel in reaches of especially stressful conditions (e.g. high temperatures), compensate for migration delays, or shift run timing enroute (Quinn et al. 1997).

In the face of extremely severe environmental conditions adult salmon are unable to survive or migrate due to physiological and bioenergetic constraints (Brett 1979; McCullough 1999). In the case of temperature, behavioral thermoregulation in the form of seeking and residing in cold water patches, or thermal refuges, is the primary option available for poikilothermic salmonids when they encounter stressfully high temperatures during migration. Thermal refuges typically take the form of thermally stratified pools, groundwater or hyporheic seeps and springs, cold tributary confluences, or cool stream reaches (Bilby 1984; Torgersen et al. 1999). Numerous researchers have documented thermal refuge use by salmonids for behavioral thermoregulation (Kaya et al. 1977; Belchik 1990; Nielsen et al. 1994; Kaeding 1996; Ebersole et al. 2001), and thermal refuges play an important role for adult Chinook in the KRB and other similar basins, such as the Yakima (Berman and Quinn 1991) and John Day (Torgersen et al. 1999). The presence and use of thermal refuges may allow for persistence and increased carrying capacity of stocks in thermally marginal streams and habitats (Burns 1971; Kaya et al. 1977; Torgersen et al. 1999; Ebersole et al. 2001).

Use of thermal refuges can occur at a wide range of temperatures, but becomes more probable with rising temperatures until it becomes the norm as thermal thresholds are exceeded (sub-lethal 20^{o}C, and upper incipient lethal 25^{o}C, Armour 1991; Bjornn and Reiser 1991; Bartholow 1995). A threshold of particular importance to salmonids is the thermal limit for migration. In the case of both adult sockeye and Chinook salmon, 21^{o}C has emerged as the currently accepted thermal limit to migration (Quinn et al. 1997; McCullough 1999). Regardless of opinion on the exact thermal threshold, when it is exceeded the majority of fish will stop migrating and use available thermal refuge habitat even if it means retreating considerable distances.

High temperatures are often associated with low flows. Migration delays that typically occur during such periods are due to one or the other or a combination of both factors. The degree to which each factor exerts control over migration appears to be location and circumstance specific (Banks 1969; Alabaster 1990; Jonsson 1991; Trepanier et al. 1996). Periods of temperatures greater than the thermal limit to migration will result in delays, regardless of flow. Delays are a trade-off between the associated costs and benefits, and can be thought off as making the "best of a bad situation" (Gross 1984). The nature and severity of costs depends on multiple factors, especially the quality and quantity of holding habitat. High quality thermal refuge holding habitat in sufficient availability can greatly reduce the costs (Berman 1990; Torgersen et al. 1999), but holding habitat can often be sub-optimal given the low flow and high temperature conditions typically associated with migration delays in addition to human induced habitat degradation. One of the most predominant costs associated with migration delays is disease mortality. Salmonids holding in poor quality habitat can become stressed and crowded (Schreck and Li 1991; Matthews and Berg 1997), perfect conditions for outbreaks of diseases such as *Flexibacter columnaris* (Holt et al. 1075; Wakabayashi 1991) and *Ichthyophthirius multifiliis* (Bodensteiner et al. 2000). Such conditions were implicated for causing large fish kills from these pathogens for sockeye salmon holding prior to admittance into engineered spawning channels in British Columbia during 1994 and 1995 (Traxler et al. 1998) and adult Chinook in the lower Klamath River during September of 2002. Determining the causes of specific migration behaviors and their associated costs in specific circumstances has both practical management applications and value in analyzing the adaptive merit of behavioral tactics from an evolutionary perspective (Legget 1985; Hyatt et al. 2003).

There is an imperative need to gain a comprehensive understanding of adult Chinook migration in the KRB, especially in response to environmental variables such as temperature and flow, so that management decisions can be made with the best available scientific understanding. Specific questions that arise as a result of the current physical conditions and management circumstances in the KRB regarding the patterns and consequences of adult Chinook migration include:

1. How do adult Chinook cope with high water temperatures during their spawning migration?

2. What temperatures are adult Chinook experiencing during their migration in comparison to river temperatures?
3. How do adult Chinook respond to environmental variables such as temperature and flow during upriver migration?
4. What spatial and temporal patterns of thermal refugia use (behavioral thermoregulation) are displayed by adult salmonids during their spawning migration?
5. What is the run timing distribution of Chinook stocks in the Klamath Basin?

In an effort to provide data to answer these questions the Yurok Tribal Fisheries Program (YTFP) initiated a collaborative radio telemetry research project on adult Chinook migration behavior beginning with a pilot study of spring Chinook in 2002. In 2003 we continued this approach, replicating the 2002 study design with an expanded scope that includes fall-run Chinook. The overarching goal of this multi-year research project is to comprehensively determine adult Chinook migration behavior in the KRB throughout the spectrum of run timing. This report is written as a stand-alone document, however, peer reviewed publications will be developed from analysis of all years of data in the future.

1.1 Study Objectives

The primary objective of this study was to document the migration behavior and thermal experience of adult Chinook salmon in the Klamath River Basin during the 2003 spawning migration season. Specific objectives of this study were to:

1. Determine the migration behavior and thermal experience of adult Chinook in the KRB throughout the spectrum of run timing;
2. Analyze behavioral responses to environmental variables such as temperature and flow;
3. Determine the spatial and temporal patterns of thermal refuge use by adult Chinook during their spawning migrations;
4. Gather data on stock specific run timing.

2.0 METHODS

2.1 Study Area

The Klamath River drains approximately 31,000 km^2 in southern Oregon and northwestern California and flows 386 km from its source at the outlet of Upper Klamath Lake, a hyper-eutrophic regulated natural lake, to its confluence with the Pacific Ocean. The Klamath River is one of only four rivers that bisect the Cascade Range, along with the Sacramento/Pit, Columbia, and Fraser Rivers. Due to this fact the Klamath River is geologically divided into two basins, which has profound affects its hydrology, geomorphology, water quality, thermal regime, fish fauna, and ecology. Upriver movement of anadromous fish populations are currently restricted by Iron Gate Dam at river kilometer (RKM) 310 (Figure 1) which has no fish passage facilities, although a mitigation hatchery for the construction of Iron Gate Dam is operated by the California Department of Fish and Game (CDFG) at Iron Gate. [Note: All river kilometers used in this report are measured from the mouth of the Klamath River]. The upper basin formerly supported large numbers of Chinook salmon and other anadromous fishes such as steelhead (Hamilton et al 2005), but these runs were extirpated with the construction of Copco Dam in 1917. Both dams are part of a series of five hydroelectric dams owned by PacifiCorp that are currently undergoing the Federal Energy Regulatory Commission relicensing process.

The Klamath River's largest tributary is the Trinity River which originates in the Trinity Alps Wilderness and flows into the Klamath at Weitchpec (RKM 70). Dams were constructed on the Trinity River at Trinity Center and Lewiston (RKM 253) in 1964 as part of the Central Valley Project, which has diverted 49-90% of the annual flow into the Sacramento River system. There are no fish passage facilities at Lewiston or Trinity Dams, although the CDFG operates a mitigation hatchery at Lewiston. The Trinity River's largest tributary, the South Fork, joins at RKM 121 and originates in the Yolla Bolly Mountains.

From the Salmon River to the Klamath River estuary, major thermal refuges have been previously observed at the mouths of Camp (RKM 92), Red Cap (RKM 85), Bluff

(RKM 80), Aikens (RKM 78.5), Hopkins (RKM 75), Pine (RKM 65.5), Tully (RKM 61.5), Ka'pel (RKM 53), Roaches (50.5), Pecwan (RKM 40), and Blue Creeks (RKM 26). On the Trinity River starting at Weitchpec (RKM 70) major thermal refuges are found at the mouths of Bull (RKM 73), Mill (RKM 84), Tish Tang (RKM 97), Horse Linto (RKM 102), and Willow Creeks (RKM 111) with no significant thermal refuges upstream on the mainstem Trinity for quite a distance, although river temperatures begin to cool rapidly above Burnt Ranch Gorge (RKM 138 to 146) due to the influence of the cold water (hypolimnetic) release from Trinity Dam. In the lower Klamath and Trinity Rivers, the furthest distance from one thermal refuge to the next is 26 km between the estuary and Blue Creek. The thermal refuge at Blue Creek is unique because it consists of the typical creek confluence refuge, but also contains a lateral scour bedrock pool that is fed by cold (10-15^{o}C) hyporheic inflow, which is partially connected to the mainstem Klamath River thus providing access for fish (Figure 2). Locally called Blue Hole, the degree of fish access to this large thermal refuge pool depends on the configuration of the gravel bar at its outlet and on the height of flow in the Klamath River.

2.2 Tagging and Telemetry

Temperature-sensitive radio transmitters were used to track the movements and internal body temperatures of adult Chinook salmon during the 2003 spawning migration in the KRB. The radio transmitters used were Advanced Telemetry Systems - ATS F1845 esophageal transmitters with external trailing whip antennae at 149 and 150 MHz (W19 x L51 mm, 24 grams). The rate of pulsed radio transmissions from these tags were subsequently used to calculate body temperatures using tag specific regression equations provided by ATS. An archival temperature device (Alpha Mach, W29 x L8 mm, 7 grams) was epoxied to a Petersen disc tag and attached below the dorsal fin, which recorded external water temperature every 60, 90, or 120 minutes depending on the tagging date in order to ensure enough data storage space for the entire migration.

Adult Chinook were captured and tagged from 5/8/2003 to 10/8/2003. Capture methods included drift gill nets, seine nets, and dip nets. Capture locations were at the mouth of the Klamath River (RKM 0), the upper Klamath River estuary (RKM 4), the lower Klamath River (RKMs 18 and 21), and at the thermal refuge at Blue Creek (RKM

26). Each captured salmon was held and immobilized in a 250 gallon live tank on the shore with the aid of a cradle, measured (fork length cm), tagged, and released immediately or revived first as necessary. A gas powered water pump was used to circulate river water through the live tank continuously. Efforts were taken to minimize capture stress and handling time. No fin clipped Chinook were tagged in an effort to increase the probability of tagging wild stocks, but all non-adipose clipped Chinook that were caught were tagged unless severe injury or severe shock was apparent.

Scanning radio receivers (Lotek SRX 400s and ATS R series) were used for mobile tracking. After pinpointing the location of each observed tagged Chinook using basic triangulation, fish position was recorded using a handheld, global positioning system (GPS). Topographic maps of the river corridors complete with river kilometer demarcations were issued to all tracking crews to aid in determining fish position. In the event of insufficient satellite contact, the nearest highway mile marker or associated landmarks were also used. For each tagged Chinook observation the agency, observers, date, time, unique frequency ID, transmitter signal pulse rate (sec), meso-habitat type, location description, UTM coordinates, river temperature (^{o}C), and fish behavior (moving versus holding) were recorded whenever possible along with any observations of cold water sources or other note worthy conditions. The tag pulse rate was determined by using a stopwatch to measure the time interval of 10 pulses with three replicates to the nearest hundredth of a second, with the average subsequently used to determine the fish's body temperature. River temperature was measured using calibrated dissolved oxygen (DO) meters or handheld thermometers accurate to the nearest 0.2 to 0.5^{o}C. An attempt was made to track tagged salmon throughout their migration path until they died. Transportation during tracking was by truck along Highways 96, 169, and 299, by jet boat, and by inflatable rafts depending on the situation. Monthly aerial telemetry flights were provided by the CDFG. Hatchery personnel and snorkel count and carcass survey participants within the study area were notified of the study in order to assist with located tagged Chinook and retrieving archival tags. Flyers were posted throughout the study area to alert fishers of the study and a $50 reward was offered to assist in the recovery of archival tags. YTFP harvest monitoring personnel also assisted with recovering tags from Tribal and sport fishers in the Klamath River.

A network of 10 automated radio listening stations (Advanced Telemetry Systems R4000/DCC and Lotek SRXs) were placed throughout the KRB at strategic locations to continuously monitor fish presence or absence and record internal body temperatures. Listening station locations are listed in Table 1. The spatial relationship of the listening stations allowed for determination of migration paths and travel rates.

2.3 Temperature and Flow Monitoring

Thermisters (Onset Optic Stowaways and Alpha Mach iBs) were used at each listening station to record the temperature of the mainstem river and of any cold water tributaries associated with the site. Thermisters were rated in accuracy to the nearest 0.1^{o}C (Onset) or 0.5^{o}C (Alpha Mach). All temperature probes were tested before deployment in high and low temperature water baths and calibrated with an ASTM certified thermometer. Temperature records were not used if discrepancies in comparison to handheld measurements taken at the same location consistently occurred that were greater than the margin of error.

Ambient water temperatures at additional sites in the mainstem Klamath River were obtained from temperature recorders operated by YTFP and the USFS Orleans District. River flows were measured by USGS gauges and obtained from their website (http://waterdata.usgs.gov/ca/nwis/current/?type=flow). Air temperatures were obtained from the National Climate Data Center website (http://www.ncdc.noaa.gov/oa/climate/stationlocator.html).

2.4 Data Analysis Approach

Radio telemetry studies are often not representative in a statistical sense given the exorbitant costs of achieving a representative sample size for large populations, as is often the case with fish. However, efforts were made to increase the representativeness of this study by attempting to tag at least several adult Chinook each week throughout the run. Regardless of the exact degree of representation, the results of this and other similar studies do provide valid illustrative results that allow a window of observation into an otherwise elusive subject.

Telemetry studies allow a determination of behavioral patterns and provide a basis for understanding the underlying causes for those patterns. Inferential statistical testing to determine statistically significant relationships in the measurements of animal behavior is one method to help determine patterns and their underlying causes. Statistical analysis can determine the level of statistical significance of the relationships tested; however, evaluating the level of biological or behavioral significance requires visually comparing telemetry data with the pertinent independent (and often autocorrelated) variables. Appropriate interpretation of animal behavior also requires applying existing knowledge of evolution and behavioral theory within the context of the specific habitats used. The analysis of data from this study to determine Chinook behavioral patterns and understand their underlying causes will consist of graphically presenting data sets at fine resolutions on commonly scaled axis.

3.0 RESULTS AND DISCUSSION

NOTE: The results and discussion reported herein are preliminary pending further analysis, including a comprehensive analysis of multiyear data sets in preparation for peer reviewed publication.

3.1 Tagging and Fate Summary

Tagging data and the final known fate or last observation of all tagged Chinook are summarized in Appendix 1. Out of the total sample of 120 adult Chinook, 87 were tagged at the mouth of the Klamath (RKM 0), 14 in the upper estuary (RKM 5), 4 in the lower Klamath River mainstem (RKM 16.5 and 20), and 15 at the Blue Hole thermal refuge at Blue Creek (RKM 26). While the true racial origin of tagged Chinook is unknown, a total of 47 Chinook were tagged in May, June, and July (5/8/2003 to 7/30/2003) and could be considered “spring” Chinook while a total of 73 Chinook were tagged in August, September, and October (8/20/2003 to 10/8/2003) and could be considered “fall” Chinook.

Determination of final fates for all tagged Chinook is problematic due to the fact that numerous fish disappeared in the estuary or nearshore ocean after tagging with the high salinities in those habitats inhibiting the detection of radio transmissions. Out of the 101 adult Chinook that were tagged at the mouth of the Klamath or in the estuary, 44 (44%) migrated upriver or were harvested after tagging while 57 (56%) disappeared in the estuary or near shore ocean after tagging. Disappearance is defined as no further detections during manual tracking or at listening stations. Based on deductive logic, the primary factors potentially contributing to the 56% disappearance rate in the estuary/nearshore were pinniped predation, tag regurgitation, unclaimed harvest, delayed tagging mortality, and inter-basin straying or visitation. For Chinook tagged at Blue Hole or the lower Klamath mainstem, 7 of 19 (37%) died (harvest or non-harvest) or disappeared before migrating upriver of their tagging location. Of these, only 2 (11%) could be definitely attributed to delayed tagging mortality. Pinniped predation was not believed to be a factor for fish tagged upriver from the estuary. Thus combining all tagging locations, 64 (53% of 120) tagged Chinook were omitted from further analysis.

While a disappearance rate of 53% substantially reduces the sample size, the benefits of tagging Chinook upon entry into the estuary are worth the costs. Tagging in the estuary is the only way to determine the entire migration history, including the critical estuarine phase, and also allows tagged fish to recover more rapidly since a variety of temperatures and salinities are available for behavioral regulation immediately after tagging. During the hot portion of the season Chinook can only be tagged in proximity to a source of cold water for recovery such as Blue Hole or the estuary. The FWS captured and tagged Chinook in the upper estuary (RKM 5) in an effort to reduce pinniped predation. The disappearance rate for Chinook tagged at this location, however, was approximately equivalent as for Chinook tagged mouth of the Klamath. This is partly because pinnipeds hunt actively throughout the entire estuary and because Chinook have a tendency to fall back several kilometers after tagging as part of an apparent fight or flight response to the stress of capture, handling, and tagging. While this fallback behavior was not displayed by all tagged Chinook, it was observed to varying degrees at all four tagging locations in 2003.

Determination of percentages of end fates for fish that did migrate upriver or were caught after tagging (*n*=56, 47%) was complicated by the disappearance of fish enroute, which occurred for a variety of possible reasons. The most common example is when a radio tag was found on the bank of a river, which could have been due to unclaimed harvest, predation, or scavenging of fish that died enroute of unknown causes but most likely disease. Additionally, tracking became increasingly difficult with the higher flows and inclement weather of November, and most of the tagged Chinook that disappeared enroute did so after that point in the season. Thus percentages assigned to the classes of fates should be viewed as the approximate minimum. Of the 56 fish that did migrate upriver or were caught after tagging at least 15 (27%) successfully migrated to spawning grounds (10) or a hatchery (5); at least 19 (34%) were harvested; at least 12 (21%) succumbed to enroute mortality of unknown cause; and 10 (18%) disappeared during migration. Out of these 56 fish, at least 14 (25%) migrated into the Klamath River above Weitchpec, at least 25 (45%) migrated into the Trinity River above Weitchpec, and 16 (29%) were never observed migrating above the confluence of the Klamath and Trinity Rivers at Weitchpec (RKM 70) due to harvest (12), unknown mortality (3), or disappearance (1). One fish spent substantial time in the lower Trinity and Klamath Rivers before ultimately migrating to spawning grounds in the Salmon River and may have been a stray Trinity River spring Chinook. A total of 5 tagged Chinook were observed migrating and/or spawning in tributaries to the Klamath or Trinity Rivers: one in Bogus Creek, one in the Shasta River, and three in the Salmon River. There is no evidence that any other tributaries were used.

For the 39 tagged Chinook that migrated past Weitchpec, reasonable assumptions can be made about their approximate destinations and likely stock origin. Their tagging data and fates are displayed in Table 2. These 39 tagged Chinook, hereafter termed migrants, will serve as the basis of the presentation of migration behavior by stock/run timing groups.

3.2 Environmental Conditions

For water management purposes, the 2003 water year was ultimately classified as "below average" for the upper KRB by the Bureau of Reclamation based on hydrological forecasts by the Natural Resource Conservation Service's National Water and Climate Center. The water year type designation directly affects river flows at Iron Gate Dam. In contrast the water year designation for the Trinity River sub-basin was "normal" in 2003 due to higher precipitation and snow pack, resulting in a flow release schedule from Lewiston Dam as presented in Figure 7. Flow releases from these dams strongly influence downriver flows on the mainstem Klamath and Trinity Rivers.

Annual hydrographs for the 2003 calendar year are presented for the Klamath, Trinity, and Salmon Rivers in Figures 3 through 8. All flows are reported as mean daily flow measured in cubic feet per second (cfs). Annual hydrographs throughout the lower KRB generally have three components: 1) summer/fall base flow; 2) rain driven high water with rain on snow flood peaks; and, 3) spring snowmelt. During 2003, spring snowmelt from unregulated tributaries generally occurred from mid-March to late-May with a peak on May 24th. The mainstem Trinity River was an exception due to controlled flow releases from Lewiston Dam which included a small geomorphic spike that peaked at 2,610 cfs on May 2nd and a spring temperature bench release of approximately 2,000 cfs which lasted until July 9th with ramping down to summer base flows being completed by July 19th (Figure 7). Summer base flow conditions were generally prevalent by mid-July throughout the KRB. The typical summer base flow pattern was interrupted by a pulse of water from Lewiston Dam on the Trinity River for the purpose of preventing a repeat of the 2002 epizootic fish kill. This Trinity River fall pulse flow (fall pulse flow) started on August 24th with a peak the next day followed by a gradual decrease until cessation on September 16th with an average flow of 1,316 cfs compared to a base flow release of approximately 450 cfs (Figure 7). Flash floods from mountains tributaries have occasionally occurred during this time of year, but the duration and magnitude of the fall pulse flow was unprecedented, and while adult Chinook were the target species, the extent of unintended negative biological consequences to aquatic organisms was unknown. The first substantial increase in river flows throughout the KRB from precipitation after the summer dry season did not occur until November 29th.

Hourly water temperatures at three locations representative of the lower mainstem Trinity (RKM 102) and Klamath Rivers (RKM 81 and 69) for the duration of the study period are presented in Figures 9, 10, and 11. Two of these monitoring sites contained cold-water tributary formed thermal refuges (Bluff Creek RKM 81 and Horse Linto Creek RKM 102). Along with Blue Creek on the lower Klamath River and Wooley

Creek on the Salmon River, these two thermal refuges are among the largest in the lower KRB based on snorkel surveys conducted by the YTFP (unpublished data).

Mean daily air temperatures at Orleans (Klamath River RKM 91) are reported in Figure 12 along with the river flow and water temperature to provide a representative example of the relationship between those three correlated environmental variables.

3.3 Migration Behavior and Experience

Behavioral Thermoregulation

During the 2003 season, radio tagged Chinook appeared to behaviorally thermoregulate primarily by holding in the estuarine salt wedge and nearshore ocean prior to commencing the freshwater phase of their spawning migration. Figure 32 displays the thermal history of a Chinook tagged at the mouth of the Klamath River in late July, showing the distinct thermal signatures of the warm freshwater layer, the intermediate estuarine salt wedge, and the cold nearshore ocean. Temperatures in the estuarine salt wedge typically stayed below 16^{o}C, even during the hottest periods of season. Combined with a large (albeit shifting) volume, the salt wedge makes the estuary the largest thermal refuge in the entire KRB with the exception of cold water reaches below the hypolimnetic release at Lewiston Dam on the mainstem Trinity River, and in the headwaters of mountains tributaries such as the South Fork Trinity, Salmon, and New Rivers.

Adult Chinook were also observed by YTFP snorkel survey crews using thermal refuges during the summer months at the confluences of cold water creeks such as Blue, Bluff, and Horse Linto Creeks, which has been the case in all previous years of creek mouth snorkel survey monitoring. The thermal refuge complex associated with Blue Creek, which includes Blue Hole, was the most heavily used thermal refuge besides the estuary in 2003. An overall examination of telemetry (manual and listening station) data and archival body temperature records, however, has not revealed any extensive (> 1 hour) use of enroute thermal refuges by tagged Chinook with the exception of those fish tagged at Blue Hole and migrant 150.253, which apparently resided in the Blue Cree/Blue Hole thermal refuge area for over a month before eventually migrating to the

Salmon River. The Blue Hole migrants were largely successful at reaching spawning grounds in the upper Trinity River.

Unpublished results from the 2002 adult spring Chinook radio telemetry study indicated that adult Chinook migration in the KRB was inhibited when mean daily temperatures (MDTs) ≥22°C, at which point adult Chinook would seek out and reside in thermal refuges or delay migration and continue to hold in the estuary. Based on the timing of tagged Chinook movements in comparison to river temperatures, this threshold relationship generally held true in 2003. While this threshold value is not unprecedented (Fresh et al 2000), biologically speaking it is substantially higher than the commonly accepted migration inhibition threshold of instantaneous temperatures equal to or greater than 21ºC (McCullough 1999).

External Archival Temperature Data

Data from 23 archival temperature tags (19% of 120) were successfully recovered. Of these, 14 were from Chinook with extensive enough migrations to yield valuable thermal history data (Figures 18 to 31), half of which were from tagged Chinook classified as migrants (see Table 2). Archival temperature tags were attached to the back of each tagged Chinook and thus measured the external water temperature experienced by the fish every 60, 90, or 120 minutes depending on the tagging date. Archival temperature data revealed a high degree of variation in water temperatures experienced prior to initiation of upriver migration from the estuary. It is unknown whether this represents fish movement between the estuarine salt wedge, the river, and/or the nearshore ocean or if it represents movement of the salt wedge over these fish with the tidal cycle, although there is evidence for both.

Run Timing

For the 39 tagged Chinook migrants with known approximate destinations, run timing based on tagging date and date of commencement of upriver migration was correlated with destination and presumed stock origin.

Migrants tagged in May and June (5/9/2003 to 6/4/2003, n=8) and early July (7/2/2003, n=3) migrated primarily to the Trinity River with survivors bound for spawning areas from Junction City to Lewiston Dam, including the Trinity River Hatchery (TRH). The exceptions were two Chinook (150.114 and 150.124) that migrated into the Salmon River during late May and subsequently died enroute and one Chinook (150.253) that apparently spawned in the Salmon River near Forks of Salmon after holding in the lower Klamath and Trinity Rivers for almost two months. Collectively these migrants will be referred to as the spring Chinook migrant group.

Migrants tagged at the Blue Hole thermal refuge on July 30th had been holding there for an unknown period of time prior to tagging and did not commence upriver migration again until the first week of August in response to sharply falling river temperatures. All of these Chinook (n=6) migrated into the Trinity River except for one fish (150.732) that continued up the mainstem Klamath River past Weitchpec, where it died enroute in the vicinity of Dillon Creek at RKM 139. The Trinity migrants in this group were all later harvested while the one survivor (149.684) was spawned at the TRH as a ‘spring’ Chinook. Collectively these migrants will be referred to as the summer Chinook migrant group.

Migrants tagged in August (8/20/2003 to 8/29/2003, n=5) and early September (9/3/2003 to 9/10/2003, n=6) all migrated up the Klamath River bound for spawning areas in the Iron Gate Dam area (i.e. Iron Gate Hatchery (IGH) and Bogus Creek) and Shasta River area. The only exceptions were migrants 149.023 (tagged at Blue Hole on 8/22/2003) and 148.953 (tagged at the mouth on 8/26/2003), which migrated up the Trinity River and are not included in this group. Including the late September Klamath migrant 149.494 (see below), these migrants will be collectively referred to as the Klamath fall Chinook migrant group.

Migrants tagged in mid-to-late September (9/11/2003 to 9/24/2003, n=9) and October (10/1/2003, n=1) all migrated into the Trinity River with the exception of migrant 149.494, which migrated to the Hornbrook area of the Klamath River (RKM 301) and is not included in this group. Including migrants 149.023 and 148.953 (see above), these migrants will be collectively referred to as the Trinity fall Chinook migrant group.

Movement Histories

Movement histories (location versus date) are an excellent index of migration behavior because it captures the speed, direction, and timing of migratory movement, which in turn reflects most behavioral tactics used by migrating adult Chinook. Ground speeds overall were highly variable but consistent patterns emerged for each of the four major migrant groups.

Spring Chinook Migrants

The spring Chinook migrant group (n=11) exhibited similar patterns of ground speeds in relation to location (i.e. river kilometer) and date with the majority of upriver migration being completed prior to the end of the full Lewiston spring bench release on July 19th for successful migrants (Figure 13). Of the seven migrants tagged in May and the one tagged in June, only those tagged before May 15th were successful in reaching spawning areas. The three Spring Chinook migrants tagged on July 2nd were also generally not successful, however, they displayed distinctly different movement patterns and experienced extended delays starting during the ramp-down of the Lewiston Dam spring bench release that began on July 10th. Both sub-groups exhibited a pattern of increasing ground speeds as they migrated upriver, which peaked around the Weitchpec (RKM 70) followed by a gradual decrease until reaching holding or spawning areas.

Several observations are relevant in trying to determine why there was such a high rate (70%) of enroute mortality among the migrants in this group. First, the two successful migrants were tagged on May 9th (150.044) and May 14th (150.064) and initiated upriver migration from the estuary by May 23rd at the latest (the third migrant tagged during this period was caught in the lower Trinity River on May 31st). As a consequence these two fish were above the high gradient Burnt Ranch Gorge (Trinity River RKM 139.5 to 146.5) prior to mid-July when water temperatures increased sharply, hitting 20ºC in the Trinity River (at RKM 102) for the first time on July 14th and 22ºC on July 18th for example, which coincided with the end of the Trinity River spring bench flow. Second, five migrants were tagged from May 15th to June 4th and initiated upriver migration from May 30th to June 16th. As a consequence, three of these five migrants were attempting to navigate Burnt Ranch Gorge during the temperature increase of mid-July and apparently died in the attempt; while the other two migrants were attempting to navigate a similarly difficult high gradient reach in the Salmon River by the time temperatures began rapidly increasing there at the end of June with the onset of summer low flow conditions (Figure 8) and apparently died in the attempt. Finally, the three migrants tagged on July 2nd began migrating the following day. Due to their late entry these fish were even lower in the Trinity River by mid-July; one continued upriver and died in Burnt Ranch Gorge, one was found mortally ill at RKM 8 after falling back from the lower Trinity, and one retreated to the Blue Creek/Blue Hole thermal refuge where it apparently resided for over a month before eventually reaching spawning grounds on the Salmon River. Thus to summarize it appears that adult spring Chinook that were not able to migrate above high gradient reaches prior to onset of acutely stressful high water temperatures (≥20ºC) had very low probabilities of survival. Under such a scenario the timing of migration is critical, and the question arises as to why didn't the unsuccessful spring Chinook migrants initiate their migration earlier? There are three possibly avenues of to explain the relatively late timing of migration initiation for these unsuccessful migrants.

First, it could be the result of natural variation. Spring Chinook face tradeoffs in terms of run timing; early migrants forego additional ocean feeding and face energetically demanding high flows but benefit from cooler temperatures, while later migrants can continue to feed in the ocean and can travel quicker at lower flows to compensate for later entry but also face higher water temperatures. In a given year there will be variation in run timing with some portion of the run 'gambling' on a later entry. The variation in run timing among Chinook is considered to be a strategy that increases population resiliency over evolutionary time scales (Secor and Rooker 2005).

Second, it could be the result of tagging stress causing a delay in initiation of upriver movement. While this possibility cannot be eliminated there is evidence which indicates this may not have been a significant factor. For example, the two successful migrants displayed a lag of 4.3 and 9.1 days (d) from tagging to initiation of upriver migration form the estuary. In comparison, the five unsuccessful migrants tagged in May and June displayed lags of 7.1, 4.1, 4.0, 10.8 and 32.4 d. The successful migrant's lag was thus within the observed range of variation for unsuccessful migrants with the exception of the 32.4 d lag exhibited by Chinook 150.084 (it is unknown why this

Chinook lagged for so long). The three unsuccessful migrants tagged on July 2nd initiated migration almost immediately after tagging, exhibiting delays of 1.4, 0.7, and 0.3 d. This result is not consistent with delays caused by tagging, rather it is consistent with the fact that these three migrants were entering the estuary during the closing window of migratory opportunity before the onset of temperatures ≥22ºC it makes sense that they could afford no delay.

Third, the late timing of initiation of migration could have been due to the Trinity River spring bench flow causing a discontinuity in the timing of migratory cues between regulated flows in the mainstem and unregulated flows in tributaries such as the Salmon or South Fork Trinity Rivers, plus a discontinuity with seasonal weather conditions. For example, the snow melt peak on the Salmon River occurred on May 24th with a gradual decline to low flow conditions by the end of June, while in contrast spring releases from Lewiston Dam peaked on May 9th to May 19th then dropped slightly to a stable bench that lasted until July 9th subsequently decreasing relatively abruptly over a period of 10 days (Figure 14). The Trinity spring bench flow release is designed to provide much needed thermal protection for out-migrating juvenile salmonids and also benefits migrating adult spring Chinook by reducing water temperatures and potentially delaying the onset of temperatures in excess of the thermal migration inhibition threshold. While there are such critical benefits there is also the possibility of serious unintended negative consequences to non-target life stages and species that could potentially be remedied by matching the timing and shape of this release to more closely match that of unregulated tributaries and seasonal weather conditions.

Summer Chinook Migrants

The summer Chinook migrants (n= 6, tagged at Blue Hole on July 30th) all exhibited similar movement patterns, including the fastest observed ground speeds for all migrants in 2003 (Figure 15). Ground speeds generally peaked between Blue Hole and Burnt Ranch Gorge. Essentially these migrants took advantage of a brief but substantial weather-induced cooling event that occurred during the first week of August to migrate rapidly into the cool reaches of the upper Trinity River. The one Chinook (150.732) in this group that migrated up the Klamath River above Weitchpec displayed a distinctly slower and different movement pattern (Figure 15). It is unknown whether this migrant was an early Klamath fall Chinook or a stray Trinity spring Chinook but it apparently died enroute in the vicinity of Dillon Creek. These rest of these migrants were likely spring Chinook based on that fact that they reached the upper Trinity River by the end of August and that TRH spring chinook have dominated the Yurok Tribal harvest in the estuary during late July and early August in recent years (YTFP unpublished data). The reason why TRH spring Chinook have been present in the estuary in such large numbers into late summer is unknown, but could be due to hybridization with fall Chinook in the upper Trinity River and at the TRH or due to selection pressures favoring the developed of a summer run in the Trinity River or some combination thereof. Answering that question is beyond the scope of this study, but it is interesting to note that these migrants were largely successful in reaching spawning areas compared to the poor success of later migrants among the spring Chinook migrant group.

Klamath Fall Chinook Migrants

Klamath fall Chinook migrants (n=10) displayed an entirely different migration pattern than the previous migrant groups with relatively consistent movement patterns characterized by slow ground speeds (e.g. 4.0 km/d) through the lower Klamath River followed by higher ground speeds (e.g. 13.7 km/d) above Weitchpec that gradually increased to a peak just prior to arriving on spawning grounds in the Iron Gate Dam area (Figure 16). The pattern of especially slow movement through the lower Klamath was displayed by at least three migrants as exemplified by the only Klamath migrant that was tagged in late September (149.494). Five migrants in this group did not have sufficient resolution of telemetry detections in order to discern the details of their movements in the lower Klamath River other than overall slower ground speeds. The remaining two migrants in this group (149.153 and 150.743), were exceptions in that they traveled slightly faster through the lower Klamath River (12.8 to 15.3 km/d) than above Weitchpec (7.1 to 9.6 km/d).

In examining the timing of migratory movements in comparison to the fall pulse flow, which arrived to the lower Klamath River at RKM 13 on 8/26/2003 and ended on 9/17/2003, it is important to distinguish between Klamath fall Chinook migrants tagged at the Blue Hole refuge (*n*=2) versus those tagged in the estuary (*n*=8) and their tagging dates. Of the three migrants tagged before arrival of the pulse flow, upriver movement commenced on August 28th and September 2nd (149.105 and 149.142, Blue Hole) and September 5th (150.743, mouth). Six migrants were tagged during the pulse flow, from September 3rd to the 10th, with initiation of upriver migration generally commencing within approximately 24 hours of tagging. One Klamath migrant (149.494) was tagged after cessation of the pulse flow.

Several aspects of these migrants' movement timing in relation to the fall pulse flow are significant: 1) initiation of upriver movement did not coincide with arrival of the pulse flow for any migrants; 2) flow releases from Iron Gate dam increased 12% at the end of August from approximately 1,000 cfs to 1,200 cfs which reached RKM 13 on September 2nd; 3) September 2nd was also the last day that water temperatures ≥22ºC and marked the beginning of a major cooling trend; 4) on average from 1996 to 2004 the last day MDTs ≥22ºC was September 1st throughout the lower Klamath and Trinity Rivers; and 5) the average peak run timing for IGH fall Chinook in the estuary occurs during the last week of August through the first week of September (YTFP unpublished data). Thus it can be concluded that the influence of the fall pulse flow in triggering upriver movement among Klamath fall Chinook migrants was negligible in comparison to the combined affects of the arrival of increased Iron Gate flows and sharply falling water temperatures of September 2nd, the timing of which matched the mean peak run timing and mean seasonal cooling of water temperatures. Separating the degree to which these different components (water temperature and Iron Gate flow, annual variation and long term averages) influenced Klamath fall Chinook migration behavior in the lower Klamath River is problematic. Since slow ground speeds in the lower Klamath River occurred both during and after the fall pulse flow it is unlikely that it decreased travel rates of Klamath fall Chinook, although the possibility that the fall pulse flow increased the ground speeds of migrants 149.153 and 150.743 cannot be ruled out. It is interesting to note that none of the Klamath fall Chinook migrants passed into the Klamath River above Weitchpec until September 7th, which was the first day MDTs did not ≥22ºC in this reach, even though migrant 149.105 arrived at Weitchpec on September 4th. Migrant 149.105 was the only migrant in this group to initiate upriver movement prior to

September 2nd, however it only traveled at 3.5 km/d from August 28th to September 2nd compared 12.1 km/d from September 2nd to September 4th. This provides evidence for what is likely the primary effect of the fall pulse flow from a fish behavior standpoint: prematurely decreasing water temperatures below the thermal migration inhibition threshold and thus allowing Chinook that were already holding in thermal refuges to move upriver. Migration beyond the confluence at Weitchpec into the Klamath River was still constrained by water temperatures in excess of the thermal migration inhibition threshold until additional seasonal cooling occurred.

Trinity Fall Chinook Migrants

The Trinity fall Chinook group of migrants (n=12) exhibited a greater amount of variability in ground speeds and moved slightly faster through the lower Klamath River (Figure 17) than the Klamath fall Chinook migrant group on average. The general pattern for this group was relatively steady ground speeds that slowly decreased as they proceeded upriver usually with an inflection point at the high gradient passage through Burnt Ranch Gorge. However, two migrants in this group (149.392 and 150.775B) moved very slowly through the lower Klamath River in a pattern very similar to that exemplified by Klamath fall Chinook migrants such as 149.494. Although it should be noted that the resolution of detection prevented discernment of detailed patterns for four of the Chinook in Trinity fall Chinook migrant group. In general, ground speeds for this migrant group were distinctly different from the spring and summer migrant groups and subtly different from the Klamath fall Chinook migrants.

In relation to the fall pulse flow, five Trinity fall Chinook migrants were tagged before or during the pulse flow while seven were tagged after its cessation. This range in tagging dates for the Trinity fall Chinook group is equivalent to the run timing of TRH fall Chinook which has a broader range than IGH fall Chinook but tends to peak during the second half of September (YTFP unpublished data). Thus the pulse flow was a non-factor in the migration behavior for a large portion of the Trinity River fall Chinook run. Of the five Trinity fall Chinook migrants that did experience the pulse flow, three did not travel farther than 30 km upriver during the pulse flow (migrants 149.392, 149.403, and 149.463) while the other two migrated more extensively upriver (149.023 and 148.953).

It is important to examine the details of these former two migrants' movements during the fall pulse flow. Chinook 149.023 was tagged at Blue Hole on August 21st where it resided until August 28th. After leaving Blue Hole this fish migrated upriver slowly at 1.8 km/d until September 2nd when its ground speed increased to 13.4 km/d. This is consistent with the behavior of Klamath fall Chinook migrant 149.105 and provides additional evidence that the cooling water temperature trend that began on September 2nd was a major trigger of upriver migration for adult Chinook in the lower Klamath River. The other migrant in question, Chinook 148.953 was tagged at the mouth of the Klamath on August 26th but resided in the estuary or nearshore ocean until commencing upriver migration on September 6th, after the seasonal cooling had begun. Thus there were no obvious correlations in movement to the fall pulse flow for this group of migrants, the majority of which were tagged after the cessation of the pulse flow as is expected given the average run timing of Trinity River fall Chinook.

4.0 SUMMARY AND CONCLUSIONS

- A total of 120 adult Chinook were tagged in 2003 of which 39 (termed migrants) provided enough data to examine migration behavior for specific stocks or run timing groups.
- The four stock/run timing migrant groups were spring Chinook (n=11), summer Chinook (n=6), Klamath fall Chinook (n=10), and Trinity fall Chinook (n=12).
- A total of 23 external archival temperature tags were recovered from radio tagged Chinook, of which seven were from Chinook classified as migrants.
- Behavioral thermoregulation was an important tactic used both prior to emergence from the estuary and while enroute. The most used thermal refuges where the estuary and Blue Hole.
- Observed Chinook behavior in 2003 was consistent with a thermal migration inhibition threshold occurring when mean daily temperatures ≥22ºC as was determined in the 2002 adult spring Chinook telemetry study.

- Spring Chinook that do not migrate above high gradient reaches (e.g. Burnt Ranch Gorge) before the onset of stressfully high water temperatures (>20ºC) have a substantially lower probability of survival.
- The Trinity River spring bench release from Lewiston Dam benefits migrating salmonids by decreasing water temperatures and potentially delaying the onset of water temperatures in excess of the thermal migration inhibition threshold; however, its timing and shape could negatively impact adult Chinook by creating a timing discontinuity between regulated flow and spring snowmelt from unregulated tributaries, plus seasonal weather patterns. This potential is magnified for wild stocks spring Chinook in the Salmon and South Fork Trinity Rivers.
- There appears to be a summer run comprised of Trinity River 'spring' Chinook that rely on enroute thermal refuges and weather induced cooling events to reach spawning areas in the upper Trinity River.
- The Trinity River fall pulse flow did not trigger upriver movement of tagged Chinook with the possible exception of Chinook already residing in thermal refuges in the lower Klamath River. Conversely the fall pulse flow did not result in slow ground speeds through the lower Klamath River either, but may have contributed to faster travel rates observed by two of ten Klamath fall Chinook migrants.
- Seasonal cooling resulted in a sharply falling temperature trend beginning on September 2nd, which coincided with the arrival of increased flows (12%) from Iron Gate Dam. The timing of these events corresponded with initiation of upriver movement by tagged Chinook in the lower Klamath River. Since seasonal cooling and increased flows from Iron Gate Dam occur during the first week of September on a consistent basis year to year, thus providing a reliable migratory cue for fall run Chinook to begin upriver migration.

5.0 TABLES

Table 1. Radio listening station locations (ID number, site name, river, and river kilometer) plus radio telemetry equipment vendor type for the 2003 adult Chinook telemetry study.

ID	Site	River	RKM	Type
1	Wakel	Klamath	7	ATS/Lotek
2	Mouth of Blue Creek	Klamath	26.0	ATS/Lotek
3	Klamath/Trinity Confluence	Klamath	70.0	ATS/Lotek
4	Mouth of Bluff Creek	Klamath	80.0	ATS/Lotek
5	Salmon River at Wooley Creek	Salmon	114	ATS
6	Mouth of Scott river	Klamath	233	ATS
7	Mouth of Shasta River	Klamath	288.5	ATS/Lotek
8	Mouth of Horse Linto Creek	Trinity	102	ATS/Lotek
9	Salyer	Trinity	125.5	ATS
10	Douglas City	Trinity	216	ATS

Table 2. Tagging data and final known fates or last observations for all 39 adult Chinook that migrated above the confluence of the Klamath and Trinity Rivers in 2003. Termed migrants, these Chinook were the basis of analysis of migration behavior and destinations. Abbreviations: gn=gill net; MIA=missing in action, disappeared; mort=mortality; obs.=observation; TRH=Trinity River Hatchery; IGD= Iron Gate Dam; IGH=Iron Gate Hatchery.

Tagging Date	Tagging Location	Tag Frequency	Disc Tag #	Disc Color	Fork L cm	Fate/Last Observation	Archival Data
9-May	Mouth	150.044	5	Y	77	spawned out Lewiston	N
14-May	Mouth	150.055	6	Y	93	caught gn 5/31 above Smokers	Y
14-May	Mouth	150.064	7	Y	74	spawned out near Douglas City	N
15-May	Mouth	150.084	9	Y	89	dead below Grays Falls	N
23-May	Mouth	150.114	12	Y	74	dead at lower Salmon	N
30-May	RKM 16.5	150.124	13	Y	78	dead at lower Salmon	Y
30-May	RKM 20.5	150.104B	14	Y	76	dead below Salyer	N
4-Jun	Mouth	150.163	18	Y	67	dead below Tunnel Flat	N
2-Jul	Mouth	150.263	28	Y	79	dead at New River confluence	N
2-Jul	Mouth	150.233	25	Y	67	dead at Wakel from Hoopa	Y
2-Jul	Mouth	150.253	27	Y	68	spawned Nordhiemer 10/29	N
30-Jul	Blue Hole	150.775	47	Y	63	caught Junction City	N
30-Jul	Blue Hole	150.233B	37	Y	71	caught Pearson's gn 8/9	Y
30-Jul	Blue Hole	150.714	42	Y	71	caught Piegon Point	N
30-Jul	Blue Hole	150.732	44	Y	94	dead at Aubrey Creek - Klamath	N
30-Jul	Blue Hole	150.684	39	Y	66	spawned at TRH	N
30-Jul	Blue Hole	150.674	38	Y	91	Steel Bridge - caught?	N
20-Aug	Mouth	150.743	52	Y	70	spawned in Bogus Cr 10/15	N
22-Aug	Blue Hole	149.023	3	G	67	Lewiston Dam 10/22	N
22-Aug	Blue Hole	149.105	9	G	78	spawned IGH 10/15	N
26-Aug	Mouth	148.953	57	Y	74	MIA above Horse Linto	N
29-Aug	Blue Hole	149.142	12	G	82	caught Ishi Pishi Falls	N
3-Sep	Mouth	149.153	60	Y	81	China Point near Happy Camp 9/24	N
3-Sep	Mouth	149.093	25	W	77	last obs. at Bluff 9/11	N
4-Sep	Mouth	149.254	68	Y	67	spawned at IGH 10/17	Y
4-Sep	Mouth	149.293	69	Y	73	spawned below IGD 11/12	N
10-Sep	Estuary	149.264	25	G	60	mort? at Independence 11/14	N
10-Sep	Estuary	149.282	26	G	87	up Shasta River 11/7	N
11-Sep	Mouth	149.392	74	Y	76	last obs. Del Loma 10/27	N
12-Sep	Estuary	149.403	24	G	65	last obs. Burnt Ranch 10/27	N
12-Sep	Estuary	149.463	4	G	67	spawned in Lewiston 11/17	N
17-Sep	Mouth	150.714B	82	Y	82	last observation Grays Falls 10/10	N
17-Sep	Mouth	150.775B	79	Y	90	last obs. Horse Linto 11/18	N
24-Sep	Mouth	149.571	88	Y	78	last obs. Salyer 11/6	N
24-Sep	Mouth	149.564	10	G	72	spawned TRH 11/13	N
24-Sep	Mouth	149.494	84	Y	72	last obs. Shasta R. Station 11/1	N
24-Sep	Mouth	149.583	15	G	74	spawned TRH 11/12	N
1-Oct	Mouth	149.673	89	Y	81	caught Pearson’s sport 10/14	Y
1-Oct	Mouth	149.693	iBCod	NA	72	spawned below TRH 11/17	Y

6.0 FIGURES

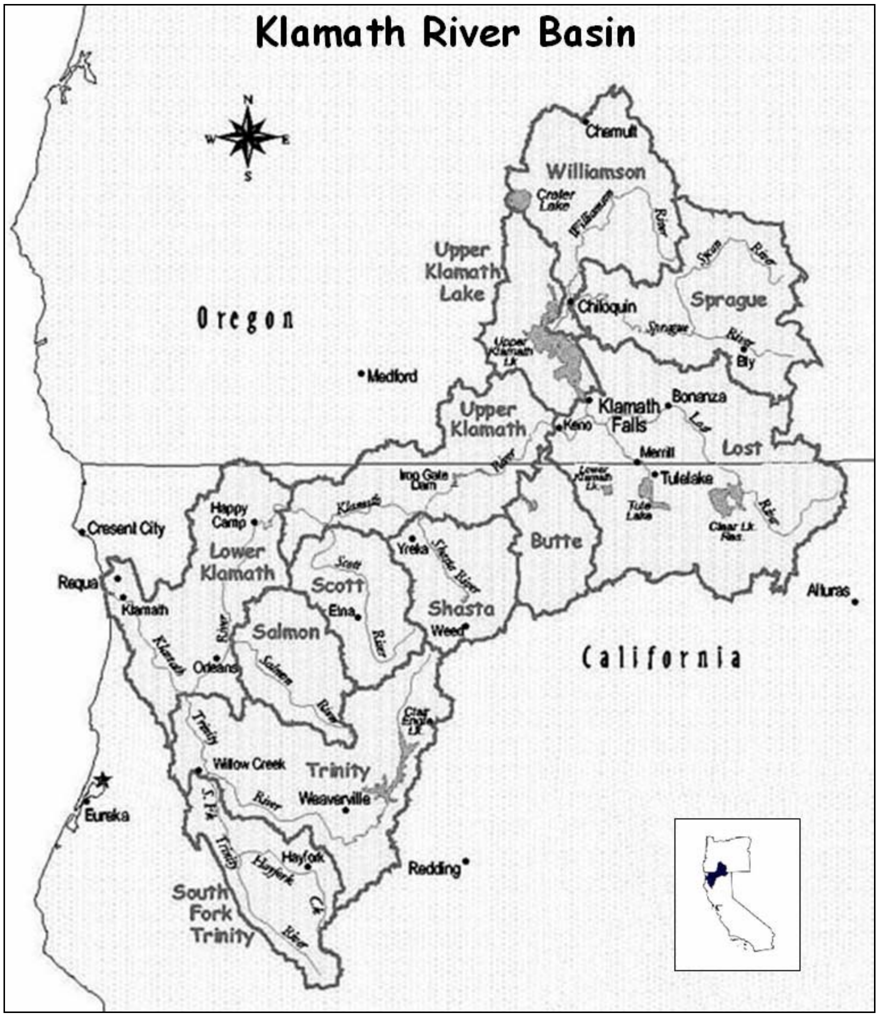

Figure 1. The Klamath River Basin of northern California and southern Oregon with sub-basins demarcated. Iron Gate Dam on the mainstem Klamath and Lewiston Dam on the mainstem Trinity River both currently limit the upriver distribution of anadromous fishes within the watershed. Historically spring Chinook were distributed throughout large areas of the Basin; presently spawning populations of spring Chinook are found in the Salmon River, South Fork Trinity, and mainstem Trinity sub-basins.

Figure 2. Aerial photograph of Blue Hole and the confluence of Blue Creek with the Klamath River in August of 2003. The Klamath River is flowing from right to left with Blue Hole at the top left and Blue Creek joining the Klamath River at the top right of the picture. The configuration in 2003 was very similar to 2002. Photo by the author; pilot Rich Anthis CA Department of Fish and Game.

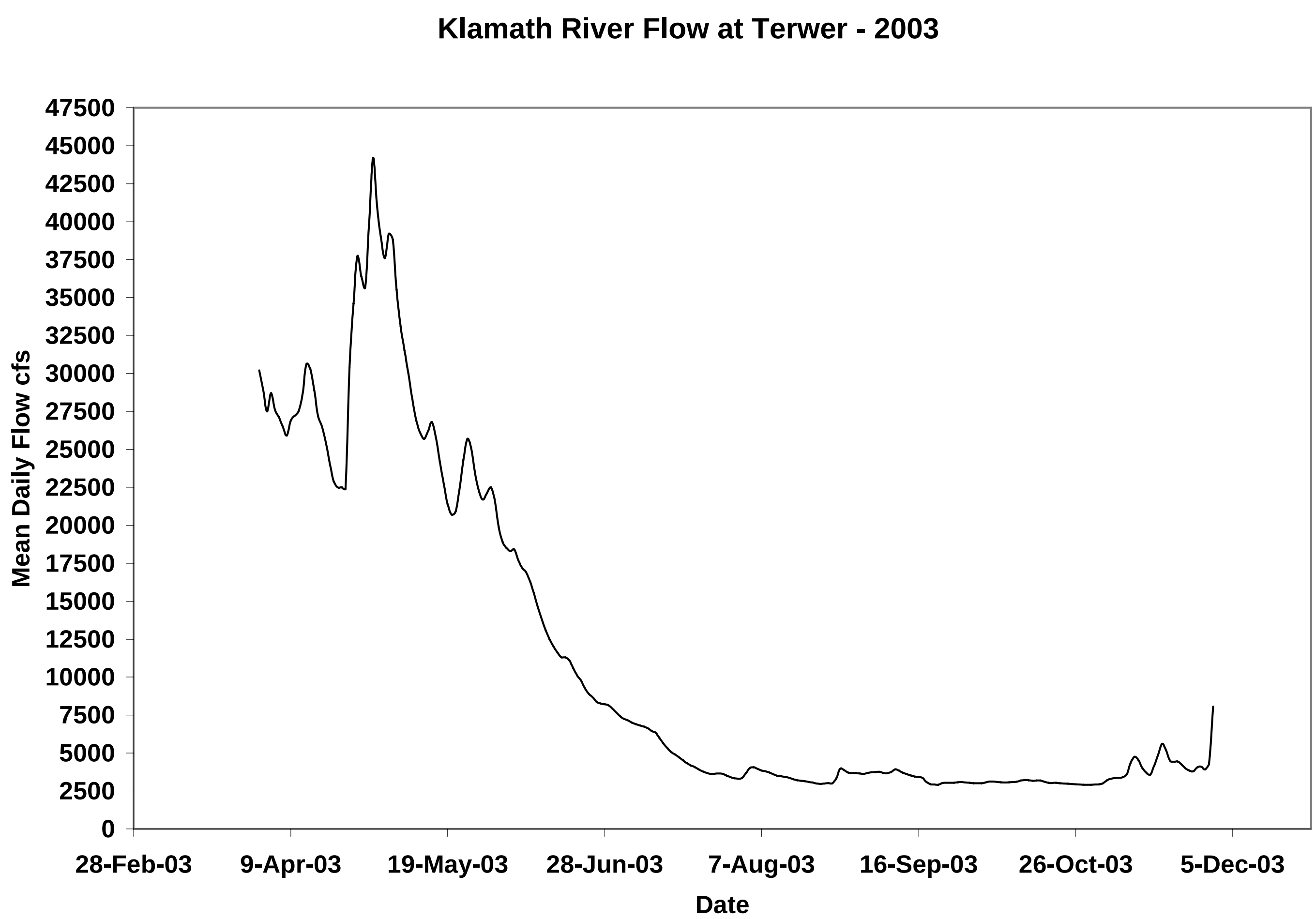

Figure 3. Mean daily flow for the lower Klamath River at Terwer (RKM 13) during the study period.

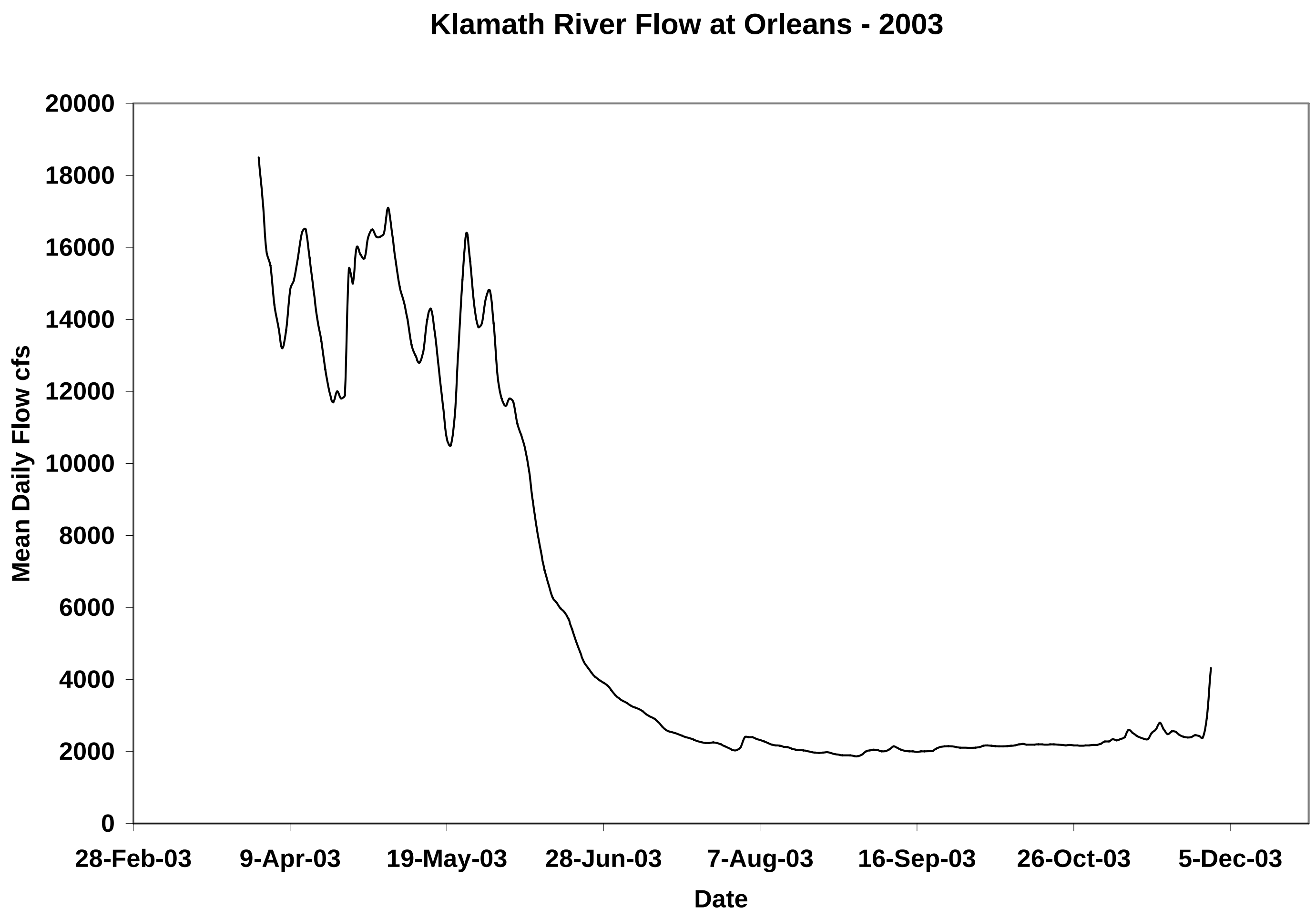

Figure 4. Mean daily flow for the mid Klamath River at Orleans (RKM 94) during the study period.

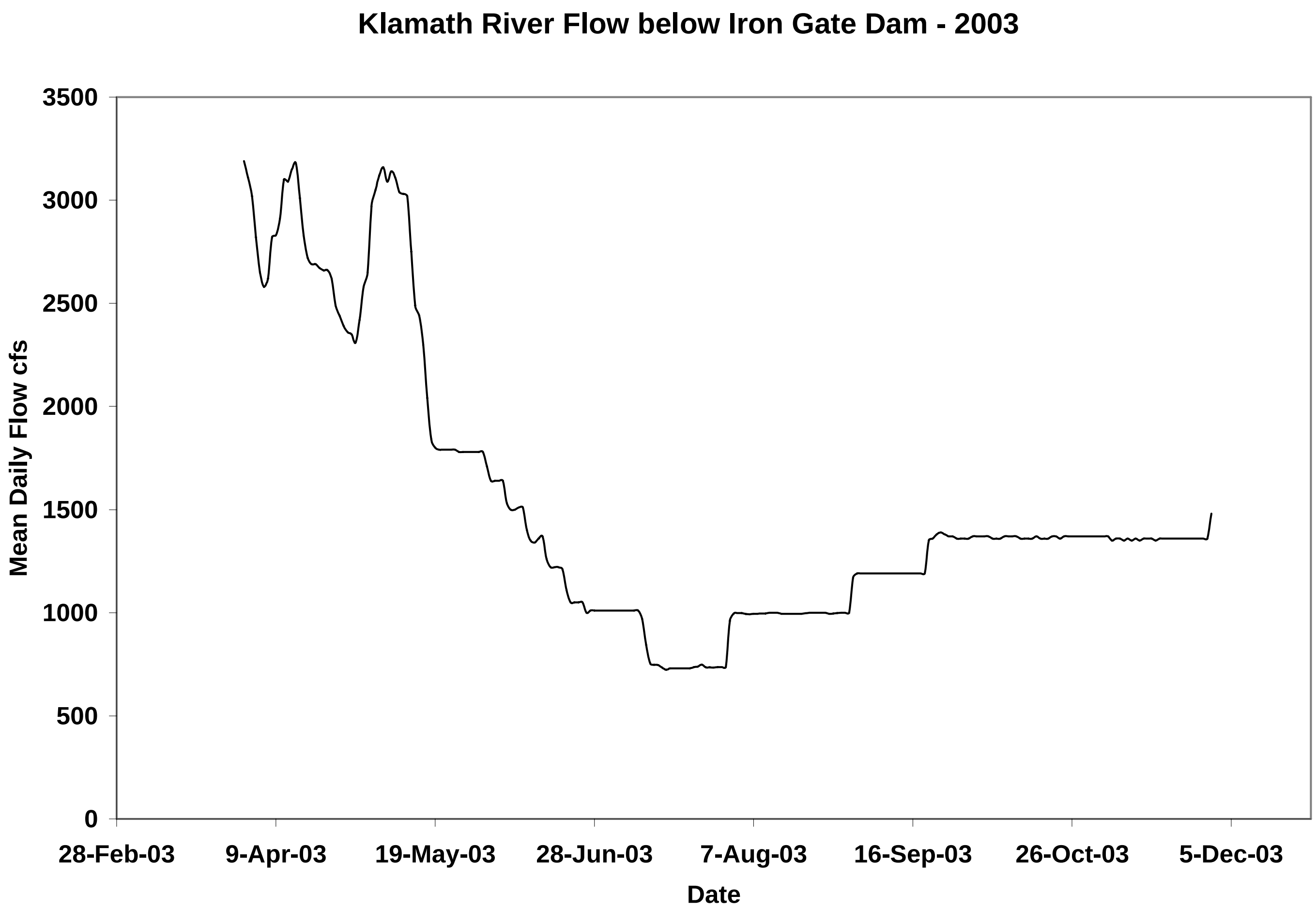

Figure 5. Mean daily flow for the upper Klamath River (RKM 308) during the study period as controlled by releases from Iron Gate Dam.

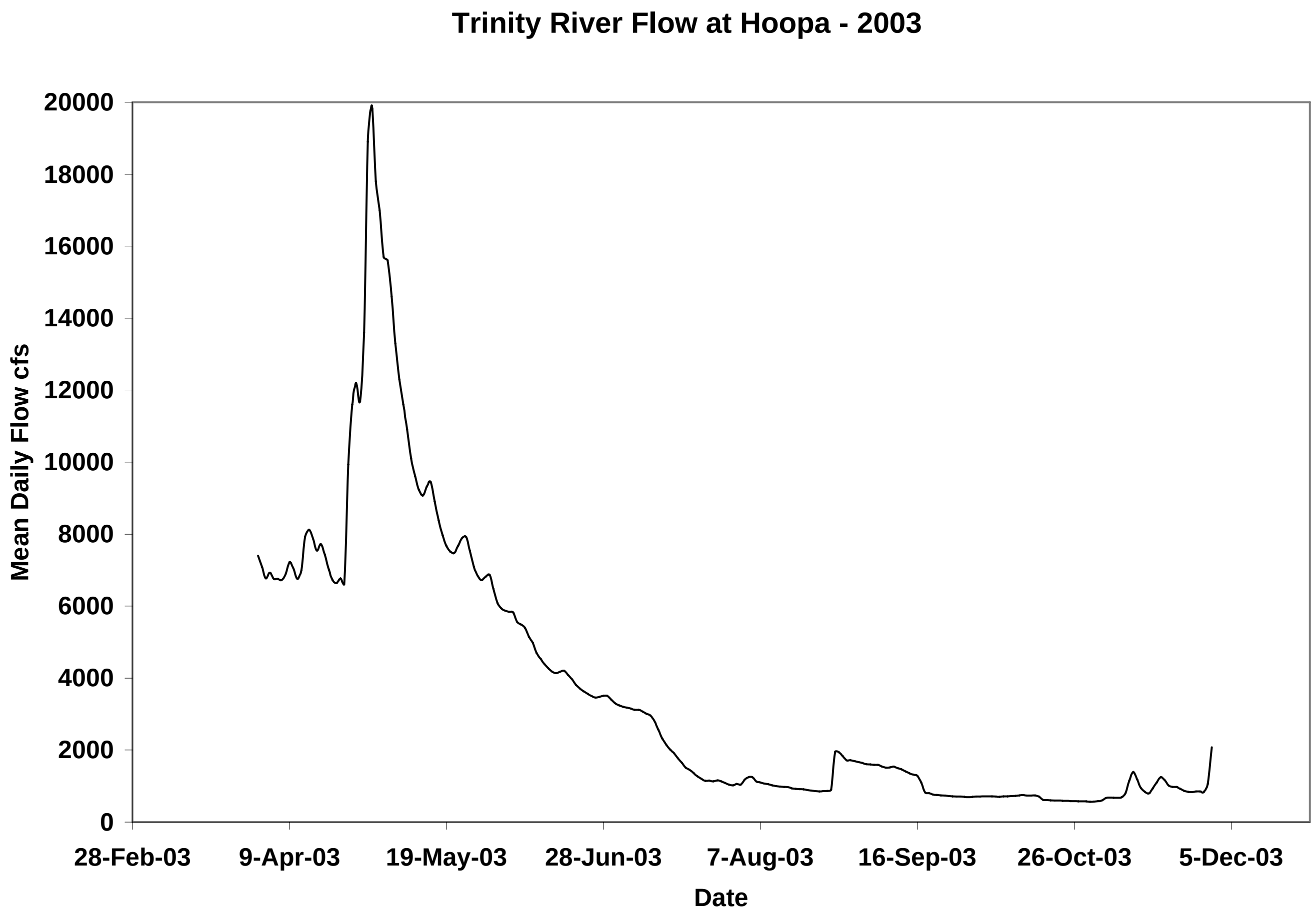

Figure 6. Mean daily flow for the lower Trinity River at Hoopa (RKM 90) during the study period.

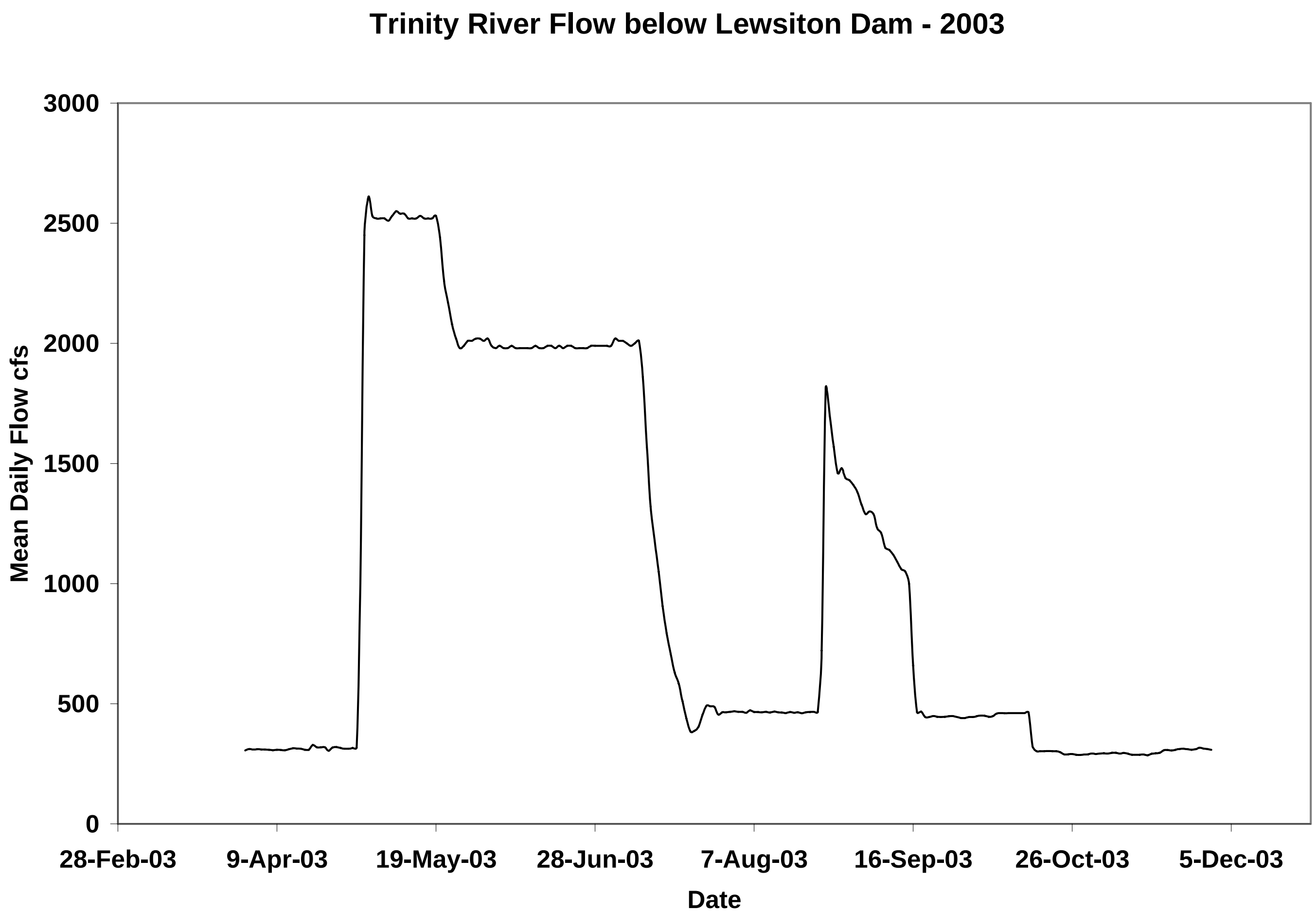

Figure 7. Mean daily flow for the upper Trinity River (RKM 252) during the study period as controlled by releases from Lewiston Dam.

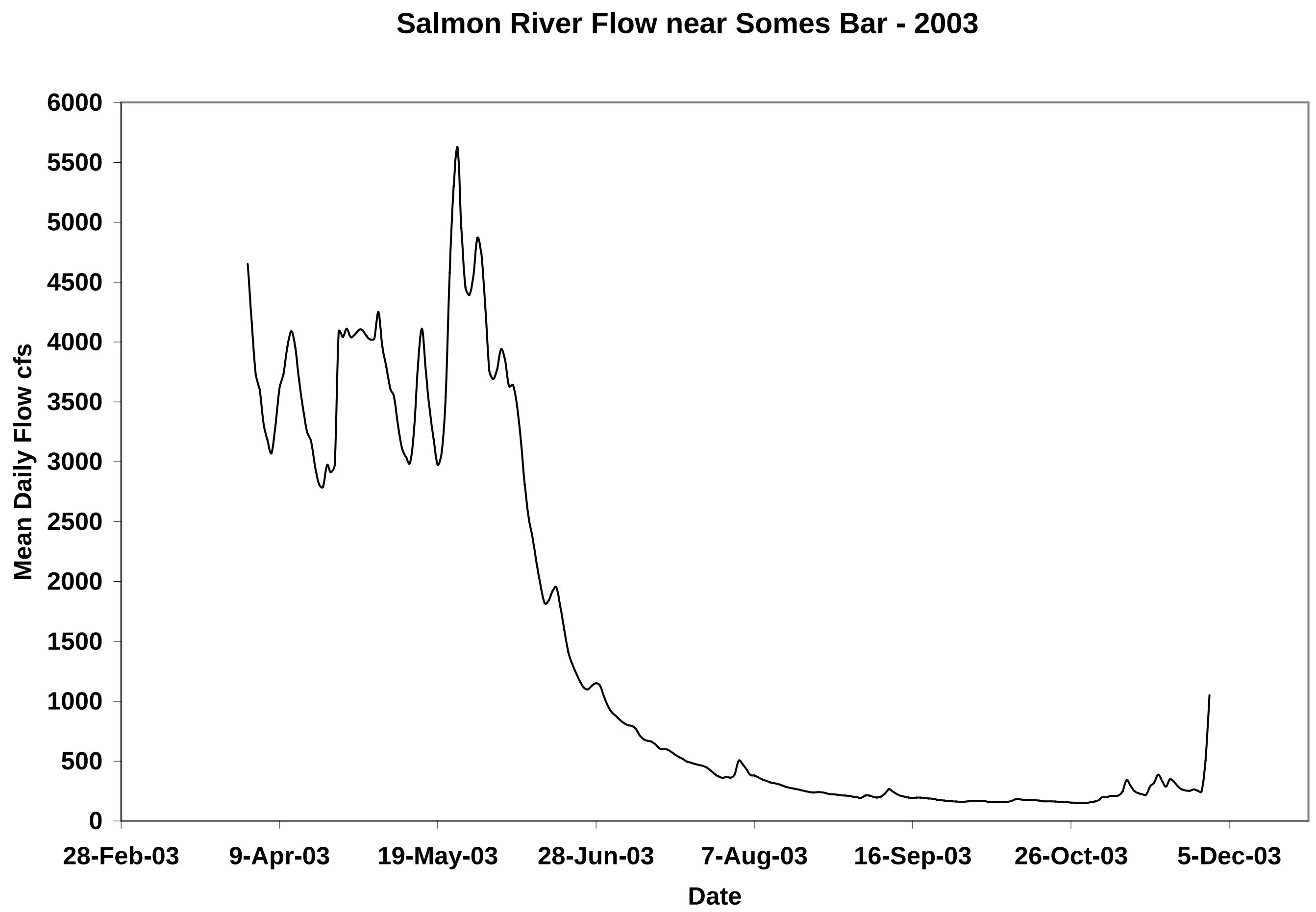

Figure 8. Mean daily flow for the unregulated lower Salmon River near Somes Bar (RKM 110) during the study period.

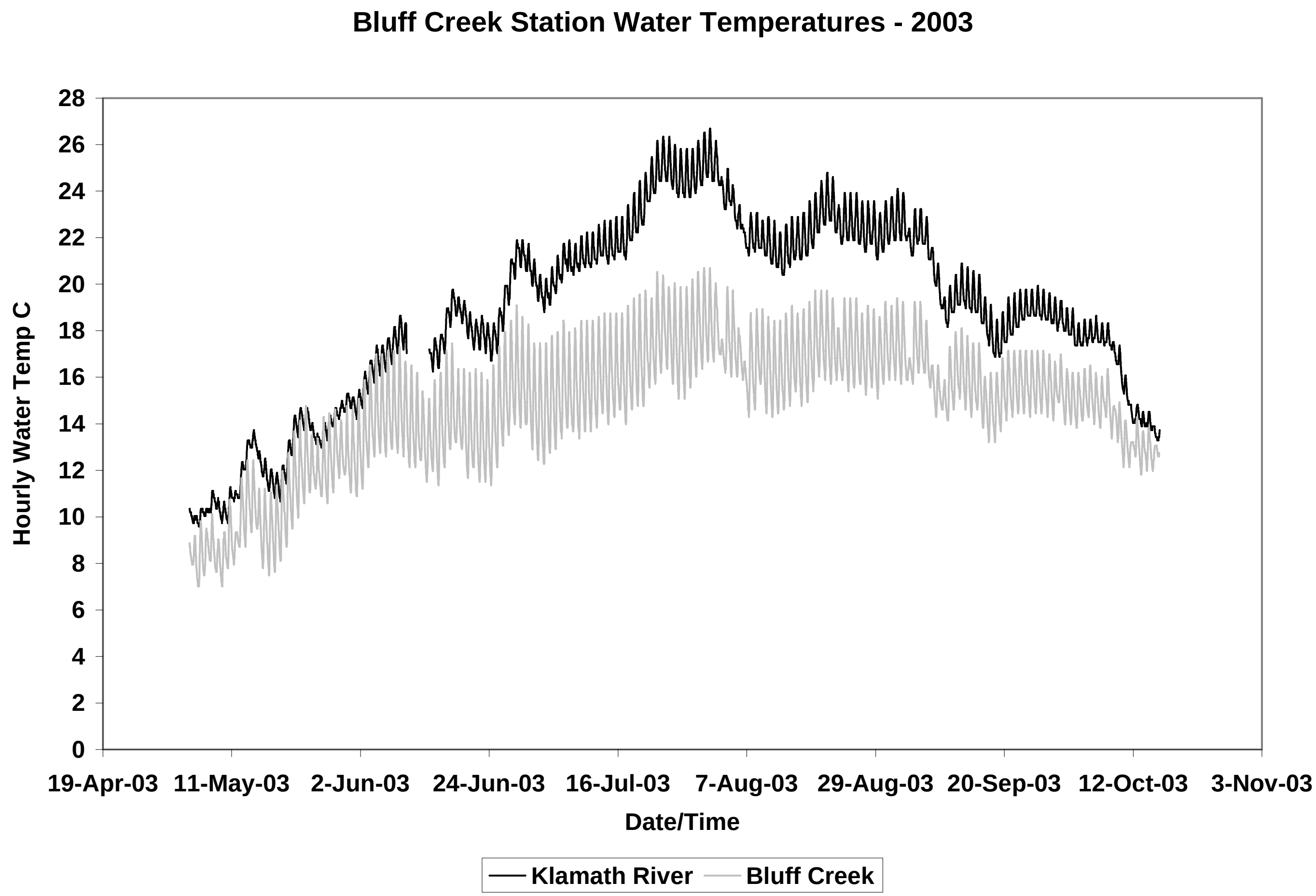

Figure 9. Hourly water temperatures for the mid Klamath River above Bluff Creek (RKM 81) and for the thermal refuge forming Bluff Creek during the study period.

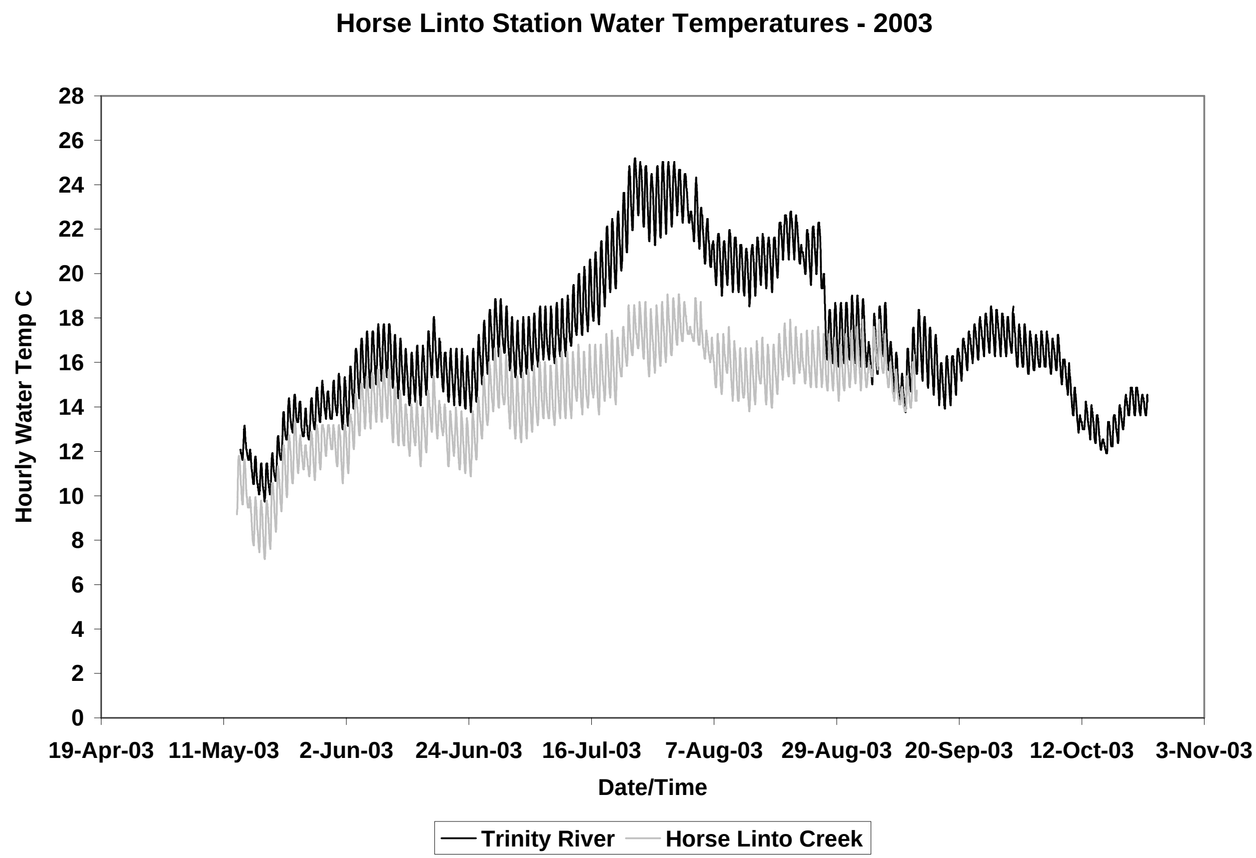

Figure 10. Hourly water temperatures for the lower Trinity River above Horse Linto Creek (RKM 102) and for the thermal refuge forming Horse Linto Creek during the study period.

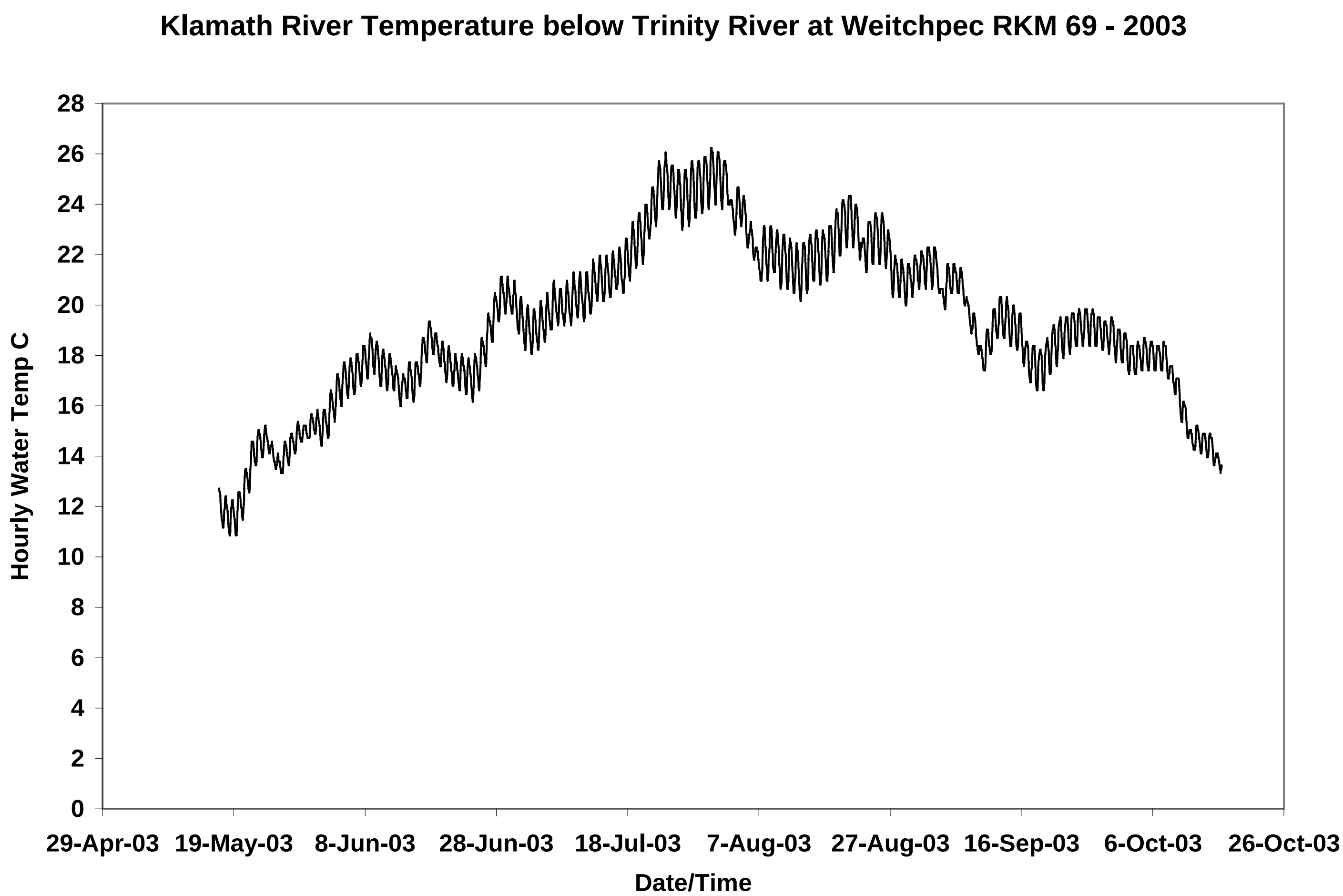

Figure 11. Hourly water temperatures for the lower Klamath River at Weitchpec below the mixing zone of the Trinity River (RKM 68) during the study period.

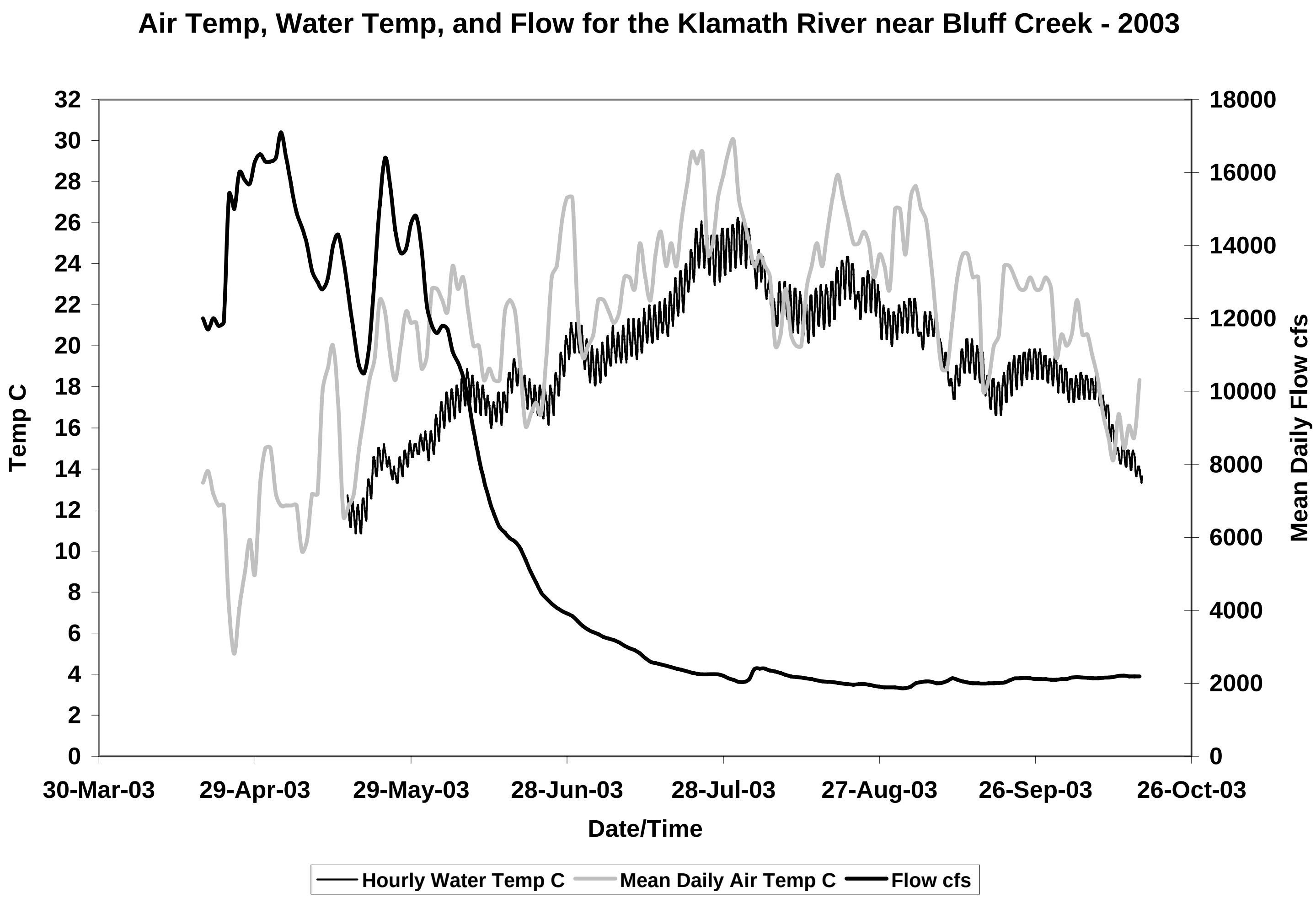

Figure 12. Comparison of air temperature, water temperature, and flows for the Klamath River in the vicinity of Bluff Creek illustrating the influence of air temperature on water temperature which is strongest during low flow periods.

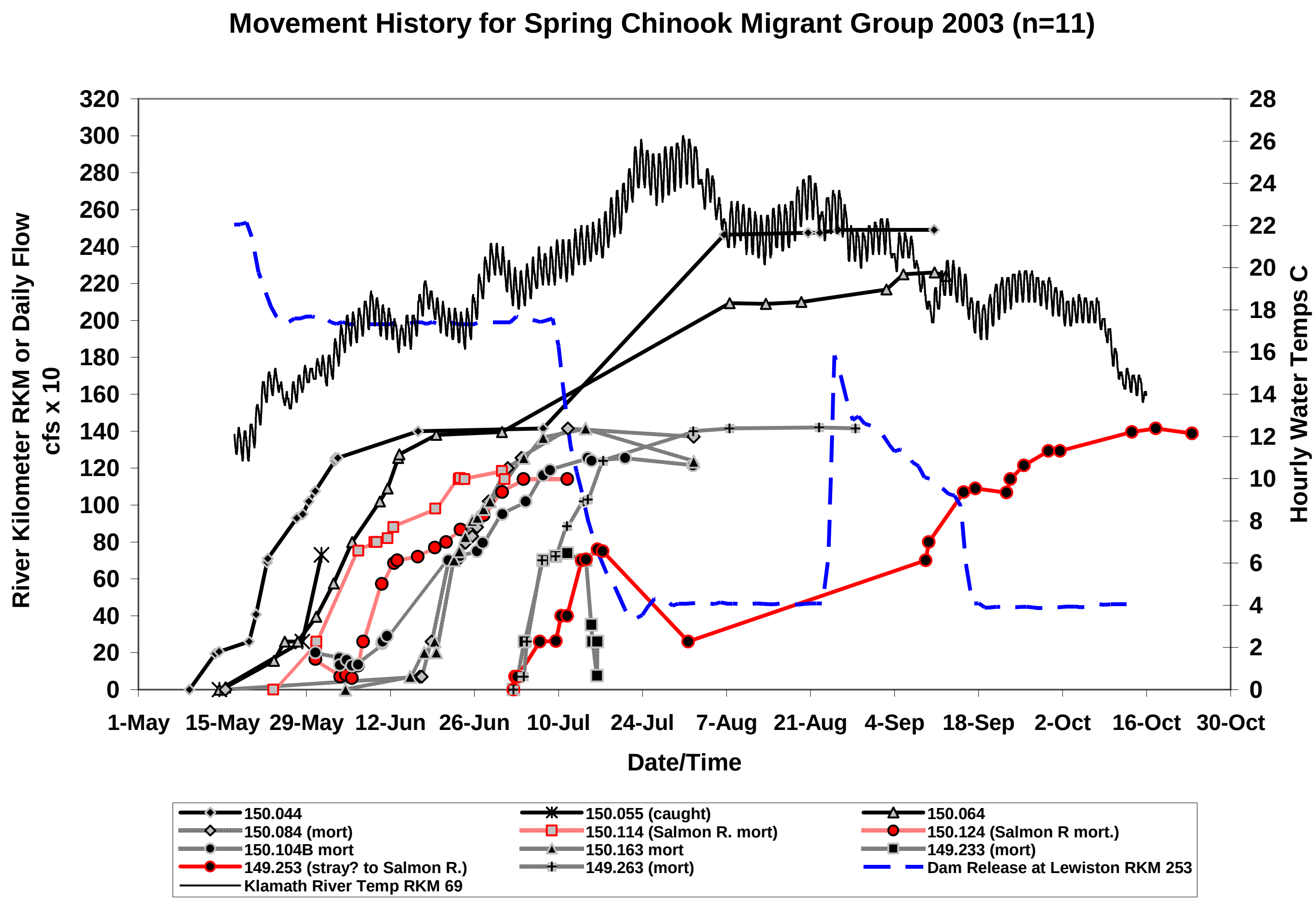

Figure 13. Movement histories for all Chinook migrants tagged in May, June, and early July with water temperature in the lower Klamath River and dam releases from Lewiston for reference. Each point symbol indicates a position observation for that tagged Chinook. If a given migrant was caught or died enroute this is noted in parenthesis in the legend, otherwise the migrant was believed to have successfully spawned or reached spawning grounds. Unless otherwise noted in the legend, all of these Chinook migrated into the Trinity River.

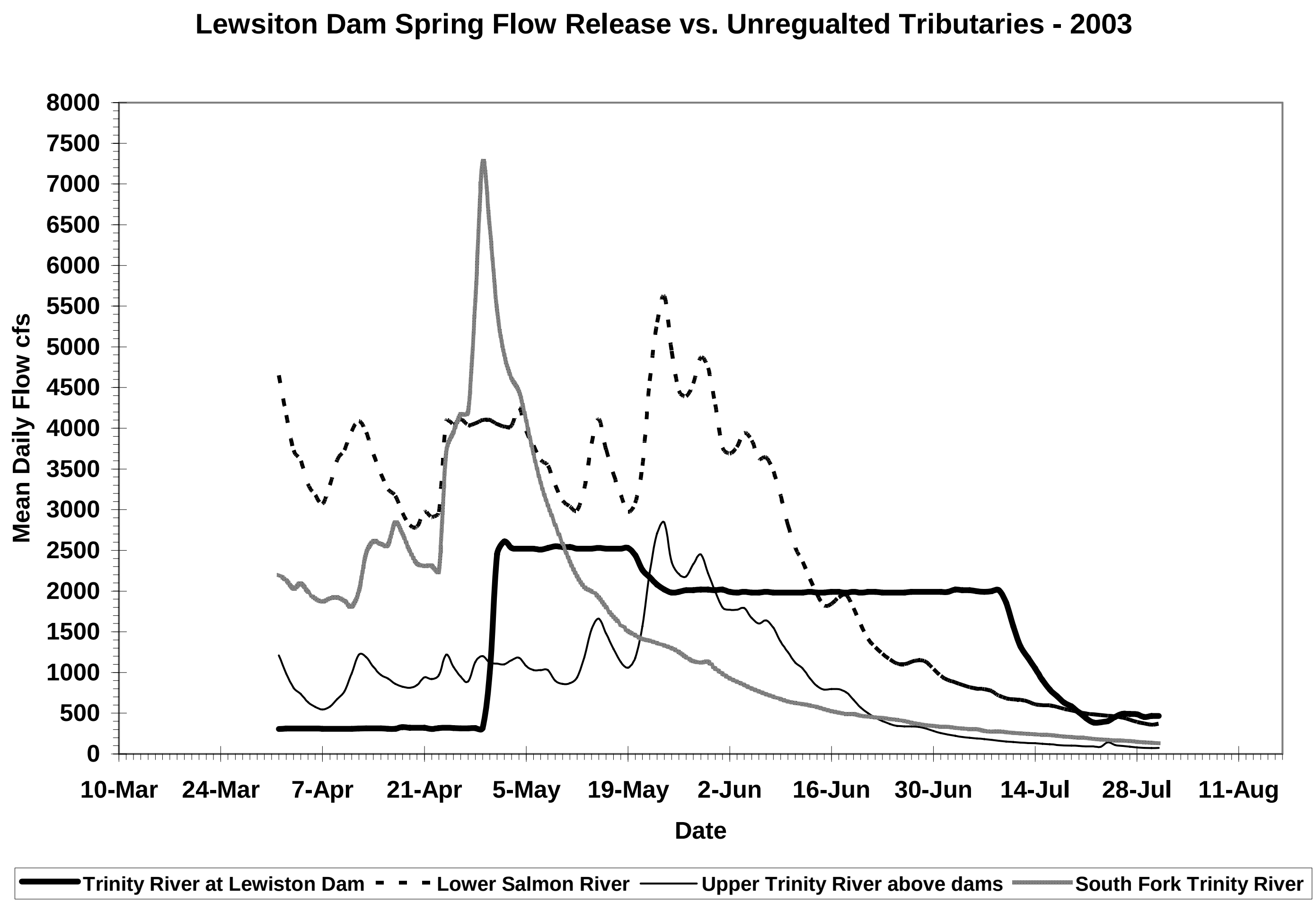

Figure 14. Comparison of 2003 spring flows for the Trinity River at Lewiston Dam versus the unregulated Salmon River near Somes Bar, the South Fork Trinity below Hyampom, and the upper Trinity River above Coffee Creek (above both dams) showing the discontinuity in the timing and shape of the respective hydrographs during the decreasing limb of the spring snowmelt period.

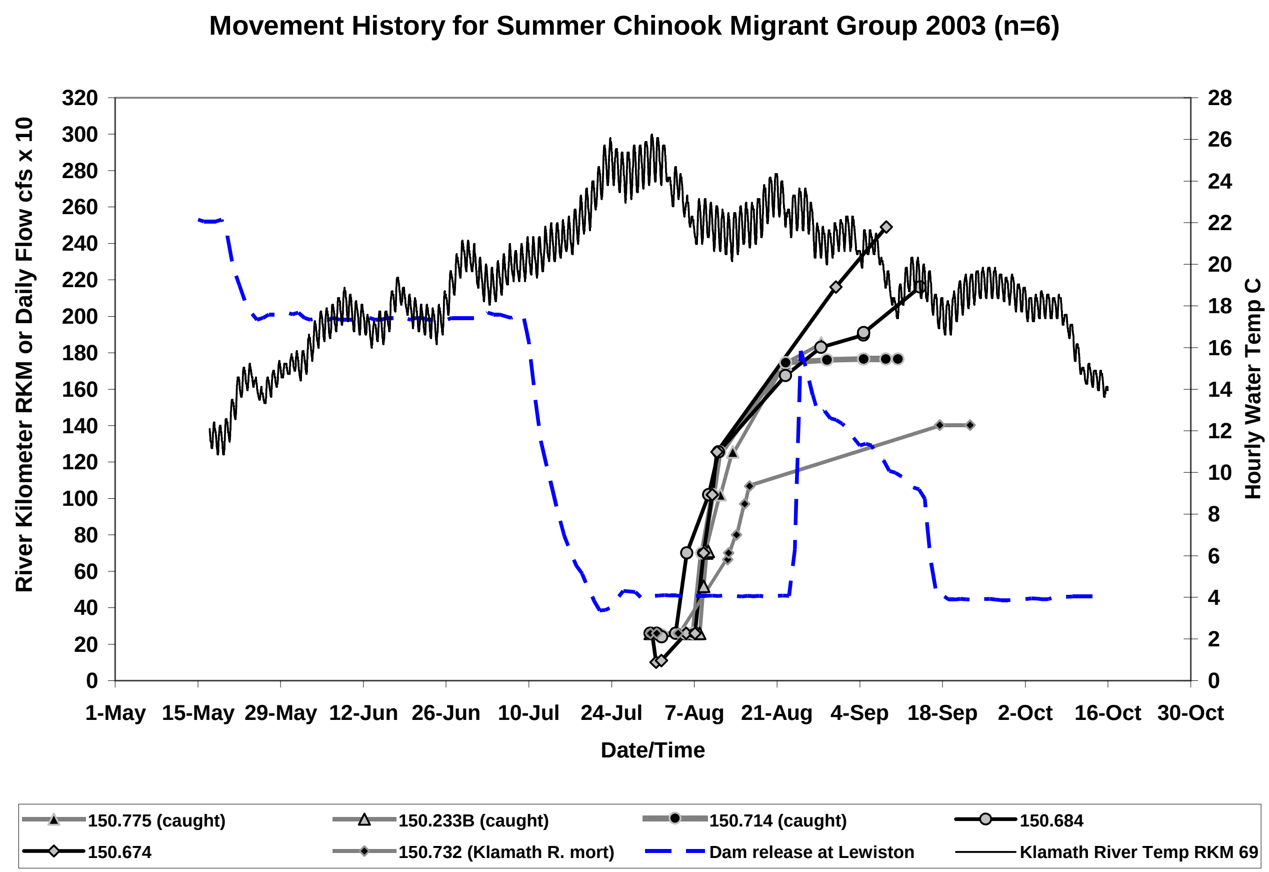

Figure 15. Movement histories for all Chinook migrants tagged in late July at the Blue Hole thermal refuge (RKM 26) with water temperature in the lower Klamath River and dam releases from Lewiston for reference. Each point symbol indicates a position observation for that tagged Chinook. If a given migrant was caught or died enroute this is noted in parenthesis in the legend, otherwise the migrant was believed to have successfully spawned or reached spawning grounds. All of these Chinook migrated into the Trinity River, except for Chinook 150.732 which died enroute in the vicinity of Dillion Creek RKM 121.

Movement History for Klamath Fall Chinook Migrant Group 2003 (n=10)

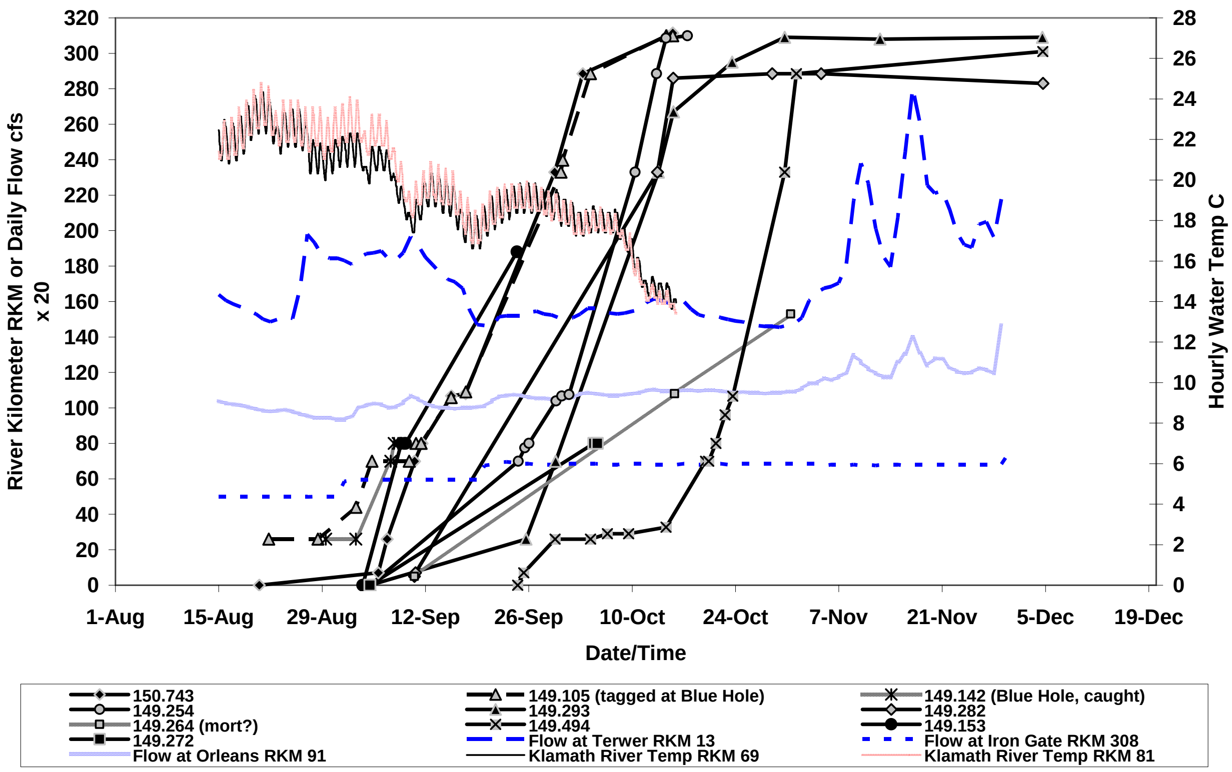

Figure 16. Movement histories for all Chinook migrants tagged in August and early September (<9/11/2003) that migrated in the Klamath River beyond Weitchpec. Water temperature in the lower Klamath River above and below the Trinity River and flow at RKM 13, 91, and 308 is shown for reference. The Trinity River fall pulse flow from Lewiston Dam reached the lower Klamath River (RKM 13) on 8/26/2003 and ended on 9/18/2003. Each point symbol indicates a position observation for that tagged Chinook migrant. If a given migrant was caught or died enroute this is noted in parenthesis in the legend, otherwise the migrant was believed to have successfully spawned or reached spawning grounds. Unless otherwise noted in the legend, all of these Chinook were tagged at the mouth of the Klamath River or in the estuary.

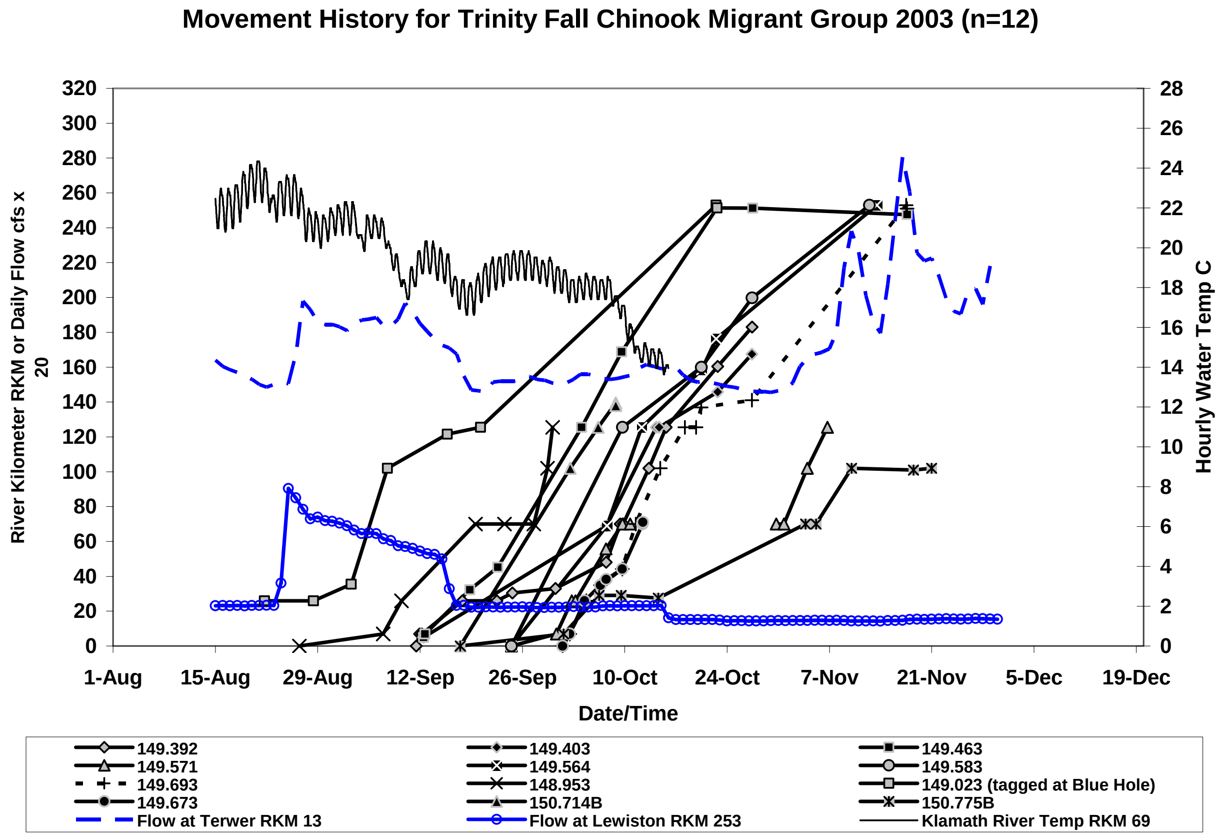

Figure 17. Movement histories for all Chinook migrants tagged from mid-September (>9/11/2003) to October that migrated into the Trinity River. Water temperature in the lower Klamath River and flow at RKM 13 and 253 is shown for reference. The Trinity River fall pulse flow from Lewiston Dam reached the lower Klamath River (RKM 13) on 8/26/2003 and ended on 9/18/2003. Each point symbol indicates a position observation for that tagged Chinook migrant. If a given migrant was caught or died enroute this is noted in parenthesis in the legend, otherwise the migrant was believed to have successfully spawned or reached spawning grounds or disappeared during tracking. Unless otherwise noted in the legend, all of these Chinook were tagged at the mouth of the Klamath River or in the estuary.

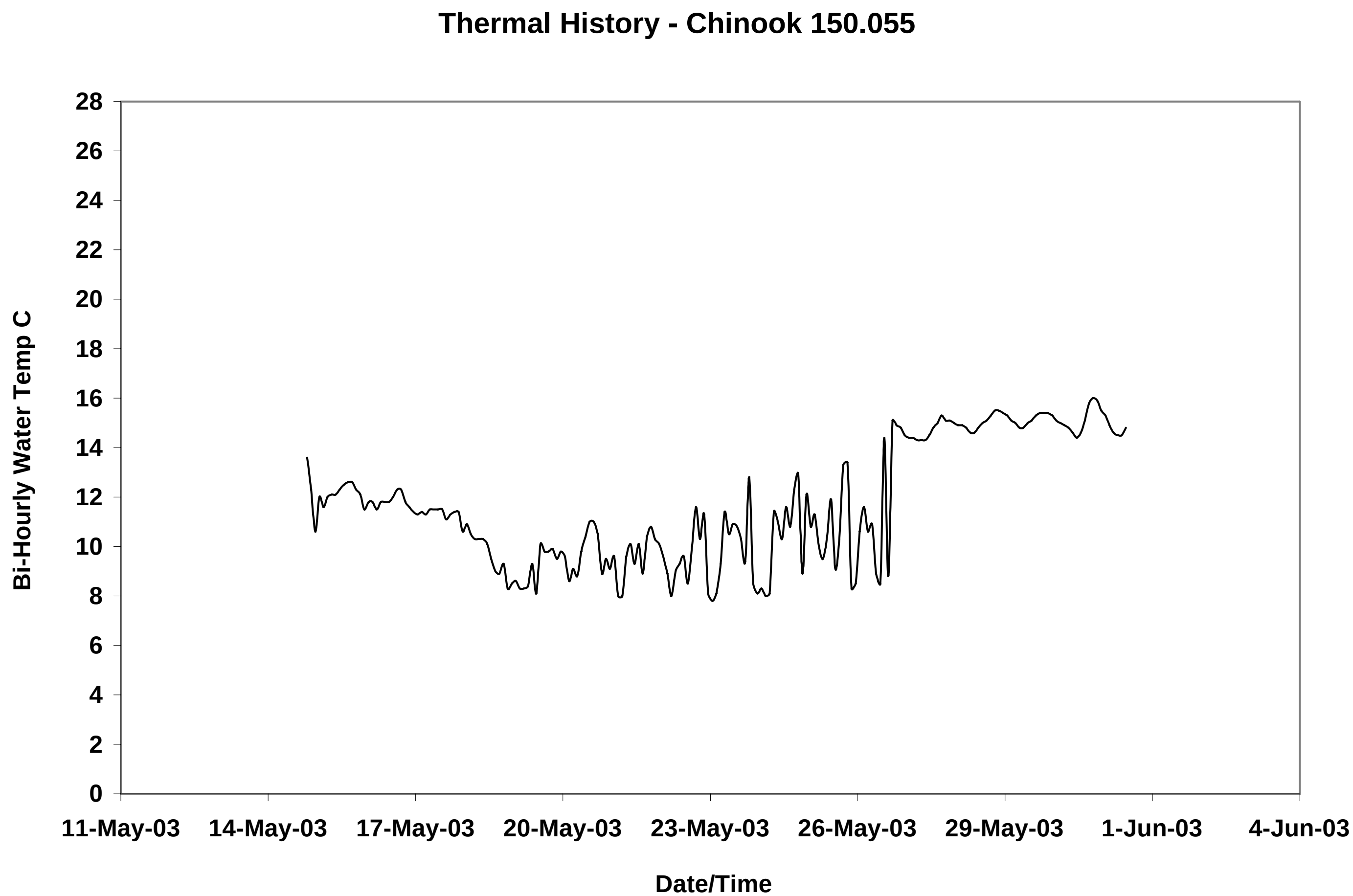

Figure 18. External water temperatures experienced by Chinook 150.055 during its migration in the lower Klamath River. This Chinook migrated upriver from the estuary on approximately 5/27/2003 and was caught in the Trinity River at Weitchpec on 5/31/2003.

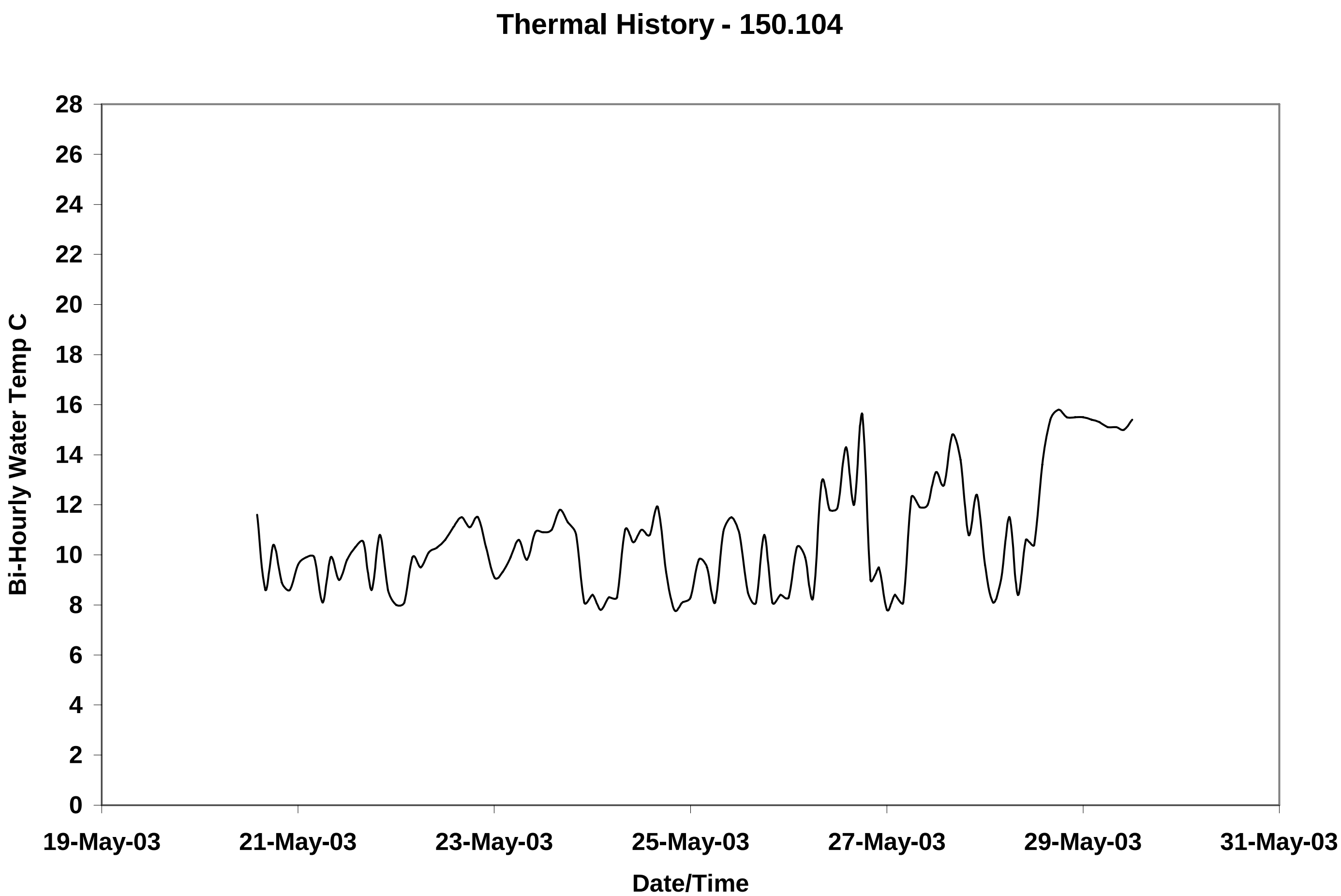

Figure 19. External water temperatures experienced by Chinook 150.104 during its migration in the lower Klamath River. This Chinook was caught at RKM 16.5 on 5/29/2003.

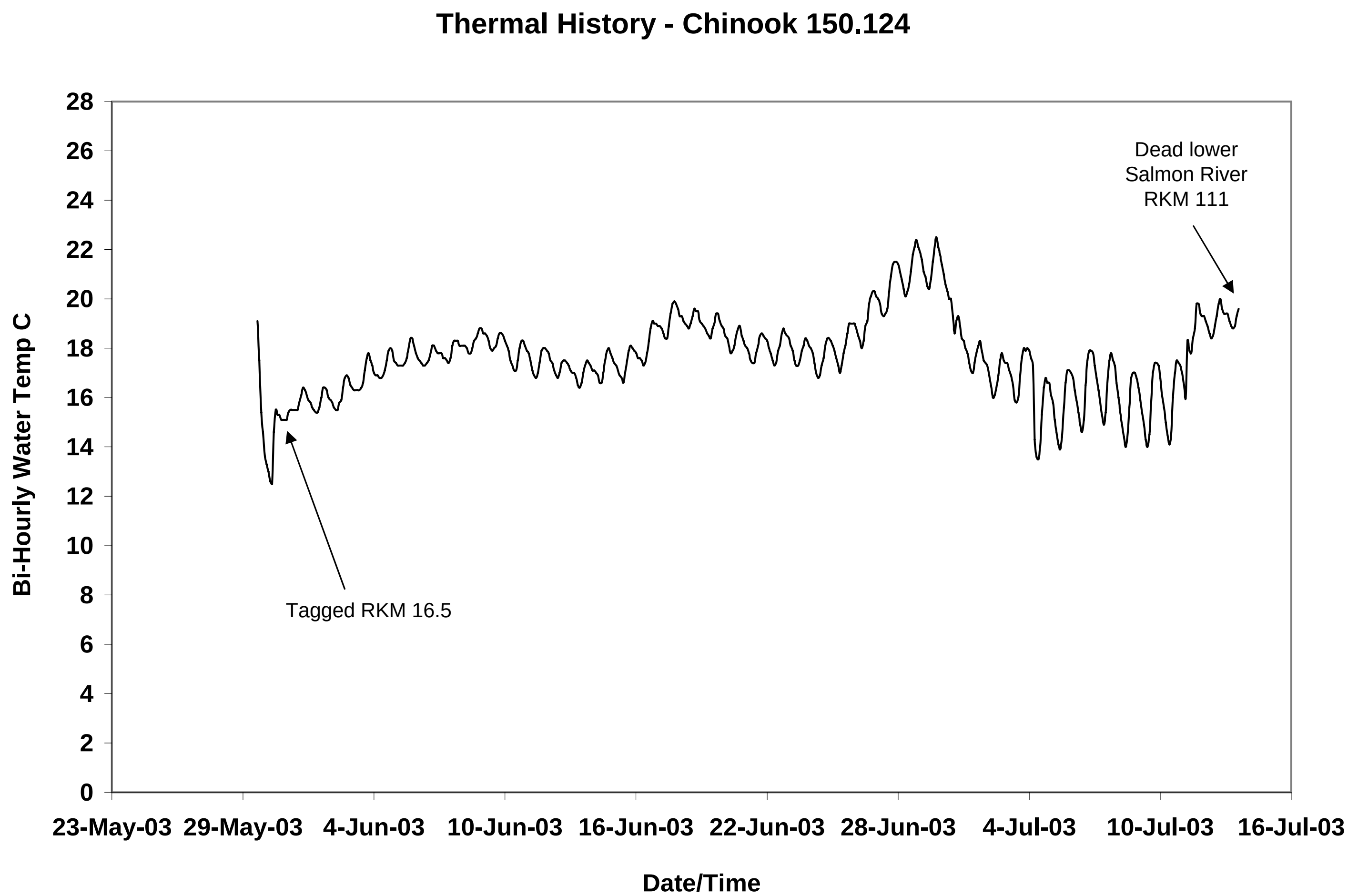

Figure 20. External water temperatures experienced by Chinook 150.124 during its migration in the lower Klamath and Salmon Rivers. This Chinook died of unknown causes.

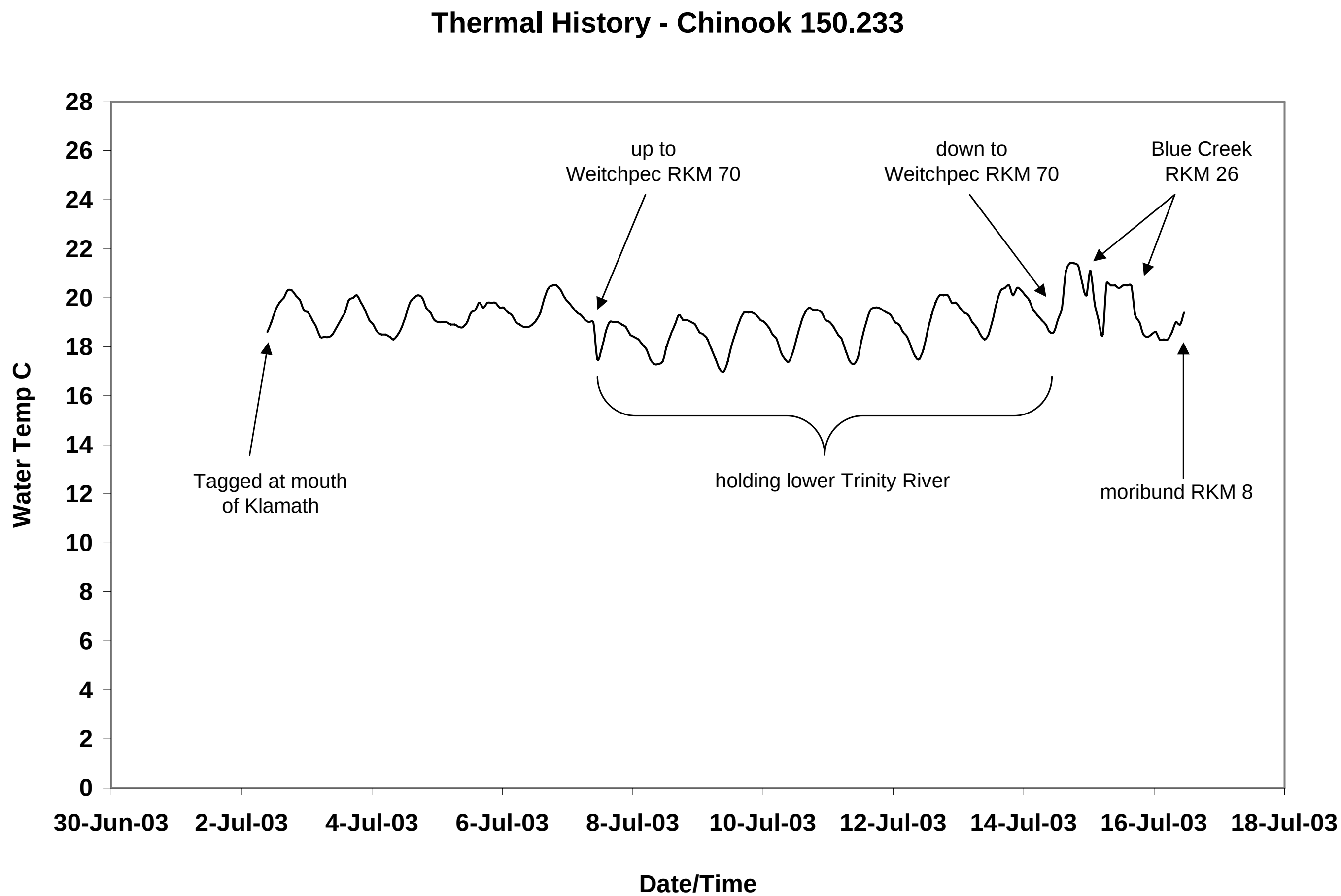

Figure 21. External water temperatures experienced by Chinook 150.233 during its migration in the lower Klamath and Trinity Rivers. This Chinook was found swimming aimlessly downriver at RKM 8 in a moribund state. Other than cloudy eyes there were no obvious symptoms of disease.

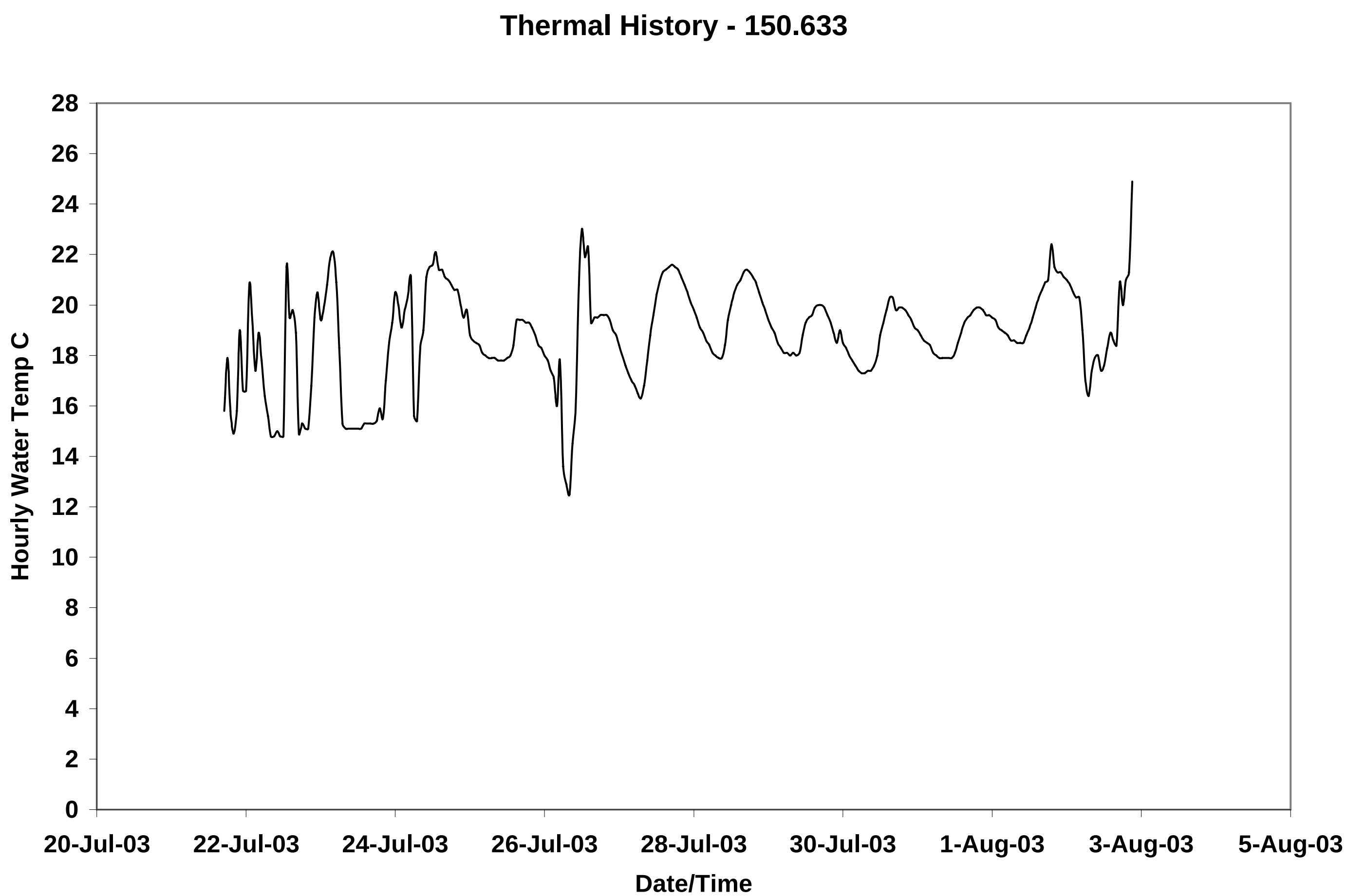

Figure 22. External water temperatures experienced by Chinook 150.633 during its residence in the Klamath River estuary where it was caught.

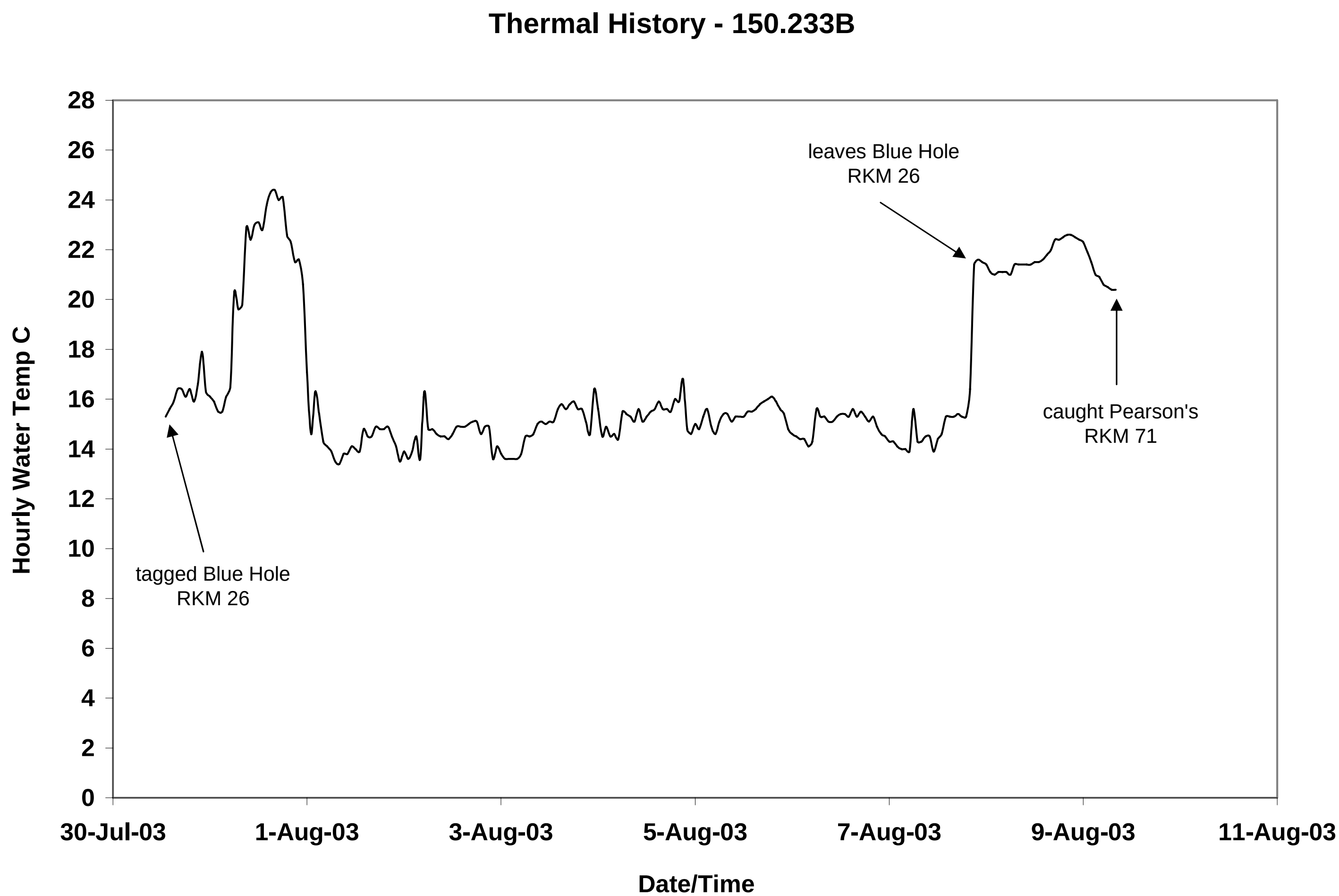

Figure 23. External water temperatures experienced by Chinook 150.233B during its migration in the lower Klamath and Trinity Rivers.

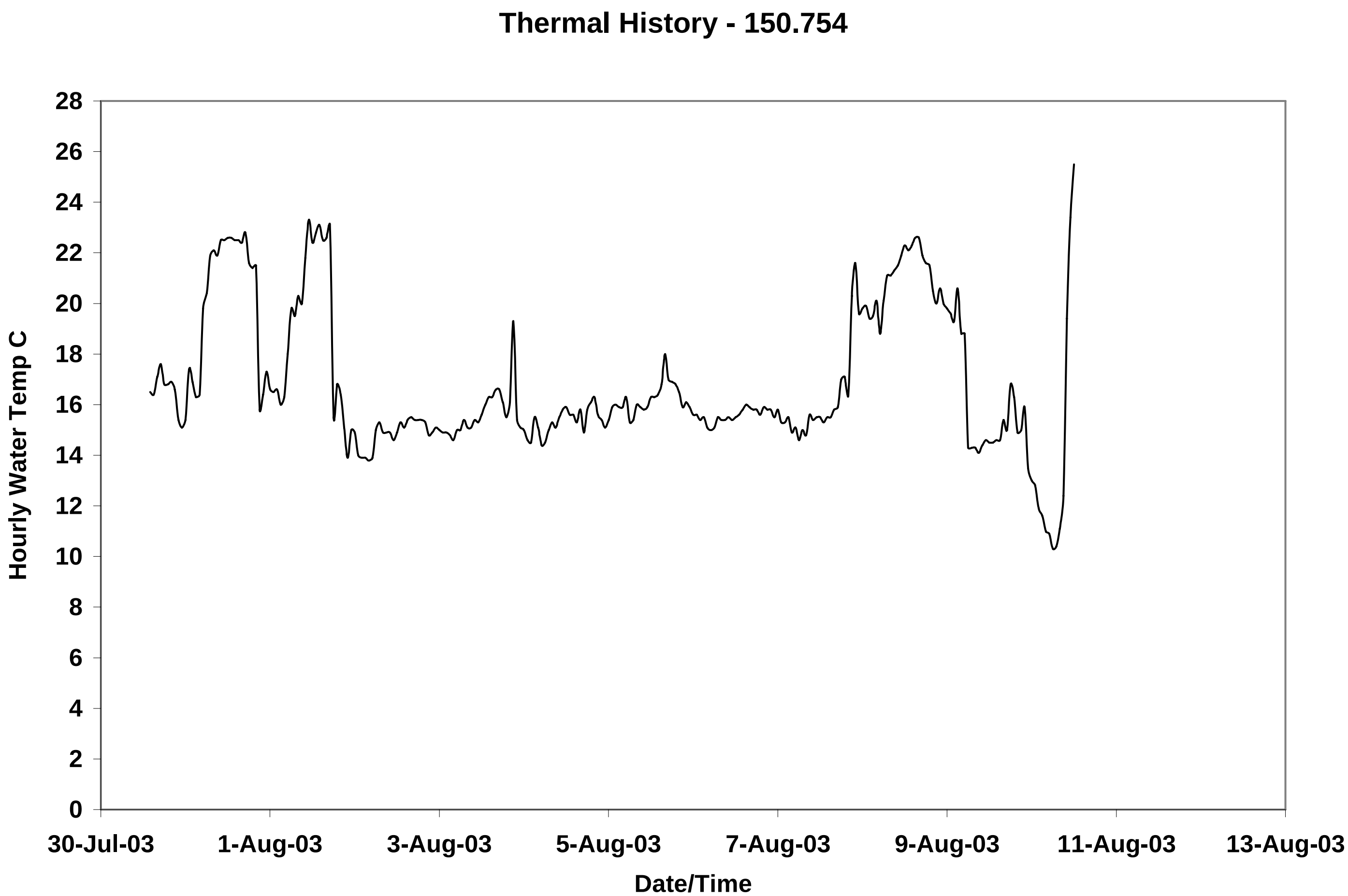

Figure 24. External water temperatures experienced by Chinook 150.233 during its residence in vicinity of the Blue Hole refuge, from where it was caught on 8/10/2003.

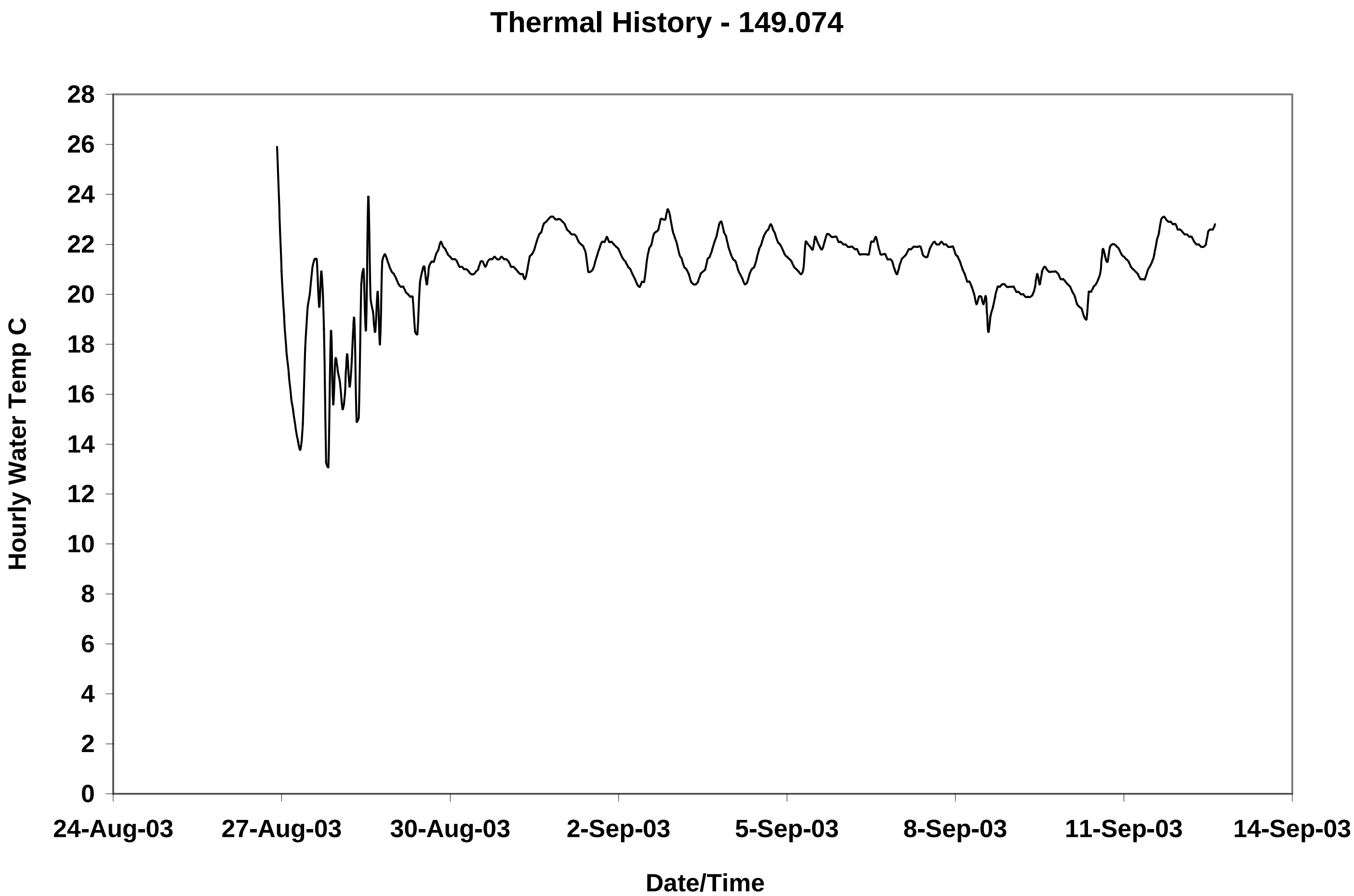

Figure 25. External water temperatures experienced by Chinook 149.074 during its migration in the lower Klamath River where it was caught somewhere within the lower 20km.

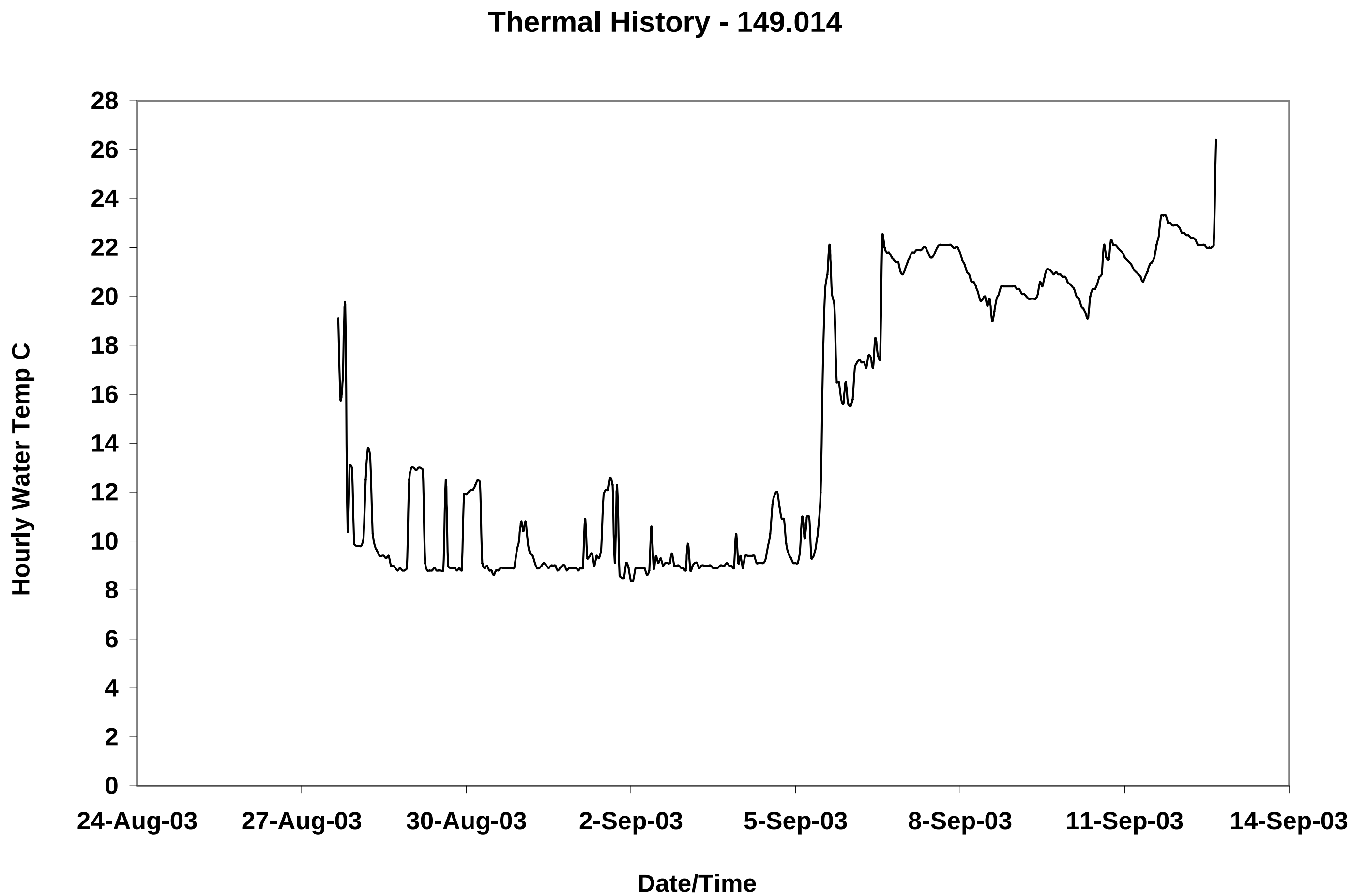

Figure 26. External water temperatures experienced by Chinook 149.014 during its residence in the Klamath River estuary where it was caught.

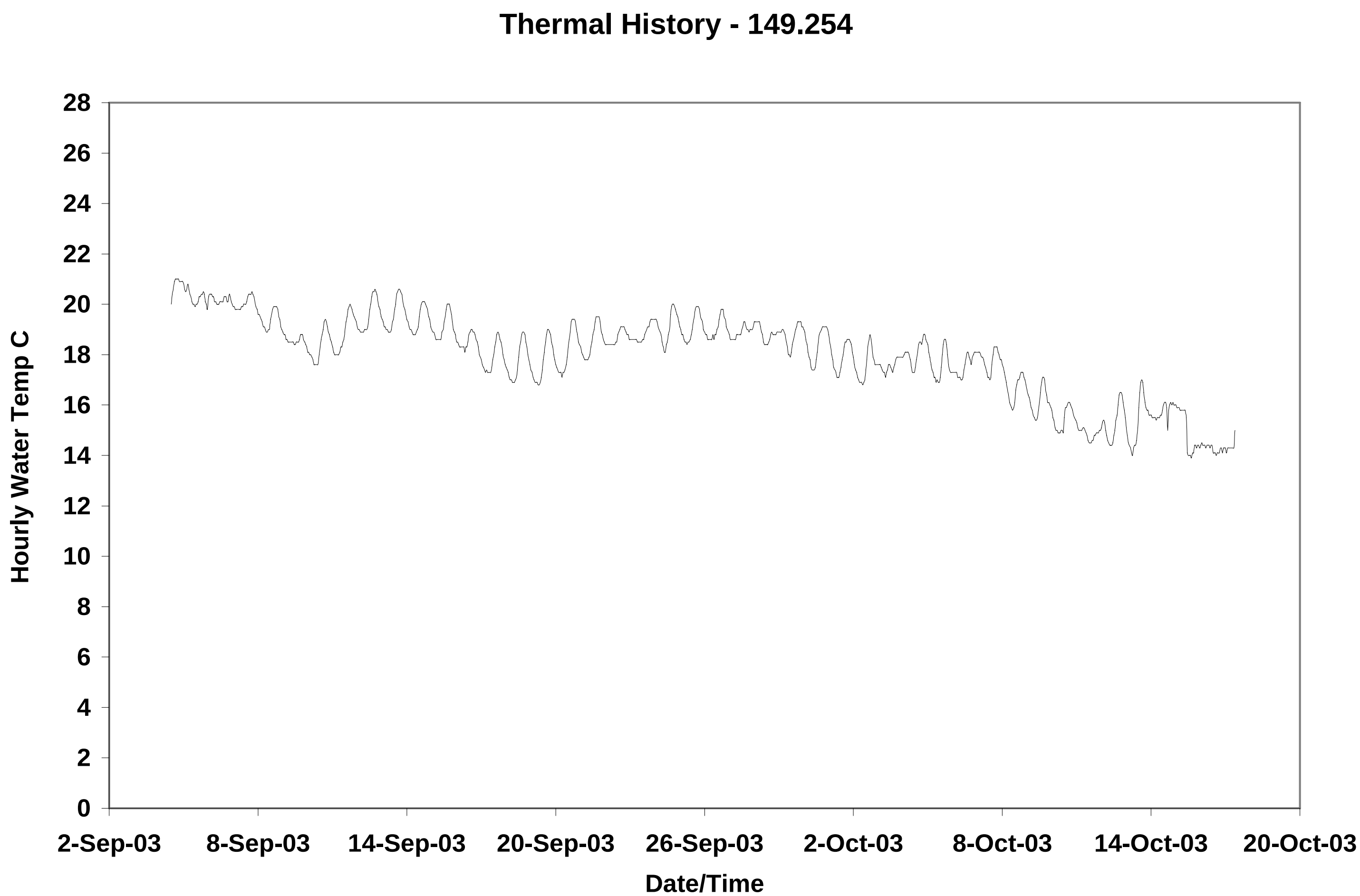

Figure 27. External water temperatures experienced by Chinook 149.254 during its migration in the Klamath River, a typical example of this migrant group. This Chinook was spawned at Iron Gate Hatchery on 10/17/2003.

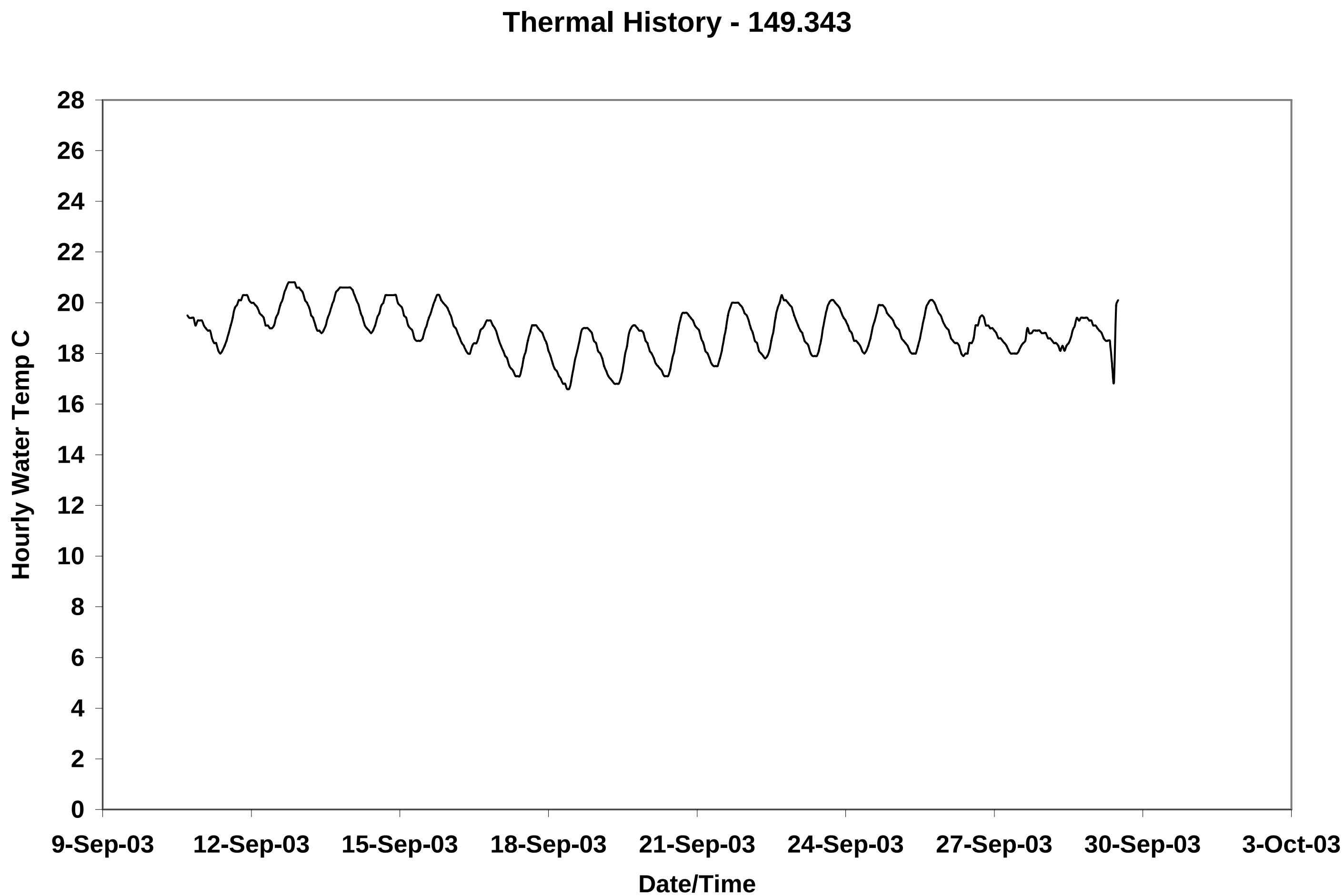

Figure 28. External water temperatures experienced by Chinook 149.343 during its migration in the lower Klamath River. The tag was found at RKM 15.

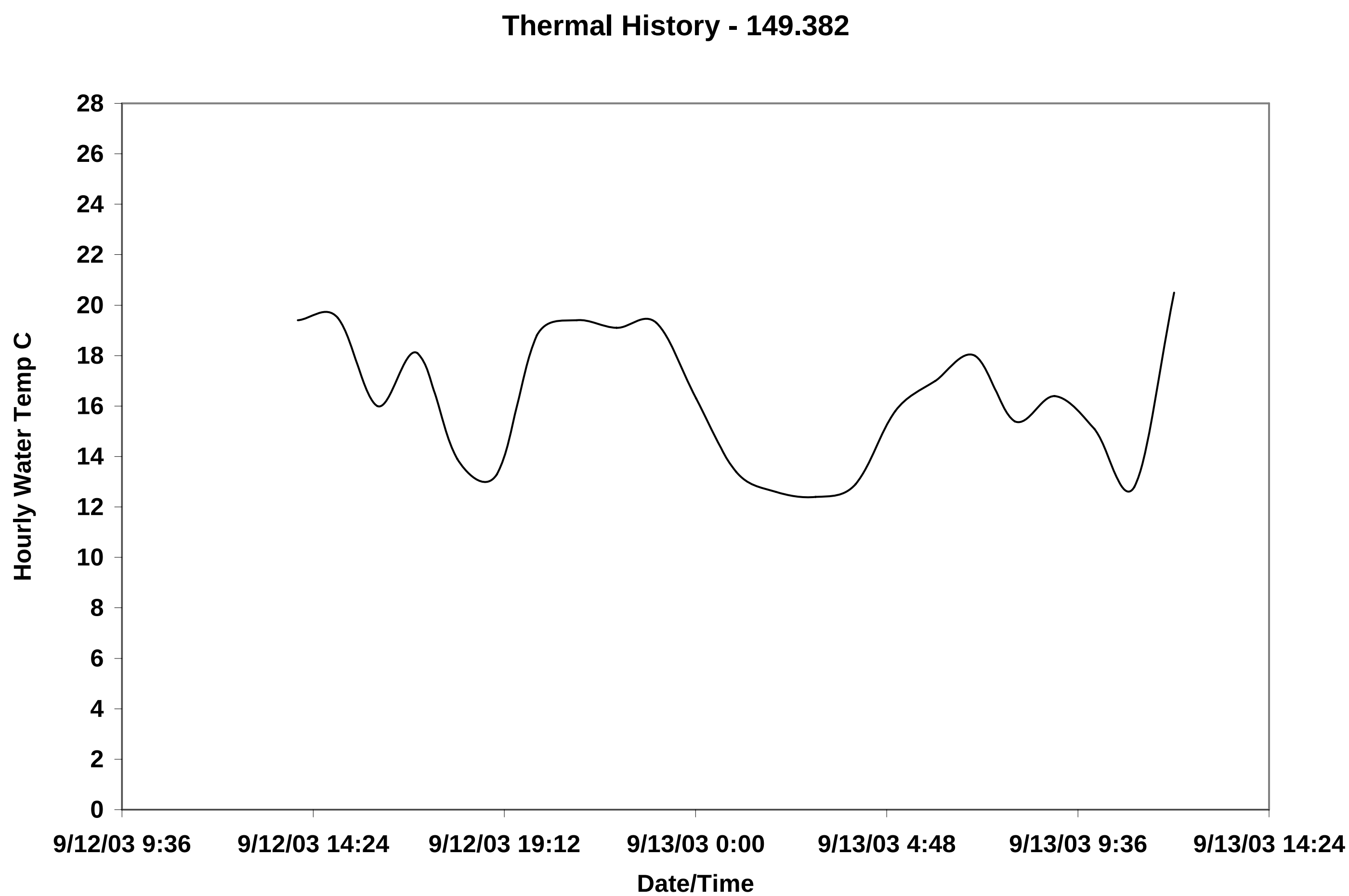

Figure 29. External water temperatures experienced by Chinook 149.382 during its residence in the Klamath River estuary, where it was caught.

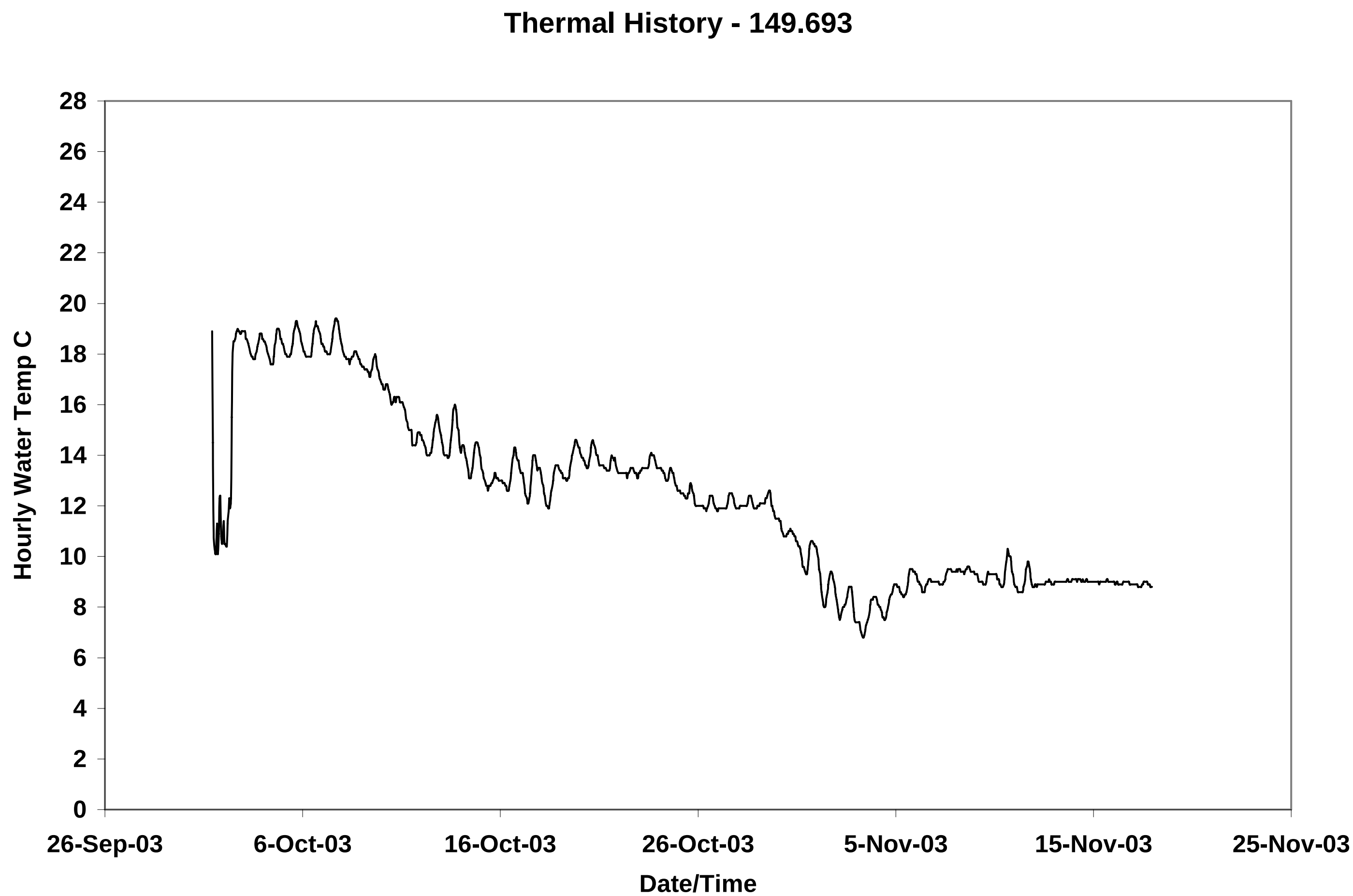

Figure 30. External water temperatures experienced by Chinook 149.693 during its migration in the lower Klamath and Trinity Rivers. This Chinook was spawned at the Trinity River Hatchery on 11/17/2003.

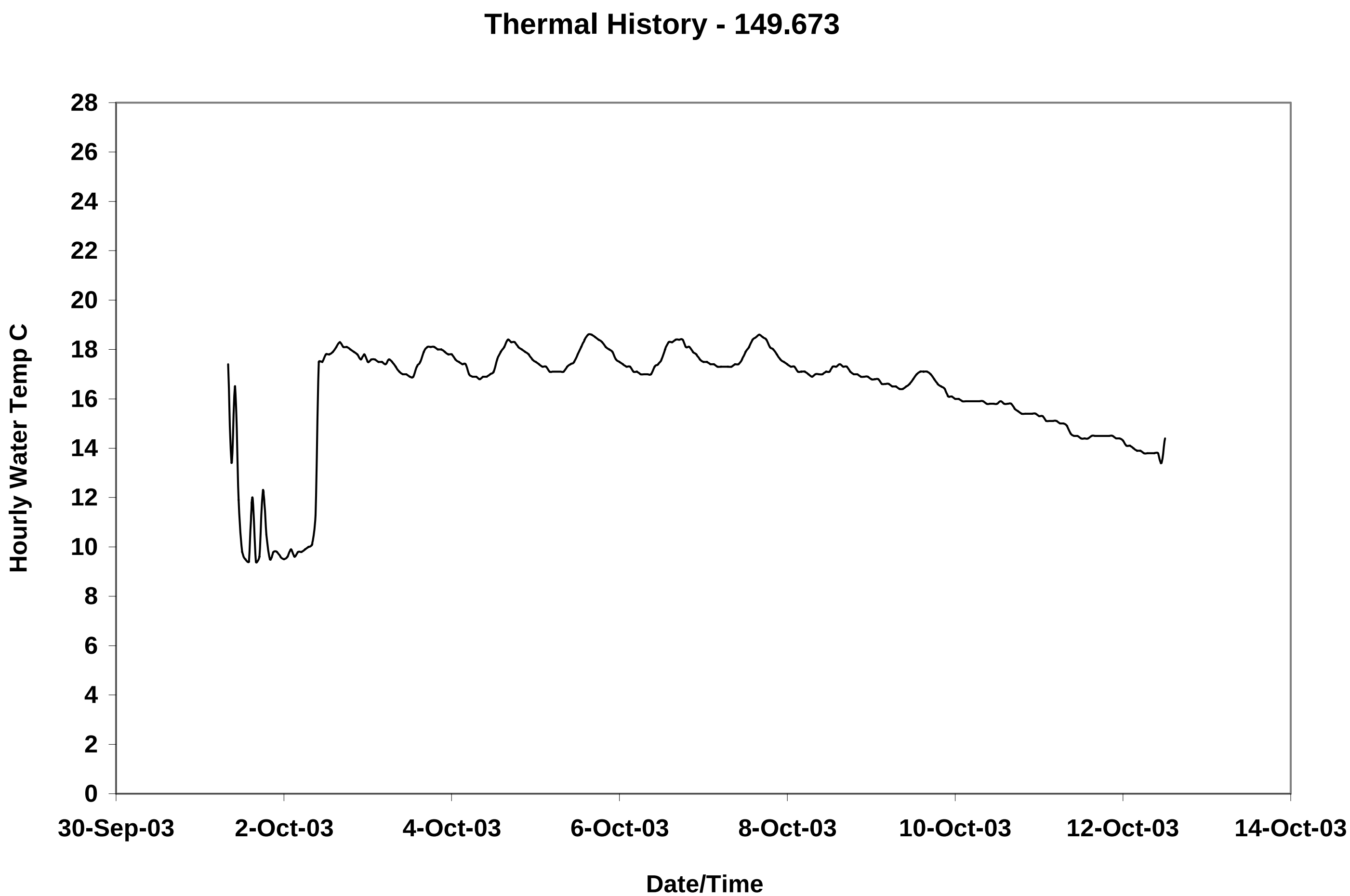

Figure 31. External water temperatures experienced by Chinook 149.673 during its migration in the lower Klamath and Trinity Rivers. This Chinook was caught in the Trinity River at Weitchpec on 10/13/2003.

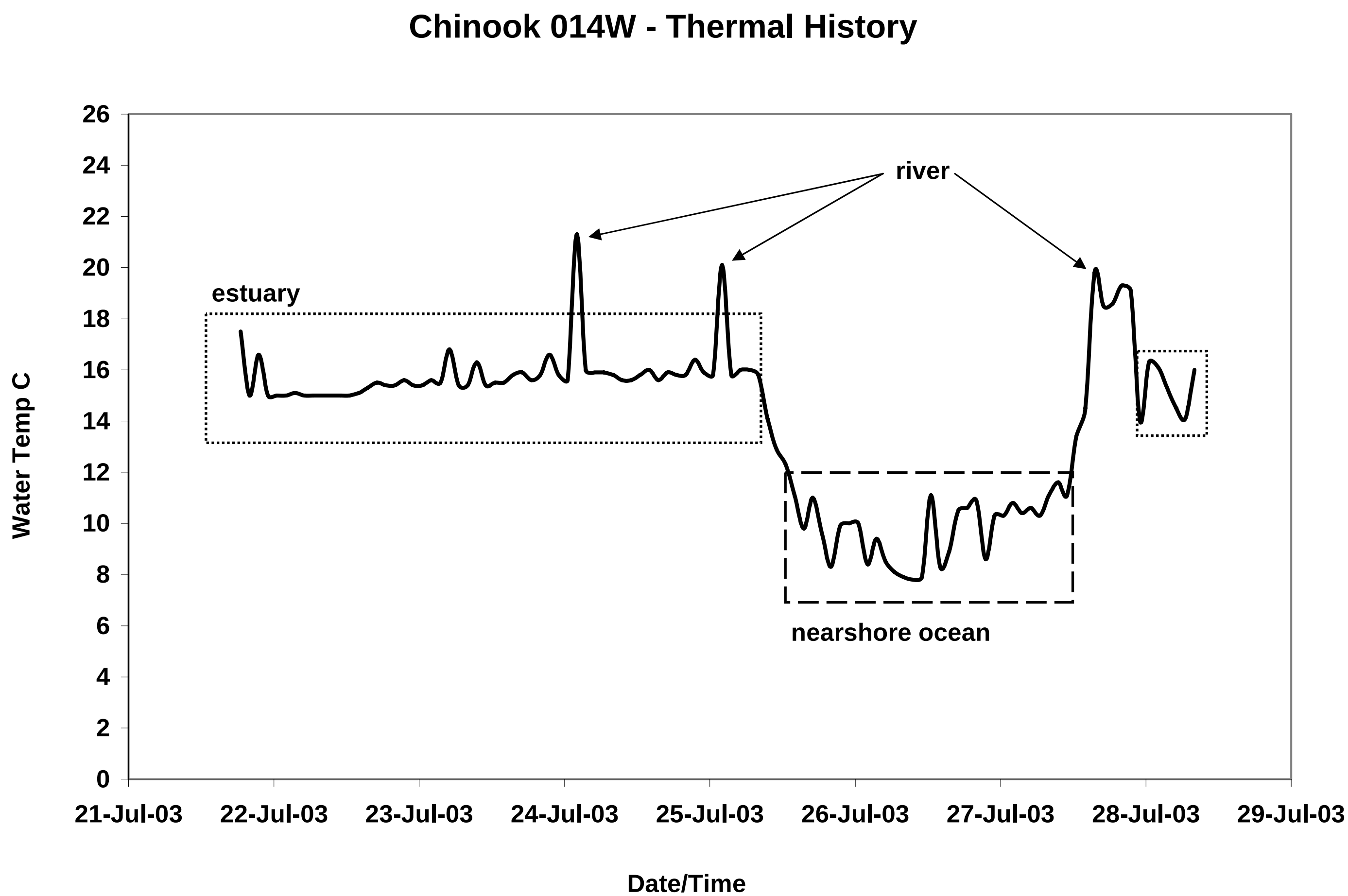

Figure 32. Thermal history for a Chinook tagged in late July at the mouth pf the Klamath River showing the distinct thermal signatures of the riverine freshwater layer, estuarine salt wedge, and nearshore ocean. Estuaries offer numerous challenges, such as predation and osmotic regulation, and benefits, such as behavioral thermoregulation, to staging adult Chinook.

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APPENDIX 1

Tagging data and final known fates or last observations for all 120 adult Chinook tagged in 2003. Bold typed designated tagged Chinook that emerged from or were caught in the estuary. Abbreviations: gn=gill net; MIA=missing in action, disappeared; mort=mortality; obs.=observation; TRH=Trinity River Hatchery; IGD= Iron Gate Dam; IGH=Iron Gate Hatchery.

Tagging Date	Tagging Location	Tag Frequency	Disc Tag #	Disc Color	Fork L cm	Fate/Last Observation	Archival Data
8-May	Mouth	150.002	1	Y	80	MIA nearshore/estuary	N
8-May	Mouth	150.013	2	Y	87	MIA nearshore/estuary	N
8-May	Mouth	150.023	3	Y	73	MIA nearshore/estuary	N
9-May	Mouth	150.034	4	Y	73	MIA nearshore/estuary	N
9-May	**Mouth**	**150.044**	**5**	**Y**	**77**	**spawned out Lewiston**	**N**
14-May	**Mouth**	**150.055**	**6**	**Y**	**93**	**caught gn 5/31 above Smokers**	**Y**
14-May	**Mouth**	**150.064**	**7**	**Y**	**74**	**spawned out near Douglas City**	**N**
15-May	Mouth	150.074	8	Y	81	MIA nearshore/estuary	N
15-May	**Mouth**	**150.084**	**9**	**Y**	**89**	**dead below Grays Falls**	**N**
20-May	Mouth	150.094	10	Y	77	MIA nearshore/estuary	N
20-May	**Mouth**	**150.104**	**11**	**Y**	**71**	**caught gn McCovey's**	**Y**
23-May	**Mouth**	**150.114**	**12**	**Y**	**74**	**dead at lower Salmon**	**N**
30-May	**RKM 16.5**	**150.124**	**13**	**Y**	**78**	**dead at lower Salmon**	**Y**
30-May	**RKM 20**	**150.104B**	**14**	**Y**	**76**	**dead below Salyer**	**N**
30-May	RKM 20	150.134	15	Y	73	MIA nearshore/estuary	N
30-May	RKM 20	150.145	16	Y	73	MIA nearshore/estuary	N
4-Jun	Mouth	150.155	17	Y	69	MIA nearshore/estuary	N
4-Jun	**Mouth**	**150.163**	**18**	**Y**	**67**	**dead below Tunnel Flat**	**N**
5-Jun	Mouth	150.173	19	Y	92	MIA nearshore/estuary	N
5-Jun	Mouth	150.183	20	Y	83	MIA nearshore/estuary	N
10-Jun	Mouth	150.194	21	Y	71	MIA nearshore/estuary	N
10-Jun	Mouth	150.203	22	Y	73	MIA nearshore/estuary	N
11-Jun	Mouth	150.213	23	Y	69	MIA nearshore/estuary	N
20-Jun	**Mouth**	**150.224**	**24**	**Y**	**70**	**caught gn 6/22 at Starwin**	**Y**
2-Jul	**Mouth**	**150.233**	**25**	**Y**	**67**	**dead at Wakel from Hoopa**	**Y**
2-Jul	**Mouth**	**150.243**	**26**	**Y**	**88**	**caught gn 7/2 @ 101 Bluffs**	**Y**
2-Jul	**Mouth**	**150.253**	**27**	**Y**	**68**	**spawned Nordhiemer 10/29**	**N**
2-Jul	**Mouth**	**150.263**	**28**	**Y**	**79**	**dead at New River confluence**	**N**
9-Jul	Mouth	150.272	29	Y	73	MIA nearshore/estuary	N
9-Jul	**Mouth**	**150.285**	**30**	**Y**	**86**	**spit out tag in lips**	**N**
10-Jul	Mouth	150.293	31	Y	84	MIA nearshore/estuary	N
16-Jul	Mouth	150.285B	32	Y	69	MIA nearshore/estuary	N
16-Jul	Mouth	150.055B	33	Y	83	MIA nearshore/estuary	N
21-Jul	Mouth	150.114B	34	Y	92	MIA nearshore/estuary	N
21-Jul	**Mouth**	**150.633**	**35**	**Y**	**80**	**caught lips hook/line**	**Y**
21-Jul	**Mouth**	**150.655**	**36**	**Y**	**74**	**found at Hunter Island**	**N**
30-Jul	**Blue Hole**	**150.233B**	**37**	**Y**	**71**	**caught gn at Pearson's 8/9**	**Y**
30-Jul	**Blue Hole**	**150.674**	**38**	**Y**	**91**	**MIA Steel Bridge - caught?**	**N**
30-Jul	**Blue Hole**	**150.684**	**39**	**Y**	**66**	**spawned at TRH**	**N**

30-Jul	**Blue Hole**	**150.694**	**40**	**Y**	**73**	**tag found at Ah Pah**	**N**
30-Jul	**Blue Hole**	**150.702**	**41**	**Y**	**83**	**tag found at Glen dock**	**N**
30-Jul	**Blue Hole**	**150.714**	**42**	**Y**	**71**	**caught Piegon Point**	**N**
30-Jul	**Blue Hole**	**150.724**	**43**	**Y**	**69**	**tagging mort, MIA below Wakel**	**N**
30-Jul	**Blue Hole**	**150.732**	**44**	**Y**	**94**	**dead at Aubrey Creek - Klamath**	**N**
30-Jul	**Blue Hole**	**150.743**	**45**	**Y**	**75**	**tagging mort**	**Y**
30-Jul	**Blue Hole**	**150.754**	**46**	**Y**	**86**	**caught Blue Creek 8/10**	**Y**
30-Jul	**Blue Hole**	**150.775**	**47**	**Y**	**63**	**caught Junction City**	**N**
20-Aug	Mouth	150.702B	49	Y	84	MIA nearshore/estuary	N
20-Aug	Mouth	150.694B	50	Y	77	MIA nearshore/estuary	N
20-Aug	Mouth	150.633B	51	Y	86	MIA nearshore/estuary	N
20-Aug	**Mouth**	**150.743**	**52**	**Y**	**70**	**spawned in Bogus Cr 10/15**	**N**
21-Aug	Mouth	150.793	53	Y	75	MIA nearshore/estuary	N
21-Aug	Mouth	150.813	54	Y	72	MIA nearshore/estuary	N
21-Aug	Mouth	150.655B	56	Y	73	MIA nearshore/estuary	N
22-Aug	**Blue Hole**	**149.023**	**3**	**G**	**67**	**Lewiston Dam 10/22**	**N**
22-Aug	**Blue Hole**	**149.105**	**9**	**G**	**78**	**spawned IGH 10/15**	**N**
26-Aug	Mouth	149.014	20	W	74	MIA	Y
26-Aug	Mouth	149.033	21	W	76	MIA nearshore/estuary	N
26-Aug	Mouth	149.053	22	W	74	MIA nearshore/estuary	N
26-Aug	**Mouth**	**149.074**	**23**	**W**	**85**	**caught estuary**	**Y**
26-Aug	Mouth	148.984	54	Y	76	MIA nearshore/estuary	N
26-Aug	**Mouth**	**148.953**	**57**	**Y**	**74**	**MIA above Horse Linto**	**N**
29-Aug	**Blue Hole**	**149.142**	**12**	**G**	**82**	**caught Ishi Pishi Falls**	**N**
29-Aug	Blue Hole	149.223	13	G	93	MIA nearshore/estuary	N
3-Sep	**Mouth**	**149.114**	**24**	**W**	**64**	**caught estuary**	**Y**
3-Sep	**Mouth**	**149.093**	**25**	**W**	**77**	**last obs. at Bluff 9/11**	**N**
3-Sep	Mouth	149.193	26	W	67	MIA nearshore/estuary	N
3-Sep	**Mouth**	**149.153**	**60**	**Y**	**81**	**China Point 9/24**	**N**
3-Sep	Mouth	149.174	63	Y	71	MIA nearshore/estuary	N
3-Sep	Mouth	149.213	65	Y	71	MIA nearshore/estuary	N
3-Sep	**Mouth**	**149.234**	**66**	**Y**	**73**	**caught**	**Y**
4-Sep	**Mouth**	**149.272**	**60**	**Y**	**77**	**MIA lower Klamath**	**N**
4-Sep	**Mouth**	**149.254**	**68**	**Y**	**67**	**spawned at IGH 10/17**	**Y**
4-Sep	**Mouth**	**149.293**	**69**	**Y**	**73**	**spawned below IGD 11/12**	**N**
4-Sep	Mouth	149.234	70	Y	71	MIA nearshore/estuary	N
4-Sep	Mouth	149.114B	71	Y	78	MIA nearshore/estuary	N
10-Sep	Estuary	149.323	14	G	68	MIA nearshore/estuary	N
10-Sep	Estuary	149.243	16	G	69	MIA nearshore/estuary	N
10-Sep	**Estuary**	**149.203**	**18**	**G**	**53**	**MIA Lower Klamath**	**N**
10-Sep	**Estuary**	**149.343**	**20**	**G**	**97**	**dead at Starwin 10/17**	**Y**
10-Sep	**Estuary**	**149.264**	**25**	**G**	**60**	**dead at Independence 11/14**	**N**
10-Sep	Estuary	149.163	25	G	69	MIA nearshore/estuary	N
10-Sep	**Estuary**	**149.282**	**26**	**G**	**87**	**up Shasta River 11/7**	**N**
11-Sep	Mouth	149.312	64	Y	80	MIA nearshore/estuary	N
11-Sep	Mouth	149.353	72	Y	91	MIA nearshore/estuary	N
11-Sep	Mouth	149.372	73	Y	64	MIA nearshore/estuary	N
11-Sep	**Mouth**	**149.392**	**74**	**Y**	**76**	**last obs. Del Loma 10/27**	**N**

11-Sep	Mouth	149.334	75	Y	74	MIA nearshore/estuary	N
11-Sep	Mouth	149.413	76	Y	86	MIA nearshore/estuary	N
11-Sep	Mouth	149.433	77	Y	73	MIA nearshore/estuary	N
11-Sep	Mouth	149.453	78	Y	77	MIA nearshore/estuary	N
11-Sep	**Mouth**	**149.475**	**80**	**Y**	**80**	**caught**	**Y**
12-Sep	**Estuary**	**149.422**	**1**	**G**	**65**	**dead at Wakel 10/17**	**N**
12-Sep	Estuary	149.442	2	G	63	MIA nearshore/estuary	N
12-Sep	Estuary	149.484	3	G	73	MIA nearshore/estuary	N
12-Sep	**Estuary**	**149.463**	**4**	**G**	**67**	**spawned in Lewiston 11/17**	**N**
12-Sep	**Estuary**	**149.403**	**24**	**G**	**65**	**last obs. Burnt Ranch 10/27**	**N**
12-Sep	**Estuary**	**149.382**	**28**	**G**	**77**	**caught estuary**	**Y**
12-Sep	Estuary	149.363	29	G	66	MIA nearshore/estuary	N
17-Sep	Mouth	149.523	74	G	74	MIA nearshore/estuary	N
17-Sep	Mouth	149.546	76	G	76	MIA nearshore/estuary	N
17-Sep	**Mouth**	**150.775B**	**79**	**Y**	**90**	**last obs. Horse Linto 11/18**	**N**
17-Sep	**Mouth**	**150.714B**	**82**	**Y**	**82**	**last obs. Grays Falls 10/10**	**N**
18-Sep	**Mouth**	**149.302**	**1**	**G**	**72**	**caught**	**Y**
18-Sep	Mouth	149.504	11	G	81	MIA nearshore/estuary	N
18-Sep	**Mouth**	**149.133**	**82**	**Y**	**67**	**tag found near AhPah**	**N**
18-Sep	Mouth	149.014B	83	Y	86	MIA	N
24-Sep	Mouth	149.594	1	O	71	MIA nearshore/estuary	N
24-Sep	Mouth	149.613	2	O	68	MIA nearshore/estuary	N
24-Sep	Mouth	149.633	3	O	72	MIA nearshore/estuary	N
24-Sep	**Mouth**	**149.564**	**10**	**G**	**72**	**spawned TRH 11/13**	**N**
24-Sep	**Mouth**	**149.583**	**15**	**G**	**74**	**spawned TRH 11/12**	**N**
24-Sep	**Mouth**	**149.494**	**84**	**Y**	**72**	**last obs. Shasta R. Station 11/1**	**N**
24-Sep	Mouth	149.514	85	Y	75	MIA nearshore/estuary	N
24-Sep	Mouth	149.534	86	Y	84	MIA nearshore/estuary	N
24-Sep	Mouth	149.554	87	Y	80	MIA nearshore/estuary	N
24-Sep	**Mouth**	**149.571**	**88**	**Y**	**78**	**last obs. Salyer 11/6**	**N**
1-Oct	**Mouth**	**149.673**	**89**	**Y**	**81**	**caught Weitchpec sport 10/14**	**Y**
1-Oct	**Mouth**	**149.693**	**iBCod**	**NA**	**72**	**spawned below TRH 11/17**	**Y**
8-Oct	Mouth	149.714	90	Y	61	MIA nearshore/estuary	N