Adult Chinook Migration in the Klamath River Basin:

2004 Radio Telemetry Study Report


Adult spring Chinook at the Bluff Creek thermal refuge. Photo by author.

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Releasing a tagged Chinook at Blue Hole. Photo by Michael Belchik.

EXECUTIVE SUMMARY

The strength of future salmon runs depends on successful completion of all phases of their life cycle, including the riverine spawning migration phase. The degree to which adult salmon are able to successfully migrate to their spawning grounds and the condition they arrive in directly impacts reproductive success, and ultimately, the maintenance and recovery of stocks such as Klamath River Basin (KRB) Chinook salmon (*Oncorhynchus tshawytscha*).

High water temperatures, low flows, prespawning mortalities, and observations of adult Chinook using enroute thermal refuges led a pilot radio telemetry study of adult Chinook migration in the KRB by the Yurok Tribal Fisheries Program (YTFP) in the spring and early summer of 2002. In September of that year a large scale disease outbreak (*Ichthyopthirius multifilis* (*Ich*) and *Flavobacter columnare*) occurred in the lower Klamath River killing an estimated 32,533 to 65,066 adult Chinook. This added urgency to this study and increased the need to evaluate migration behavior and environmental conditions in relation to pathogen transmission, thus the collaborative 2003 radio telemetry study included fall Chinook and an expanded sample size. In 2004, this study effort continued using a refined version of the 2003 methodology and relied on temperature sensitive esophageal radio transmitters coupled with archival temperature tags along with mobile manual tracking and stationary receivers to determine the movements and body temperatures of migrating adult Chinook. The overarching goal of this ongoing collaborative research project is to comprehensively determine and understand adult Chinook migration behavior in the KRB throughout the spectrum of run-timing; specific components include determining run-timing, estuary residence, travel rates, thermal refuge use, thermal experience, migration patterns, and behavioral responses to environmental variables such as water temperature and river flow.

During 2004 a total of 95 adult Chinook were tagged; 92 at the mouth of the Klamath River from 5/21/04 to 10/22/04 and three at the Blue Creek thermal refuge on 8/18/04. Data from 28 archival temperature tags was successfully recovered. A total of 25 tagged Chinook (termed migrants) survived to migrate past the confluence of the Klamath and Trinity Rivers at Weitchpec, and four distinct groups or runs emerged based on run-timing, migration behavior, and destinations: spring Chinook (*n*=3), summer Chinook (*n*=7), Klamath fall Chinook (*n*=10), and Trinity fall Chinook (*n*=5).

Spring Chinook migrants were tagged from 6/3/04 to 6/14/04 with a mean estuary/nearshore ocean residence of 11.7 days. Spring migrants traveled relatively rapidly and steadily into the Trinity River during the descending limb of the natural snowmelt peak, during the spring bench release from Lewiston Dam, and with rising water temperatures that were below mean daily temperatures (MDTs) of 22.0ºC. No use of enroute thermal refuges was documented with the exception of brief use (defined as <24 hours) of the Blue Creek refuge by one spring migrant, and the mean thermal experience (defined as body temperatures from tagging to arrival on pre-spawning holding areas or spawning grounds) of a typical spring migrant was 14.6ºC with a maximum of 20.0ºC. One spring Chinook migrant died attempting to pass through the high gradient Burnt Ranch Gorge of the Trinity River and the other two were harvested in the upper Trinity River.

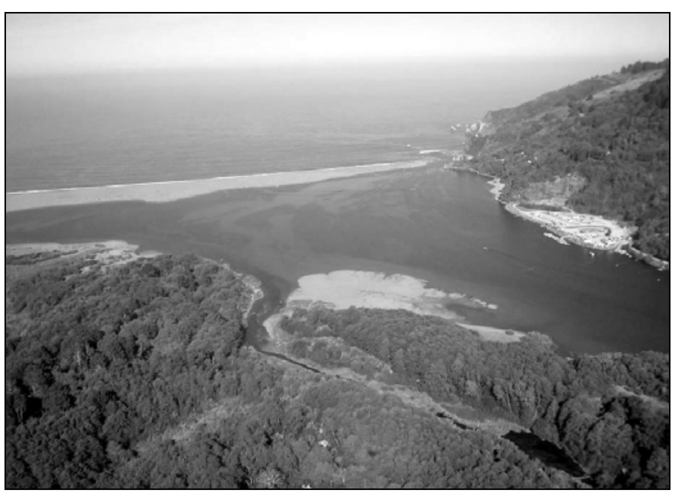
Summer Chinook migrants were tagged from 7/9/04 to 7/26/04 in the estuary, with one migrant tagged at Blue Creek on 8/18/04. Mean estuary/nearshore ocean residence was 13.9 days. Summer migrants entered the river after the onset of summer base flows and MDTs ≥22.0ºC, and initiated upriver migration in response to a brief (several days) weather-induced cooling event during the first week of August (with the exception of the migrant tagged at Blue Creek), thereafter traveling at the fastest rates observed for any migrants in 2004. Summer migrants largely passed by enroute thermal refuges but three of these migrants were documented briefly using thermal refuges at creek confluences in the lower Trinity River. The resulting mean thermal experience for a typical summer migrant was 16.6ºC with a maximum of 24.4ºC. Two summer migrants were caught in Hoopa, three likely spawned in the upper Trinity River, and two were spawned as 'spring' Chinook at the Trinity River Hatchery.

Klamath fall migrants were tagged from 8/16/04 to 9/6/04 with the exception of one migrant tagged on 10/1/04. Mean estuary/ nearshore ocean residence was 9.7 days. The majority of Klamath fall migrants were tagged when MDTs were still ≥22.0ºC with initiation of upriver migration occurring as soon as a MDTs dropped below this threshold; prior to the arrival of the Trinity fall pulse flow or as late as 10/1/04. Thus initiation of upriver migration occurred both before, during, and after the Trinity fall pulse flow. Once upriver migration had been initiated, Klamath fall migrants exhibited the slowest travel rates through the lower Klamath River of all migrants in 2004, with periods of extended holding in deep pools between Blue Creek and Weitchpec. Once passing Weitchpec, travel rates increased on average by approximately 260% with steady travel to spawning areas in the upper Klamath River. No enroute use of thermal refuges was documented other than brief use of Blue Creek by two of these migrants. The mean thermal experience for a typical Klamath fall migrant was 18.8ºC with a maximum of 24.0ºC. One Klamath fall migrant spawned in Bogus Creek, three or four were spawned at Iron Gate Hatchery, four or five likely spawned naturally between the Scott River confluence and Iron Gate Dam, and one died enroute.

Trinity fall migrants were tagged from 9/16/04 to 9/22/04 and on 10/22/04 with a mean estuary/nearshore ocean residence of 3.0 days. Travel rates were relatively slow through the lower Klamath River with at least one Trinity fall migrant displaying the same type of extended holding as Klamath fall migrants. No use of enroute thermal refuges was documented with the exception of brief use of the Blue Creek refuge by one migrant, and the mean thermal experience of a typical Trinity fall migrant was 14.5ºC with a maximum of 18.8ºC. One Trinity fall migrant was harvested in Hoopa, one was last observed in Burnt Ranch Gorge, and three likely spawned naturally in the upper Trinity River.

The fates and destinations of tagged adult Chinook matched run-timing, harvest, and escapement data for the entire 2004 Chinook run remarkably well, and results from 2004 were generally consistent with previous study years. Based on all pertinent observations, it can be concluded that the thermal threshold for migration inhibition for KRB adult Chinook is trend dependent, occurring at MDTs of approximately 23.5ºC during falling temperature trends, 21.0ºC during rising temperature trends, and 22ºC during stable trends. The Trinity spring bench release delayed the onset of MDTs ≥22°C by approximately two weeks in the lower Klamath River below Weitchpec, which extended the migratory window for Trinity spring Chinook. The timing and ramp-down rate of the bench release did not, however, match that of natural snowmelt from unregulated tributaries thus potentially miscuing biota including adult spring Chinook. Holding in the estuary/nearshore ocean until physiological or riverine conditions are optimal or acceptable is a cornerstone of migration strategies for KRB Chinook, and while the estuary serves as a critical thermal refuge, estuary/nearshore ocean residency is also driven by other factors. The extent of residency in the estuary versus the nearshore ocean is still unknown.

The migration timing of adult Chinook salmon and associated migration behaviors are evolved life history traits adapted to the long-term average conditions and constraints imposed by their migratory routes and spawning ground locations. The existence of a summer run of Chinook in the KRB has historical precedent, but the summer migrants of today appear to be Trinity River 'spring' Chinook, and the extent to which their run-timing is driven by environmental conditions and/or hybridization with fall Chinook is unknown. Adjustment of travel rates in order to delay or speed migration through specific reaches with desirable or adverse conditions is one of the most critically important migration behaviors employed by KRB adult Chinook. Slow travel and extended holding in the lower Klamath River by fall Chinook was especially distinctive for Klamath fall migrants and appears to be an important component of their normative migration behavior but also increases their vulnerability to pathogen (i.e. *Ich*) transmission. The Trinity fall pulse flow had a negligible affect on adult Chinook migration behavior, with the possible exception of adult Chinook holding at enroute thermal refuges, consistent with the evolutionary axiom of adaptation to long-term average conditions. Thus Trinity fall pulse flow did not accomplish stated goals of reducing fish densities by inducing upriver migration, although combined with higher base flows compared to 2002, it did reduce the risk of pathogen (i.e. *Ich*) transmission by increasing turnover rates and water velocities. Given that KRB fall Chinook appear to be generally unresponsive to pulsed flows, increasing base flows during their migration season is the most important tool available for reducing the risk of *Ich* outbreaks by increasing turnover rates and water velocities, especially in holding habitat within the lower Klamath River.



The lower two kilometers of the Klamath River estuary in August of 2004. Photo by the 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 adult 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 component 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 specialized locomotion behavior and physiological response to temporally (e.g. seasonal) and spatially (e.g. 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 migrations 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 adult spring and fall Chinook (*Oncorhynchus tshawytscha*) for example. With spring Chinook, their 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 that require higher flows to access but as a consequence requires foregoing additional ocean feeding opportunities. With fall Chinook, their run-timing also avoids high water temperatures but allows continued ocean feeding and growth during the summer. The problem with this tidy story is outliers such as Chinook with summer run-timing.

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 hottest summer months of July and August when mean daily water temperatures (MDTs) typically exceed 20°C. Understanding if 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. Historically water temperatures during the summer in the KRB were high but the magnitude, duration, and timing of high water temperatures have undoubtedly changed; indeed data from the last several decades shows trends of increasing water temperatures throughout the Pacific Northwest (Beschta et al. 1987; Quinn and Adams 1996), including the KRB specifically (Bartholow 1995 and 2005). 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 semelparous salmon (Quinn and Adams 1996). Another possible explanation is that behavioral flexibility within the summer run-timing strategy compensates for the adverse environmental conditions, permitting an otherwise untenable run-timing.

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 and upriver migration 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 previous study years suggest that adult Chinook use the Klamath River estuary and associated nearshore ocean in this way, although the details are currently unknown. 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 freshwater spawning migration, adjustments of travel rates is another one behavioral tactics 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 enroute run-timing (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 severely 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 (personal observation) and other similar basins, such as the Yakima (Berman and Quinn 1991) and John Day (Torgersen et al. 1999). The presence of thermal refuges, if in sufficient quantity, quality, and distribution, may allow for the persistence and increase the 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 obligatory as thermal thresholds are exceeded (Armour 1991; Bjornn and Reiser 1991; Bartholow 1995; McCullough 1999; McCullough et a. 2001). Such 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, although higher values have been reported (Quinn et al. 1997; McCullough 1999; McCullough et al.

2001). Regardless of opinion on the exact value of that 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 as has been observed in previous study years.

High water temperatures are often associated with low flows. Migration delays that often 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), however, studies reviewed by Jonsson (1991) suggest that large rivers are less susceptible to delays caused by low flows. Obviously water temperatures greater than the thermal limit to migration will result in migration 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 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 and serious cost associated with migration delays and associated poor quality habitat 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 (Ich)* (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 Klamath River (32,533 to 65,066 dead in the lower 40 km) during September of 2002 (George Guillen FWS, person. comm.). Determining the causes of specific migration behaviors, such as delays, 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 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 regarding the patterns and consequences of adult Chinook migration that arise as a result of circumstances in the KRB include:

1. How do adult Chinook cope with high water temperatures and/or low flows during their spawning migration?
2. What actual body 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 refuge use (behavioral thermoregulation) are displayed by adult salmonids during their spawning migration?
5. What is the run-timing distribution of Chinook stocks in the KRB?
6. How can management prescriptions be improved to increase the success of adult Chinook migration in the KRB?

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 in 2002 of spring Chinook, followed by an expanded sample size and inclusion of fall Chinook in 2003. In 2004 we continued this approach, replicating the 2003 study design and providing another year's worth of data. The overarching goal of this research project is to comprehensively determine and understand adult Chinook migration behavior in the KRB throughout the spectrum of run-timing.

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 KRB during the 2004 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 response 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 migration;
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 2004 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). An archival temperature device (Alpha Mach, W20 x L12 mm, 9 grams) was attached to the base of each radio transmitter and recorded internal body temperature every hour or ever other hour depending on the tagging date. No external marks were made.

Adult Chinook were captured using drift gill nets, tagged, and released at the mouth of the Klamath River from 5/21/04 to 10/22/04, with the exception of a small sub-sample of Chinook that were captured using a seine net, tagged, and released at the Blue Creek thermal refuge on 8/18/04. 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 (using standard procedures), and released immediately or revived first as necessary. A gas powered water pump was used to circulate river water through the live tank continuously. Tissue samples were taken from dorsal or anal fins and stored in 100% ethanol to allow for genetic analysis of racial origin at a later date. Efforts were taken to minimize capture stress and handling time. All Chinook that were caught were tagged regardless of the presence of an adipose fin or not, unless severe injury or shock was apparent.

Scanning radio receivers (Lotek SRX 400s) 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 kilometers 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 number, 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. Four aerial telemetry flights were provided by the CA Department of Fish and Game. Hatchery personnel, 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 15 automated radio listening stations (Advanced Telemetry Systems R4000/DCC, Grant Systems Engineering Orions, 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 and dates of deployment 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 that were associated with the site. The thermisters used were rated in accuracy to the nearest 0.1^{o}C or 0.5^{o}C respectively. 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, the US Geological Survey (USGS), and the USFS Orleans District. River flows were measured by USGS sensors and obtained from their website at http://waterdata.usgs.gov/ca/nwis/current/?type=flow

Air temperature summaries from weather stations operated by the US Forest Service throughout the KRB were obtained from the National Climate Data Center website at 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. This study was no exception; however, efforts were made to increase the representativeness of the study by attempting to tag at least several adult Chinook each week throughout the run and by minimizing selection bias by tagging all competent fish. 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 are ultimately a measurement of animal behavior and often the associated physiological and environmental conditions. The resulting measurements allows for a determination of behavioral patterns and an examination of the underlying causes for those patterns. Statistical testing to determine statistically significant relationships in the measurements of animal behavior is one method to determine patterns and their underlying causes. Not all statistical tests are appropriate or efficient for such analysis thus caution will be used in applying statistical analysis to the results from this study which will mostly occur at a later time prior to peer reviewed publication.

Statistical analysis can determine the level of statistical significance of the relationships tested, however, determining the level of biological or behavioral significance requires comparing telemetry data with the pertinent independent (and often autocorrelated) variables simultaneously at high levels of resolution. The analysis of data from this study to determine Chinook behavioral patterns and their underlying causes will emphasize this former approach by graphically presenting data sets at fine resolution on common axis (such as date/time). Appropriate interpretation of animal behavior also requires applying existing knowledge of evolution and behavioral theory within the context of the specific habitat.

3.0 RESULTS

3.1 Tagging and Fate Summary

Tagging data and the final known fate or last observation of all tagged Chinook is summarized in Appendix 1. Out of the total sample of 95 adult Chinook, 43 (45%) migrated or were harvested after tagging while 52 (55%) disappeared in the estuary or nearshore ocean after tagging. High salinities preclude the detection of tagged Chinook in the estuary or nearshore ocean thus definitive information regarding their fates is lacking; however, seal and sea lion (pinniped) predation, tag regurgitation, unclaimed harvest, delayed tagging mortality, and inter-basin straying were the factors that potentially contributed to the 55% disappearance rate in the estuary.

Determination of percentages of end fates is complicated by the disappearance of fish enroute which could have occurred for a variety of reasons. Thus percentages assigned to the classes of fates should be viewed as the approximate minimum. Taking this into account, of the 43 tagged Chinook that did not disappear or were harvested in the estuary/nearshore after tagging at least 17 (39.6%) successfully made it to spawning grounds or a hatchery; at least 15 (37.2%) were harvested; at least 5 (11.6%) succumbed to non-harvest enroute mortality; and 5 (11.6%) disappeared during migration. Of the 17 fish that successfully migrated, approximately 11 (64.7%) spawned in natural areas with 6 (35.3%) being spawned at hatcheries (4 at Iron Gate Hatchery and 2 at Trinity River Hatchery). Among the 16 fish that were harvested, 43.8% were harvested in the Klamath River estuary, 31.2% were harvested in the lower Klamath River between the estuary and Weitchpec, and 25.0% were harvested in the Trinity River. Out of these 43 fish, at least 10 (23.2%) migrated into the Klamath River above Weitchpec (RKM 70), at least 15 (34.9%) migrated into the Trinity River above Weitchpec, and 18 (41.9%) were never observed migrating above Weitchpec due to harvest (11), non-harvest mortality (3), or disappearance (4). With the exception of Bogus Creek, which is adjacent to Iron Gate Hatchery, there is no evidence that any tagged Chinook migrated or spawned in any other tributaries including the Shasta, Scott, Salmon, and South Fork Trinity Rivers.

A total of 25 tagged Chinook migrated past the confluence of the Klamath and Trinity Rivers at Weitchpec and thus reasonable assumptions can be made about their approximate destination and likely stock origin. Hereafter termed 'migrants', their tagging data and fates are displayed excluding all other tagged Chinook in Table 2. These fish will serve as the basis of analysis of migration behavior by run-timing and destination/stock groups, also termed migrant groups.

3.2 Environmental Conditions

3.2.1 River Flow

Annual hydrographs for the 2004 calendar year are presented for the Klamath and Trinity Rivers plus their primary tributaries in Figures 3 through 12. Flows for the Salmon River were not available due to the funding related lack of gauge data for most of 2004. All flows are reported as mean daily flow measured in cubic feet per second (cfs) and all RKMs are measured from the mouth of the Klamath River.

The 2004 water year was ultimately classified as "dry" for the upper KRB, which resulted in flow releases from Iron Gate Dam (Figures 7 and 8) as dictated by the Bureau of Reclamation's (USBR) Ten Year Water Plan. In contrast the water year designation for the Trinity sub-basin was "wet" in 2004 due to higher precipitation and snow pack, which resulted in flow releases from Lewiston Dam (Figure 11) as dictated by the Trinity Record of Decision. Flow releases from these dams strongly influence downriver flows on the mainstem Klamath and Trinity Rivers.

Annual hydrographs throughout the lower KRB generally have three components: summer/fall base flow, rain driven high water with rain on snow flood peaks, and spring snowmelt. During 2004, spring snowmelt from unregulated tributaries generally occurred from mid-March to mid-May with a peak on 5/4/04, which includes all gauged tributaries to the Klamath mainstem above Weitchpec with a spring snowmelt component and the unregulated Trinity River above Trinity Dam. Two exceptions were the South Fork Trinity River, which experienced an earlier snowmelt period that peaked for the last time on 4/21/04 (Figure 12), and the mainstem Trinity River which had spring flows controlled by releases from Lewiston Dam which included a geomorphic spike that peaked at 6,200 cfs on 5/17/04 and an extended spring temperature bench of ~ 2,000 cfs which lasted until 7/19/04 (Figure 11). Summer base flow conditions were generally prevalent by 7/1/04 in the mainstem Klamath River and its tributaries with the exception of the mainstem Trinity River. The first substantial increase in river flows from precipitation after the summer dry season occurred from 10/20/04 to 10/27/04 throughout the KRB.

3.2.2 Water Temperature

Hourly water temperatures at five locations (Klamath RKMs 26, 81, and 153; Trinity RKMs 102 and 187) throughout the KRB for the duration of the study period are presented in Figures 13 to 17 respectively. Water temperatures at these five sites are compared in relation to the biologically important thresholds of mean daily temperatures >20^{o}C and 22^{o}C in Table 3. Three of these sites contained cold-water tributary formed thermal refuges (e.g. Blue Creek RKM 26, Bluff Creek RKM 81, and Horse Linto Creek RKM 102), thus water temperatures for the creek or cold water source that created the thermal refuge are reported in addition mainstem river temperatures above the thermal refuge (Figures 13 to 15). These thermal refuges are among the most significant in the lower KRB and are the only ones where radio listening stations were placed.

3.2.3 Air Temperature

Mean daily air temperatures at three locations in the lower KRB are reported in Figures 18 to 20, which include mean daily flows and mean daily water temperature at approximately the same location to allow comparisons. The three locations are the Klamath Glen at RKM 13, Orleans at RKM 95, and Big Bar on the Trinity River at RKM 174. Data sets from these locations were chosen because they are among the few long standing (i.e. >50 years) air temperature data sets from representative locations available in the KRB. This is important because it allows for determination of normal monthly temperatures (based on last 50 years) and analysis of longer term trends.

3.3 Migration Behavior

3.3.1 Telemetry Summary

Telemetry observations were recorded for a total of 38 tagged Chinook. All valid telemetry observations for each fish during manual tracking and the first recording at each relevant radio listening station are summarized in Appendix 2. Time is reported in 24 hour clock format, and all river kilometers are as measured from the mouth of the Klamath River. Body temperature was calculated from the pulse interval of the radio transmitter for each observation and is subject to error from the tag's thermister (0.2^{o}C), error in measuring the interval, and any leftover influence of the temperature of the water from where the fish was coming from within the last hour. Thus body temperatures should be viewed with this in mind. More accurate body temperature data was provided by archival temperature data. An asterisk next to the tag frequency indicates internal body temperature data was successfully recovered from the archival tag. All river temperatures were recorded at the time and location where the fish was observed or at the closest available temperature probe (within approximately 15 km). Travel rates are reported in kilometers per day (km/day) and represent the travel rate from the last observation (date, time, and RKM) to the current observation. Thus net downstream movement resulted in negative travel rates. Telemetry observations in the estuary below Wakel (located just upriver from the Highway 101 Bridge at RKM 7) were negligible since radio transmitters are non-detectable in high salinity water.

3.3.2 Run-timing

For tagged Chinook with known destinations, run-timing based on tagging date (estuary entry) and date of commencement of upriver migration (freshwater entry) were correlated with destination and presumed stock origin. Tagged Chinook that died, disappeared, or were caught in the lower Klamath River or estuary were headed to unknown destinations and thus have been excluded from an analysis of run-timing and travel rates.

Excluding those fish, distinct patterns emerged in terms of run-timing and destinations for the remaining tagged Chinook, termed migrants (Table 2, *n*=25). Migrants tagged in June (6/3/04 to 6/14/04, *n*=3) and July (7/9/04 to 7/26/04, *n*=6) all migrated to the Trinity River with survivors bound for spawning areas from Junction City to Lewiston, including the Trinity River Hatchery.

Two migrants emerged from the limited tagging efforts at the thermal refuge at the mouth of Blue Creek on 8/18/04. These fish had been holding there for an unknown period of time. One of these migrants (149.063) eventually migrated into the Trinity River and spawned in lower Junction City area, and while the other (149.270) eventually migrated to the upper Klamath River and likely spawned in the Iron Gate Dam area.

Migrants tagged in August (8/16/04 to 8/31/04, *n*=7) and early September (9/6/04, *n*=2) at the mouth of the Klamath River all migrated up the Klamath River bound for spawning areas in the Iron Gate/Bogus Creek area, including Iron Gate Hatchery. One exception was Chinook 149.564, which apparently migrated into the lower Trinity River for a period of 17 days before turning around and migrating up the Klamath River above Weitchpec where the tag was later found at RKM 219.

Migrants tagged in mid-September to late October all migrated into the Trinity River (*n*=6) with the exception of Chinook 150.923, which was tagged on 10/1/04 and migrated up the Klamath River, apparently spawning in the area (RKM 235) between the Scott River and Horse Creek.

3.3.3. Travel Rates

Travel rates were highly variable among all migrants and for a given migrant and ranged from no movement during periods of holding to values in excesses of 50 km/d during rapid upriver migration with no clear patterns emerging when viewed in total (Figure 21). When grouped by run-timing/stock origin, however, consistent patterns emerged in travel rates as a function of river kilometer, which also suggested more precise sub-groupings based on migration behavior.

Trinity River Chinook tagged during June, July, and August exhibited similar patterns of travel rates in relation to location (e.g. river kilometer) but with considerably different magnitudes. Travel rates versus location for June tagged Trinity River Chinook, termed spring migrants, are presented in Figure 22. Travel rates versus location for July and August tagged Trinity River Chinook, termed summer migrants, are represented in Figure 23. Both groups exhibited a pattern of increasing ground speeds as they migrated upriver, which peaked around the Weitchpec (RKM 70) followed by a gradual decrease to a relative minimum in the high gradient (~100 ft/mile) Burnt Ranch Gorge, with a subsequent increase to a moderate rate until reaching holding or spawning areas. Several fish moved quickly to spawning areas in the vicinity of Lewiston or to the Trinity River Hatchery after extended holding periods in the Junction City area. Summer migrants, however, traveled at much higher rates.

Klamath fall Chinook migrants displayed an entirely different migration pattern than Trinity spring and summer Chinook. Klamath fall Chinook migrated as a relatively cohesive group which resulted in consistent pattern of travel rates by river kilometer characterized by slow travel rates through the lower Klamath River followed by higher travel rates above Weitchpec that slowly increased until a peak just prior to arriving on spawning grounds in the Iron Gate Dam area (Figure 24). This pattern also held true for the one Klamath fall Chinook migrant (150.923) tagged in October but was initially different for the one Klamath fall Chinook migrant (149.270) tagged at Blue Creek.

Trinity fall Chinook migrants traveled slightly faster through the lower Klamath River than the Klamath fall Chinook, but did not show a marked increase in ground speed after passing Weitchpec (Figure 25). Travel rates did not peak until passing through Burnt Ranch Gorge. In general, travel rates for Trinity fall Chinook were distinctly different from spring and summer Chinook migrants and subtly different from Klamath fall Chinook migrants.

3.3.4 Behavioral Thermoregulation

During the 2004 season, radio tagged Chinook behaviorally thermoregulated primarily by holding in the estuarine salt wedge and nearshore ocean prior to commencing upriver (freshwater) migration, although estuary/nearshore residence is not driven entirely by behavioral thermoregulation. The longest period of holding in the estuary/nearshore ocean was 22.6 days for Chinook 149.413, which was tagged on 7/9/04 at the mouth of the Klamath River and subsequently migrated to the Trinity River Hatchery. Temperatures in the estuarine salt wedge typically stayed below 15^{o}C, even during the hottest periods of season. Combined with a large (albeit shifting) volume, the salt wedge makes the Klamath River 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 River, and New River.

Adult Chinook were observed using thermal refuges by YTFP snorkel survey crews during the summer months at the confluences of cold water creeks such as Blue Creek, Bluff Creek, and Horse Linto Creek, which has been the case in all previous years of creek mouth monitoring. In addition, several Chinook were tagged while holding in the thermal refuge at the mouth of Blue Creek in August, thus some use of thermal refuges did occur beyond the estuary in 2004. An overall examination of telemetry (manual and listening station) data and archival body temperature records, however, did not reveal any extensive use of enroute thermal refuges by tagged Chinook once freshwater migration commenced. Based on all available data sets for tagged Chinook in 2004, what thermal refuge use that did occur beyond the estuary consisted of brief forays (<24 hours) at the Blue Creek thermal refuge complex and tributaries to the lower Trinity River such as Mill and Tish Tang Creeks. Migrants documented using the refuge complex at Blue Creek included Chinook 149.424, 149.714, 149.973, and 150.274. Only summer Chinook migrants were documented using thermal refuge in the lower Trinity River and consisted of Chinook 149.743, 149.392, and 149.494. Four Chinook migrants were documented residing in the cold waters of Bogus Creek, but this should not be considered behavioral thermoregulation since this was associated with spawning behavior and mainstem temperatures were relatively low (<17^{o}C). No thermal refuge use was documented by tagged Chinook at the Bluff Creek or Horse Linto Creek refuges.

Unpublished results from the 2002 and 2003 adult Chinook radio telemetry studies indicated that adult Chinook migration in the KRB was inhibited when mean daily river temperatures equaled or exceeded 22^{o}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 and body temperatures, this relationship generally held true in 2004 except that tagged Chinook were observed migrating at substantially higher real-time temperatures (up to 24.8^{o}C) and mean daily temperatures up to 23.6^{o}C, but also choose not to commence migration at mean daily temperatures as low as 21.5^{o}C.

3.4 Thermal Experience

Internal Archival Temperature Data

Data from 28 archival temperature tags (29% of 95 total tagged Chinook) was successfully recovered. The recovery rate of archival tags and their performance was major accomplishment of the 2004 study. Archival temperature tags were attached to each radio transmitter and thus measured internal body temperature every hour or every other hour depending on when the fish was tagged (body temperature was measured bi-hourly for all fish tagged before 7/16/04, hourly after that). Archival data is graphed along with benchmarks of fish locations in Figures 26 to 51 arranged in order of tagging date.

4.0 DISCUSSION

4.1 Tagging and Fates

4.1.1 Tagging

Tagging methods used in this study were successful although not without drawbacks as exemplified by the 55% rate of disappearance in the estuary/nearshore after tagging. This may appear to be low post-tagging survival, especially compared to the high survival rates reported for adult salmonid radio tagging studies elsewhere (ex. Columbia River). However, these studies were conducted away from the influence of pinniped predators and the possibility of inter-basin straying. The rate of disappearance has been consistently close to 50% during all study years thus far suggesting that such a level of disappearance is not anomalous to a given year but is to be expected when tagging in the estuary. Other factors that potentially contributed to the 55% disappearance rate include tag regurgitation, delayed tagging mortality, and unclaimed harvest. Determining the contribution of each potential factor was confounded by the inability of radio signals to penetrate high salinities such as occurs in the estuary and nearshore ocean.

Regurgitation rates with esophageal tags can commonly reach 10% for adult Chinook, which is most likely to occur soon after tagging (Jeremy Dueher, ATS, persn. comm.). In this case that would mean regurgitating tags in the estuary or nearshore where they could not be detected. Size dependent disappearance could be a factor if: 1) larger fish regurgitated tags more often due to their larger esophaguses; or, 2) smaller fish experienced greater delayed tagging mortality due to the larger tag to stomach size ratio. To evaluate these possibilities, all tagged Chinook were categorized into a group of known survivors (including those harvested in the estuary) and a group of fish that disappeared. The survivor group had a larger mean fork length (77cm vs. 75cm), however this was not statistically different from the mean of the disappearance group when tested using a two-tailed t test assuming unequal variances ($t=1.33$, $t_{0.05(2)91}=1.987$, $p=0.19$) (Zar 1999). In addition, large fish up to 95cm FL were successfully tagged as were small fish of 65cm FL. Thus size dependent factors did not appear to exert any significant influence on the disappearance rate.

The disappearance rate by month, excluding Chinook tagged at Blue Creek, is as follows: May 67%, June 50%, July 53%, August 36%, September 68%, and October 65%. The number of tagged Chinook harvested in the estuary for each month is as follows with known or suspected unclaimed harvest reported in parenthesis: May=0, June=0, July=2, August=2 (2), September=1 (2), October=0 (1). Chinook tagged during periods of high river temperatures (>20^{o}C) are expected to experience greater tagging stress; however, 60% of the 35 Chinook tagged in the estuary when daily maximum river temperatures were below 20.0^{o}C disappeared as compared to 53% of the 57 Chinook tagged above that temperature. Out of the 31 Chinook that were tagged in the estuary when daily maximum river temperatures exceed 22ºC, only 39% disappeared. Thus high river temperature is not correlated with a higher rate of estuary/nearshore disappearance. Plus Chinook tagged at the mouth of the Klamath River have a wide range of temperatures and salinities to select from which aids recovery and helps mitigate tagging stress.

Data on inter-basin straying rates is not available; however, one Chinook tagged in May (149.044) migrated to the vicinity of Blue Creek before heading back downriver; passing into the estuary at a high rate of travel and presumably back to the ocean.

Retreating downriver to the estuary or other thermal refuges has been observed on other occasions but only when water temperatures rose above the migration inhibition threshold as the fish was enroute, with subsequent resumption of upriver migration when temperatures cooled. Chinook 149.044 retreated back to the estuary when water temperatures were cool, however, and was never detected in the KRB again suggesting this fish was from another river basin (e.g. Rouge River). Inter-basin straying is considered to be the least of the factors contributing to the disappearance rate, but based on this evidence it is considered to be a contributing factor.

Tribal and sport harvest are monitored in the estuary and flyers posted notify the public about the reward program for tagged Chinook, however, not all tagged Chinook that are subsequently caught by the members of the public are claimed or returned for rewards. Circumstantial evidence demonstrates that unclaimed harvest does occur, intentional or not, although the frequency of occurrence is not known.

The most obvious potential source of 'disappearance' of tagged Chinook in the estuary/nearshore is pinnipeds (i.e. seals and sea lions). Due to the seemingly large numbers of pinnipeds that gather at the mouth of the Klamath River annually and the purportedly excessive predation, the YTFP undertook a visual observation and scat analysis study of seal and sea lion predation beginning with a pilot study in 1997 with follow up studies in 1998 and 1999 (Williamson and Hillemeier 2001). Predation rates for the entire fall Chinook run ranged form 2.3 to 8.8% with California sea lions (*Zalophus californianus*) being responsible for 87 to 93.5% of this predation. Even assuming the highest estimated value of 8.8%, the pinniped predation rates observed by Williamson and Hillemeier (2001) were substantially lower than even half of the 55% disappearance rate observed for tagged Chinook in the estuary/nearshore during 2004.

Several facts suggest that the pinniped predation rate that occurred in 2004 for tagged Chinook, whatever it may have been, was higher than observed for fall Chinook in the late 1990s. First, Williamson and Hillemeier (2001) compared their results to studies conducted ten to twenty years earlier and concluded that the temporal presence and associated predation pressure from California sea lions was on the increase. If this trend continued since the 1990s then the predation rate by 2004 would be expected to be even higher. Second, tagged Chinook will experience higher predation rates due to increased vulnerability to pinniped predation after release as a consequence of tagging stress. Additionally, the ratio of pinnipeds to salmon is much higher early in the migration season resulting in the potential for higher predation rates on spring and summer Chinook tagged in May, June, and July. There were no direct observations of pinniped predation on tagged Chinook in 2004, but on numerous occasions sea lions were observed hunting in the immediate vicinity of tagged fish.

In conclusion, tagging Chinook at the mouth of the Klamath River has drawbacks, such as the presence of pinnipeds and an active fishery; but also has critical benefits such as allowing fish to behaviorally reduce thermal and ionic shock by seeking refuge in the adjacent ocean or estuarine salt wedge. Approximately 50% of Chinook tagged at the mouth of the Klamath River would be expected to ultimately disappear due to a variety of factors in any given year. Most importantly, tagging Chinook at the mouth of the Klamath River captures their entire migration history, which allows for comprehensive analysis and a more complete understanding of their migration behavior.

4.2.2 Fates

Understanding the normality of end fates experienced by tagged Chinook requires comparison to the fates experienced by the 2004 Chinook run as a whole. Preliminary estimates of the 2004 Chinook run size in the KRB is 93,136 adults (jacks excluded) of which approximately 14,374 (15%) were considered spring Chinook and approximately 78,762 were considered fall Chinook (85%) (KRTAT 2004; Patrick Garrison, CDFG, persn. comm.; Petey Brucker, SRRC, persn. comm.).

The vast majority of spring Chinook in the KRB are of Trinity River origin (97% in 2004). Not surprisingly all of the tagged Chinook migrants that could be considered ‘spring’ Chinook migrated to the Trinity River (10 of 25 or 40%). Three of these 10 Chinook were tagged in June and exhibited what is generally considered “typical” spring Chinook run-timing and migration behavior. This sub-group of migrants were not successful at spawning however, as one perished below Gray’s Falls and the other two were caught by sport fishermen while holding in the upper Trinity River above Junction City. In contrast, of the remaining seven ‘springers’ (tagged in July and August), two were caught in Hoopa while five safely migrated to the upper Trinity River at or above

Junction City and appear to have spawned (three naturally, two at the Trinity River Hatchery). These contrasting survival rates highlights a potentially significant dynamic; early spring Chinook hold longer prior to spawning than later arriving summer migrants and thus have a greater probability of being caught in the upper Trinity River. This is one factor that could potentially contribute to shifting the composition of successfully reproducing spring Chinook towards later arriving summer migrants.

Preseason forecasts predicted a run of 98,600 adult fall Chinook, considerably higher than the estimated 78,762 adults that showed up. Fall Chinook escapement to natural spawning areas was especially low with the 35,000 natural spawning escapement floor falling short by 10,753 spawners. Spawner estimates in tributaries to the Klamath and Trinity Rivers hit records lows in particular, thus it's not surprising that there is no evidence that any tagged fall Chinook migrated into or spawned in any tributaries with the exception of Bogus Creek.

Bogus Creek is part of a spawning complex that consists of a mix of Iron Gate Hatchery fish and natural spawners, concentrated from Iron Gate Dam to I5 and Bogus Creek. In 2004, approximately 19,214 fall Chinook comprised this spawning complex with 3,493 (18%) spawning in Bogus Creek, 5,038 (26%) in the Klamath mainstem, and 10,683 (56%) being taken into Iron Gate Hatchery. In comparison, of the seven tagged Chinook that successfully migrated to this spawning complex with known fates, four (57%) were spawned at Iron Gate Hatchery, two (29%) spawned in the mainstem, and one (14%) apparently spawned in Bogus Creek. Thus the spawning location percentages for tagged Chinook were remarkably similar to the percentages for the entire fall Chinook run in the Iron Gate spawning complex. Regarding Bogus Creek, the amount of time a given tagged Chinook spent there can be determined from archival temperature data because of Bogus Creek's distinct thermal signature. Out of the seven Chinook migrants discussed above, five archival tags were recovered, four of which (149.173, 149.714, 149.732, and 149.872) showed evidence of spending at least some time in Bogus Creek or in its confluence, including two fish that were spawned at Iron Gate Hatchery and the one fish that apparently spawned in lower Bogus Creek. As an interesting side note, one of the natural spawners from the Iron Gate area drifted at least 49 kilometers downriver while still alive during the highwater event on 12/9/04, suggesting considerable movement of carcasses and moribund salmon during periods of highwater.

Only two Klamath fall Chinook migrants did not end up in the Iron Gate area. One of these fish (150.923) was the only Klamath fall Chinook migrant tagged in October and appeared to have spawned in mainstem Klamath around RKM 235 between Horse Creek and the Scott River. The other fish (149.564) stopped migrating abruptly near Walker Creek were it died a few days later, an apparent enroute mortality. Chinook 149.564 was the only tagged Chinook that was documented migrating in both the Klamath and Trinity Rivers during the 2004 season, spending 17 days in the lower Trinity River (based on a process of elimination) before migrating up the mainstem Klamath River above Weitchpec. Pending genetic analysis there is no method to determine the true stock origin of this fish, but this fish may have been a stray Trinity stock fall Chinook.

In the Trinity River sub-basin an estimated 12,399 adult fall Chinook were spawned at the Trinity River Hatchery at Lewiston Dam with another 12,885 spawning naturally in the mainstem Trinity River, primarily in the first few kilometers below Lewiston Dam. Six tagged Chinook migrated into the Trinity River during the fall run, with four successfully migrating to spawning areas in the upper Trinity River mainstem, one being caught in Hoopa, and the other last observed migrated through the Burnt Ranch Gorge. Regarding the first four migrants, one disappeared after passing the site of the Junction City weir and of the remaining three, two spawned in the Junction City area and one (150.274, ad clipped hatchery coded wire tag 1162uu) spawned in the Lewiston area.

The percentages of spawning locations for Trinity fall Chinook migrants did not match that of the entire Trinity fall run with natural spawners being overrepresented in the sample. Overall, Trinity fall Chinook were underrepresented among the 25 tagged migrants given that there were 1.2 Trinity fall Chinook spawners for each Klamath fall Chinook spawner in the KRB for 2004, where as the same ratio for tagged Chinook migrants was 0.5 to 1. This is potentially due to the higher than average disappearance rate in the estuary during the latter half of September (74% from 9/13/04 to 9/22/04), which is when Trinity fall Chinook entry timing peaks in the lower Klamath River (Figure 52). No explanation is forthcoming to account for the higher disappearance rate during this period, although an increase in the numbers of pinnipeds during September is a possibility.

This study was not designed with the objective of determining in-river harvest rates for Chinook; however, the ability to pinpoint the exact location of radio tags along with the reward and outreach program did yield information on harvest rates of tagged Chinook. As previously reported, of the 43 tagged Chinook with known fates at least 16 (or 37.2% of 42) were harvested. In comparison, the total estimated in-river harvest of fall Chinook in the KRB in 2004 was 31,917 fish or 40% of returning fall Chinook; a relatively high percentage that roughly matches the harvest rate estimate from tagged Chinook (in-river harvest of fall Chinook in 2003 was 42,396 fish or 22%) (KRTAT 2004). Of the 16 harvested tagged Chinook, 75% were caught in the estuary or lower Klamath River below Weitchpec, compared to approximately 89% for the entire run. Of the 16 harvested tagged Chinook, 25% were caught in the Trinity River compared to 7% for the entire run. However, spring Chinook are almost exclusively of Trinity River origin and the assumption that harvest rates were equivalent for spring versus fall Chinook does not hold (plus spring Chinook harvest is not comprehensibly monitored in the KRB as there is no quota system despite their greatly depleted status). Thus excluding spring Chinook the percentage of tagged Chinook caught in the Trinity River drops to 6%, almost exactly the same as for the entire Trinity fall Chinook run.

Tribal harvest of tagged Chinook ranged from 62.5-87.5% and sport harvest ranged from 12.5-37.5%. Circumstantial evidence suggests that all four unclaimed tags were likely caught in Tribal fisheries (recovered on the south spit at the mouth of the Klamath River during the Yurok Tribal commercial fishery, in Weitchpec, and in Hoopa). If true, the breakdown of tagged Chinook harvested would be 12.5% sport and 87.5% Tribal. This is almost identical to the breakdown for the entire KRB fall Chinook run in 2004 which was 12% sport and 86% Tribal.

In summary, the end fates of tagged Chinook closely matched that of the entire in-river run of fall Chinook in the KRB for 2004. This corroborates the accuracy of harvest and escapement data and provides supporting evidence that telemetry tagging was relatively representative; although Trinity fall Chinook were slightly under represented in among the 25 migrants.

4.2 Environmental Conditions

4.2.1 Flow

The 2003/2004 water year was initially classified by USBR as “below average” for the upper Klamath River Basin but subsequently downgraded to “dry” and was classified as “wet” for the Trinity River sub-basin based on hydrological forecasts by the Natural Resource Conservation Service’s National Water and Climate Center. Summer base flows in the lower Klamath River are determined by Iron Gate Dam releases more than any other single source, thus IGD releases have a significant impact the environmental conditions migrating adult Chinook face when entering the Klamath River during the summer and fall (Hardy and Addely 2001).

Hardy and Addely (2001) recommend that flows from Iron Gate Dam never drop below 1,000 cfs for temperature and ecological reasons; however, flow releases from Iron Gate Dam were below this benchmark by at least 15% continuously from 6/17/04 to 8/23/04 with a mean flow release of only 660 cfs from 7/1/04 to 8/23/04. Flow releases increased starting on 8/24/04 for a period of seven days for the Yurok boat dance ceremony with a two day peak of 1,320 cfs. However, during the vast majority of the fall Chinook migration season flow releases from Iron Gate Dam were below this benchmark with a mean flow release of 924 cfs in September through November. The timing, duration, and magnitude of flow release below 1,000 cfs from Iron Gate Dam in 2004 is a serious concern given the recommendations of Hardy and Addely (2001) and due to the importance of water velocities and turnover rates in the infectivity of *Ich* (Bodensteiner et al. 2000). While there was no repeat of the 2002 fish kill, non-lethal consequences and associated pre-spawn mortality on spawning grounds may have been substantial and the level of ecological risk was increased.

During the spring of 2004, migratory conditions for adult Chinook were improved by an above average snowpack throughout most of the lower KRB. Comparing spring Chinook run-timing to typical hydrographs in the KRB shows that their run-timing avoids the flood events of late winter/early spring and results in migration during the descending limb of the snowmelt peak. This strategy represents trade-off between the increased energetic costs of swimming against higher flows earlier in the season with the increased energetic and physiological costs and potential migratory blocks associated with higher water temperatures later in the season (Hinch and Rand 2000).

The snowmelt peak on the Klamath River at Orleans (Figure 5) and on the Salmon River at Somes Bar occurred on 5/5/04, followed by the Trinity Dam driven "snowmelt" peak on the lower Trinity River in Hoopa on 5/17/04 (Figure 10). The first Chinook of the season was tagged at the mouth of the Klamath River on 5/21/04 after the snowmelt peak, with spring Chinook continuing to enter the river until a noticeable drop-off after mid-June. Thus the river entry timing of spring Chinook in 2004 based on tagged Chinook matched the descending limb of the snowmelt peak as expected. All three spring Chinook migrants in 2004, bound for the upper Trinity River, initiated upriver migration during the spring bench release from Lewiston Dam. This fact highlights the primary benefits of this spring bench release for adult salmonids in that it extends the window of passable migratory conditions by delaying the onset of summer base flows and associated high temperatures in excess of the thermal limit to migration. However, these three spring Chinook migrant were attempting to pass through Burnt Ranch Gorge when the bench flow abruptly ended over a nine day period, with one migrant falling to successfully pass the second Burnt Ranch Falls. In 2003, four of four migrants that were trying to pass Burnt Ranch Gorge when the ramp down of the spring bench release was occurring were not successful. The ramp down rate for the spring bench release is substantially greater than ever occurs naturally during the descending snowmelt limb in unregulated KRB tributaries, and this appears to miscue migrating adult Chinook. Another potential miscue resulting from the Trinity spring bench release is the discontinuity in the timing of the release in comparison to unregulated KRB tributaries (Figure 53), which was especially noticeable in 2004 and has the potential to miscue wild spring Chinook bound for the South Fork Trinity or Salmon Rivers.

4.2.2 Water Temperature

Before discussing river temperatures during the 2004 migration season it is necessary to review the dynamics that govern thermal regimes in rivers. Riverine thermal regimes are determined by a suite of interacting climatic, insolation (solar radiation), and hydrologic factors as depicted in Figure 54. The regional climate is determined by latitude, longitude, altitude, and continentality (Ward 1985). Of the resulting climatological factors, air temperature by far has the greatest influence on thermal regimes of rivers (Sinokort and Stefan 1993; Mohseni and Stefan 1999). In the absence of substantial groundwater, snowmelt, or dam release inflows (Ward 1985), stream and air temperatures exhibit a strong linear relationship at most temperatures (Sinokrot and Stefan 1993). Air temperature also governs groundwater temperatures, which in the absence of geo-thermal heating, are usually within $1^{o}C$ of the local mean annual air temperature (Ward 1985).

The thermal template created by climate and insolation is altered by a suite of hydrologic factors. Substantial inputs of groundwater, snowmelt, dam releases, or cold tributary flow dramatically affect river temperatures down the longitudinal profile until enough distance has passed to allow for mixing and equilibrium with air temperatures (Ward 1985; Lowney 2000).

The influence of dam releases on river temperature is a function of the magnitude and duration of release along with the temperature of the released water which is in turn a function of the release intake location in relation to thermal profile of the reservoir. For example, water released from Lewiston Dam is cold ($<10^{o}C$) throughout the summer due to a hypolimnetic (i.e. bottom) release from the larger Trinity Dam directly upstream. The downstream extent of cooling caused by releases from Lewiston Dam is thus determined by the magnitude and duration of the releases. The differences between water temperatures on the mainstem Trinity River at RKM 102 between mid-August prior to the Trinity fall pulse flow and in late-August during the Trinity fall pulse flow provides a clear example of this relationship (Figure 14). Water releases from Iron Gate Dam are withdrawn from the warmer metalimnion and exert a subtler influence on mainstem river temperatures than releases at Lewiston Dam. The affect of Iron Gate Dam on mainstem river temperatures was recently discussed in detail by Bartholow (2005), among which is substantial warming of water temperature in the Klamath River during the fall (i.e. delayed onset of cooler fall river temperatures).

Stream temperatures can also be strongly affected by precipitation events which reduce insolation, decrease air temperatures, and can flush out groundwater or drastically lower runoff temperatures as exemplified by cold storms (Ward 1985). For example, from 2002 to 2004 a cold front has passed through the KRB during the first week of August, causing a brief but substantial decrease in stream temperatures basin-wide during a period of stable low flows. In this case precipitation runoff was minimal, thus reduce air temperatures and cloud cover were the primary drivers of decreased mainstem river temperatures.

When viewing graphs of air temperature, water temperature, and river flow at locations throughout the KRB (Figures 18 to 20) the correlation of these variables becomes apparent and several ecologically important patterns emerge. First, the shape or pattern of water temperatures is the same throughout the KRB, including non-regulated tributaries, demonstrating the overarching influence of air temperature and seasonal levels of insolation. Comparing water temperatures for Bluff Creek to the mainstem Klamath River above Bluff Creek provides a typical example (Figure 15). Second, even though the shape of thermographs were generally the same, the magnitude of water temperatures vary given the specific hydrologic and climatic factors for that location. Third, the timing of the cessation of snowmelt and the onset of high air temperatures coincided during late June, resulting in a rapid increase in water temperatures, with the exception of the mainstem Trinity River, which stayed cooler due to the extended spring bench flow release from Lewiston Dam that lasted until 7/19/04.

Comparisons of mean daily water temperatures for the lower mainstem Klamath River at three locations is shown in Figure 55: near Bluff Creek (RKM 81, above the influence of the Trinity River); Weitchpec below the Klamath/Trinity confluence (RKM 67); and near Blue Creek (RKM 26). June water temperatures were equivalent at these locations due to the influence snowmelt throughout the KRB. By July snowmelt had ended on the mainstem Klamath River above Weitchpec but continued due to the extended spring bench release from Lewiston Dam on the Trinity River, thus cooling temperatures at RKM 67 which subsequently warmed as the water traveled downriver to RKM 26. The Trinity spring bench release delayed the onset of mean daily temperatures $\geq 22^{o}C$ by approximately two weeks in the lower Klamath River below Weitchpec (Table 3). The unnaturally fast ramp down rate of the Trinity spring bench release combined with its timing during the hottest part of the summer also resulted in water temperatures rising extremely rapidly.

From the end of the Trinity spring bench release to the beginning of the Trinity fall pulse flow, river temperatures were again roughly equivalent at these locations with a moderate downriver cooling trend due to the coastal affect. This is the typical summer pattern in the lower Klamath River. Starting with the arrival of cool weather and the Trinity fall pulse flow, water temperatures dropped precipitously in the lower Klamath River below Weitchpec and demonstrated a pattern of downriver warming similar to what occurred in July. After the cessation of the Trinity fall pulse flow, temperatures reverted to a typical fall pattern with downriver warming due to the moderation of nighttime low temperatures by the coastal affect.

4.2.3 Air Temperature

Evaluating air temperatures in the KRB during the 2004 migration season requires putting air temperature data into the context of normal values. Thus departures from the 50 year average (i.e. normal) of mean monthly temperatures at three representative locations in the KRB are presented in Figure 56. Air temperature on the coast (Klamath Glen RKM 13) departed from normal to a more often and to greater extent than inland with every month except November showing an increase from normal. April and August were especially hot on the coast, each with a 3.4^{o}F increase over normal mean monthly temperature, the largest departure observed for all three sites. Inland air temperatures (Orleans Klamath RKM 95 and Big Bar Trinity RKM 174) were also warmer than normal in April, approximately normal in May and June, warmer in July and August, but considerably cooler in September and October.

4.3 Migration Behavior

4.3.1 Run-timing

Before discussing run-timing it is important to define the terms used herein. As properly used in fisheries biology the term ‘run’ denotes a specific group of fish ascending a river to spawn. A given run of fish is distinct but could be comprised of mixed stocks or populations of varying degrees of genetic similarity or differentiation with one or multiple destinations. Thus the term 'run-timing' denotes the timing of migration of a specific group of fish and generally has four main components: river entry from the ocean into the estuary, initiation of upriver migration from the estuary, arrival at a subjective point along the migration path, and arrival to pre-spawn holding areas or spawning grounds. For example the phrase 'summer run' as used herein denotes a group of migrating adult Chinook that are distinct in their run-timing (all components) and migration behavior from other groups (i.e. spring run, Klamath fall run, and Trinity fall run). Determining the actual genetic origins and relationships to other runs require performing the appropriate genetic analysis from tissue samples. Such an analysis is possible but has not yet been conducted and is thus beyond the scope of this report. Run-timing is under genetic control and is adapted to long term average conditions (Gharrett et al. 1987; Stewart et al. 2002) with behavioral flexibility allowing for attunement to the specific conditions in a given year (Potts and Wooton 1984).

Spring Chinook Migrants (*n*=3) – Run-timing

A total of 14 spring Chinook with typical spring run-timing were tagged from 5/21/04 to 6/18/04. Ultimately, three migrants emerged from this group with tagging dates ranging from 6/3/04 to 6/14/04.

Upriver migration did not commence immediately; in the case of tagged spring Chinook for which there is data, estuary/nearshore residency was 16.9, 16.3, 1.9, 9.0, and 8.3 days. Radio telemetry results for all study years has shown extended residency in the estuary/nearshore after tagging prior to commencing upriver migration for a large portion of tagged Chinook. Chinook salmon returning to rivers to spawn require some minimal amount of time at the salt/fresh water interface to undergo osmotic transformation back to a freshwater environment and to allow homing mechanisms to function. The minimum amount of time required at this interface is unknown, but the extended estuary/nearshore residency observed for most tagged Chinook certainly goes beyond this requirement, in the case of adult Chinook entering during periods of excessively high water temperatures, it amounts to using the estuary/nearshore as a thermal refuge habitat while waiting for a decrease in river temperatures.

Reasons for extended estuary residency in the absence of river temperatures exceeding the thermal migration inhibition threshold are not as evident. The estuary arrival timing of spring Chinook is genetically programmed to the long term average conditions (Gharrett et al. 1987; Stewart et al. 2002); however, extended estuary/nearshore residency observed by spring Chinook may amount to behavioral fine tuning of the timing of commencement of upriver migration to better match variability in river conditions. Being in close proximity to the river would permit monitoring of riverine conditions while preserving the option to continue feeding in the nearshore ocean and conserving energy by residing in colder water. This hypothesis is supported by observations of fresh prey commonly found in the stomachs of spring Chinook caught at the mouth of the Klamath River.

Spring Chinook face energetic trade-offs in deciding when to initiate upriver migration. High flows during peak spring snowmelt result in higher water velocities, which greatly increase the energetic costs of swimming and decrease travel rates for spring Chinook that choose or are forced to begin migration early in the season. Conversely, spring Chinook that choose or are forced to begin migration late in the season face increased risks of thermal stress, energy depletion, or migration delays due to higher water temperatures and/or excessively low flows. The run-timing of spring Chinook is generally a compromise between these costs and risks; a compromise that is accomplished by migrating on the descending limb of the snowmelt peak, which is analogous to migrating during the closing window of opportunity prior to the onset of adverse summer conditions. This strategy also allows maximization of ocean feeding and thus increased body energy content. This compromise was evident in the timing of initiation of upriver migration for tagged spring Chinook, which began on either 6/2/04 or from 6/16/04 to 6/24/04, a relatively narrow span. Conditions in the lower Klamath River during that period where characterized by the falling limb of the snowmelt peak (Figure 5) and rising temperatures that had recently climbed above 18^{o}C for the first time in 2004 (Figure 13). This period also corresponded to the Trinity spring bench release from Lewiston Dam which stabilized on 6/19/04 at ~2,000 cfs and ramped down to summer base flow levels from 7/10/04 to 7/21/04 (Figure 11).

No Chinook were tagged from 6/19/04 to 6/30/04 reflecting a lull in the run and the onset of high river temperatures in excess of the thermal threshold for migration inhibition. This break in the run separated true spring Chinook from summer run 'spring' Chinook.

Summer Chinook Migrants (*n*=7) – Run-timing

Summer Chinook migrants were tagged starting in July after the onset of river temperatures in excess of 22^{o}C (Figure 13). These Chinook held in the estuary/nearshore until river temperatures began dropping rapidly on 8/1/04 due to a cold weather front. Thus the fish tagged earliest among this group (149.413; 7/9/04), had the longest estuary/nearshore residence at 22.6 days. Conversely Chinook 149.494 and 149.515 were tagged on 7/26/04 and resided in the estuary/nearshore for 7.6 and 6.4 days respectively. The last fish (149.063) in this group was tagged at Blue Hole on 8/18/04 and likely missed the window of cooler temperatures during early August and was forced to seek refuge at the Blue Creek thermal refuge until temperatures cooled again starting 8/26/04. All of the Chinook in this group migrated to the Trinity River. The primary presumed benefit of the run-timing strategy of this group is extended ocean feeding and the primary presumed costs are increased exposure to high water temperatures and increased risk of excessive delays in the onset of upriver migration.

Understanding the reasons for such an apparently high risk strategy requires understanding the evolutionary and historical context. Historically there was a large summer Chinook run in the KRB, as determined by Yurok Tribal oral histories and analysis of 1920's catch records from the estuary by Snyder (1931). Whether these fish were truly 'summer' run or 'early fall' run was debated, but regardless large numbers of Chinook entered the river in July and August. This harvest data was collected after the extirpation of Chinook populations in the upper KRB above Copco Dam but prior to construction of dams on the Trinity River and these fish were of unknown stock origin.

However, it is unlikely that these fish were of Trinity River stock because the pre-dam upper Trinity River experienced high temperatures and extremely low flows (e.g. <100 cfs) during the summer and early fall (TRFE 1999), which presumably blocked Chinook migration to spawning areas until the onset of fall rains. Such a scenario is also consistent with the later run-timing of Trinity fall Chinook as compared to Klamath fall Chinook. Post-dam conditions in the upper Trinity River are very different with cold temperatures and flows adequate for rapid migration occurring throughout the summer and fall. This relatively new situation, coupled with weather-induced cooling events, allows adult Chinook to migrate rapidly through the warm reaches of the lower Klamath and Trinity Rivers to holding areas in the cool-reach below Lewiston Dam.

Weather-induced cooling events have occurred consistently during the first week of August in all study years with the resulting rapid upriver migration of summer Chinook. Preliminary analysis of air temperature records from 1903 to 2004 at Orleans (Klamath RKM 95) and 1908 to 1955 at China Slide (Trinity RKM 146) show a greater than 50% probability of such a weather event occurring between late July and late August. The relatively consistent long-term occurrence of weather-induced cooling events during the summer in the KRB suggests that appropriate adult Chinook stocks may have evolved run-timing to take advantage of this opportunity. As previously discussed, this was likely not applicable to Trinity River stocks. Klamath stocks that were migrating far upriver may have taken advantage of the weather-induced cooling to begin migration, using thermal refuges as needed, in order to reach spawning grounds in time for an earlier than typical spawn date due to the colder incubation temperatures of the upper KRB. This scenario is supported by the early onset of cool fall water temperatures that occurred prior to the construction of dams/reservoirs on the mainstem Klamath River (Bartholow 2005), which would have favored an earlier run-timing for Klamath fall Chinook.

While the historical summer Chinook run may have been dominated by the furthest upriver Klamath fall Chinook stocks, the summer run of today is dominated by Trinity 'spring' Chinook based on coded wire tag recoveries in the estuary and radio telemetry tagging results (Table 4). With one exception thus far, all summer Chinook migrants have migrated to the Trinity River and spawned during the 'spring' Chinook spawning window including migrants spawned at the Trinity River Hatchery. Such 'spring' Chinook with summer run-timing could be adapting to post-dam conditions in the Trinity River but could also be the result of crossbreeding of spring and fall Chinook in the upper Trinity River producing a genetically controlled intermediate run-timing.

This possibility is given credibility by the narrow two-week separation in the spawning of spring and fall Chinook at the Trinity River Hatchery along with the spatial and temporal overlap of spring and fall run natural spawners in the upper Trinity River due to truncation of spring Chinook spawning distribution by the dams. The interbreeding of spring and fall Chinook has caused problems with genetic homogenization and shifted run-timing leading reduced spawning success elsewhere, must notably the Feather River hatchery in the Sacramento River system (Campbell and Moyle 1991; Williamson and May 2005). Genetic analysis may provide may eventual provide more definitive data on the degree to which crossbreeding is occurring, but this trends observed in 'spring' Chinook run-timing warrant further investigation and management actions.

Klamath Fall Chinook Migrants (*n*=10) – Run-timing

No adult Chinook were captured for tagging from 7/29/04 to 8/15/04 reflecting a lull in the run. Subsequently a new pulse of fish entered into the estuary with high numbers of Chinook being tagged starting on 8/16/04. Between this date and 9/6/04, all Chinook tagged in the estuary that survived to migrate beyond Weitchpec continued up the mainstem Klamath River, primarily to Iron Gate/Bogus Creek spawning area. Of the three adult Chinook tagged at Blue Creek on 8/18/04, one fish (149.270) migrated into the Klamath River above Weitchpec, eventually spawning in the Iron Gate/Bogus Creek area coincident with Klamath fall Chinook migrants, thus this fish is included in this group and likely represented the earliest migrants in this run of Chinook.

Residence times in the estuary/nearshore for all Chinook that were tagged during this period and survived to emerge from the estuary ranged from 1.0 to 23.3 days with a mean of 9.0 days. The timing of emergence from the estuary/nearshore and commencement of upriver migration for this group occurred between 8/21/04 and 9/22/04 with a mode of 9/1/04. The Trinity fall pulse flow arrived to the estuary on 8/24-8/25/04 with a peak on 8/29/04 (Figure 4). While the timing of commencement of upriver migration from the estuary generally overlapped with the Trinity fall pulse flow, there are several important facts that show it was not the causative variable in the initiation of Klamath fall Chinook upriver movement.

First, one tagged Chinook (149.714) left the estuary on 8/21/04 prior to arrival of the Trinity fall pulse flow. The emergence timing of this migrant corresponded with a decreasing trend in river temperatures caused by a cold weather front that moved into the region on beginning on 8/20/04. This occurred during a period of stable flows and shows that at least some adult fall Chinook migrated strictly in response to changes in water temperatures.

Second, the Trinity fall pulse flow was intended to reach the estuary just prior to peak run-timing (commencement of upriver migration) for fall Chinook and continue until the majority of the fall run was expected to have arrived. Based on coded wire tag recoveries in the lower Klamath River sport fishery from 1988 to 2001, the peak run-timing for Klamath stock (i.e. Iron Gate Hatchery) fall Chinook occurs on Julian Week (JW) 35 (week beginning on approximately the last week of August to first week of September) (Figure 54). Specifically for 2004, estuary entry based on coded wire tag recoveries of Iron Gate Hatchery Chinook in Yurok Tribal estuary harvest occurred from the weeks beginning on 8/8/04 (approximately JW 32) to 8/22/04 (approximately JW 34) with a bi-modal peak (Figure 57), and commencement of upriver migration based on Iron Gate Hatchery coded wire tag recoveries in the sport creel in the lower Klamath River occurred primarily from JWs 34 (8/20/04) to 38 (9/17/04) with a peak on JW 36 (9/3/04) (Figure 57). In comparison for tagged Klamath fall Chinook migrants in 2004, the median date of estuary entry timing was 8/21/04 (JW 34) and the median date of commencement of upriver migration was 9/2/04 (JWs 35-36), excluding the two Klamath fall Chinook migrants tagged at Blue Creek or after September. Thus the run-timing of Klamath fall Chinook in 2004 was within their normal range and was apparently not shifted to an earlier or later date due to the Trinity fall pulse flow. Further evidence supporting the lack of behavioral response to the pulse flow is provided in later sections.

Viewed in an evolutionary context the general non-response of adult Chinook to the Trinity fall pulse flow makes sense; long term average conditions do not include pulse flow type events during the summer/fall baseflow period. Such artificial pulse flows are outside of the adaptive history of KRB fish and are likely viewed by migrating salmon as an unpredictable and ephemeral flash flood and treated accordingly. Using this logic, the peak run-timing (commencement of upriver migration) of JWs 35-36 observed for

Klamath fall Chinook should correspond to a predictable set of conditions that are favorable to such timing. During this period flows are typically stable although flow releases from Iron Gate Dam usually increase by approximately 10%, and there is a very predictable decrease in water temperatures due to seasonal changes in the amount of solar radiation (height and angle of the sun, length of daylight) and daily low air temperatures, which results in a predictable cooling trend in water temperatures throughout the KRB. Preliminary analysis of water temperature records shows the last day with a mean daily water temperature ≥22^{o}C consistently occurs in the first week of September (JWs 35-36).

Trinity Fall Chinook Migrants (*n*=5) – Run-timing

None of the Chinook tagged from 9/9/04 to 9/14/04 emerged from the estuary thus their destinations are unknown, but were likely primarily Trinity fall Chinook based on coded wire tag recoveries in 2004 (Figures 52 and 57). The first tagged fall Chinook that migrated up the Trinity River was tagged on 9/16/04, with four more Trinity fall Chinook migrants tagged subsequently (median of 9/22/04 or JW 39). Peak run-timing of Trinity fall Chinook in the lower Klamath River occurs during JW 39 (and to a lesser extent JW 38) on average based on coded wire tag recoveries in the sport fishery. Thus, the run-timing of Trinity fall Chinook migrants in 2004 matched that of the average peak for Trinity fall Chinook from 1988-2001, but was later than the coded wire tag peak observed in the estuary and lower Klamath River in 2004 by approximately two weeks.

The Trinity fall pulse flow ended in the lower Klamath River on 9/15/04, prior to the tagging of any of the five Trinity fall Chinook migrants and during the week of peak Trinity fall Chinook coded wire tag recoveries in the lower Klamath River. Thus the Trinity fall pulse flow was ending just as the majority of Trinity fall Chinook were commencing upriver migration, which was within the range of normal run-timing, suggesting that the pulse flow did not induce an early run-timing or otherwise noticeably impact Trinity fall Chinook migration behavior. Again the general non-response to the Trinity fall pulse flow makes sense given the lack of such over the long term evolutionary history of this group of Chinook.

Run-timing Summary

In a review of run-timing adaptations of adult sockeye to prevailing thermal regimes, Hodgson and Quinn (2002) found that populations in areas of moderately high thermal regimes (annual mean maximum >19^{o}C) displayed two basic strategies of run-timing to compensate: enter freshwater early in the season before the onset of high temperatures or wait until late in the season after the cessation of high temperatures. These run-timing strategies are exemplified by most spring and fall Chinook in the KRB, however, the latter portion of the spring run (i.e. Trinity summer Chinook) plus the early portion of the Klamath fall Chinook run violate this strategy and enter the river during the hottest months of July and August.

In the case of Trinity summer 'spring' Chinook, this apparently high-risk strategy could have evolved in response to post-dam conditions in the upper Trinity River coupled with crossbreeding of spring and fall Chinook due to truncation of habitat and hatchery practices. The extent to which each of these factors is responsible for this summer run-timing is currently unknown; however, genetic analysis shows the best promise for unraveling contribution of these potential causative factors.

In the case of Klamath fall Chinook, their early fall run-timing allows them to enter freshwater and begin upriver migration, albeit at a slow rate, as soon as river temperatures fall below the migration inhibition threshold (e.g. MDT ≥22ºC). This is a necessary strategy for Klamath fall Chinook given their migration path and the relatively unique thermal regime of their spawning grounds. As a consequence of their summer run-timing (river entry), both of these migrant groups displayed the longest estuary/nearshore residence times, the highest level of thermal refuge use, and relied upon adjustments in travel rates to compensate for migration delays.

The timing of salmon migrations evolve under the influence of the hydrologic and thermal regimes of their home river systems and oceanic ranges (Groot and Margolis 1991). As the average conditions in these habitats change over time, run-timing will need to adapt in order ensure continued reproductive success. Some changes will be advantageous and others will be detrimental, but most important is the rate of environmental change in comparison to the rate of evolutionary response; environmental changes that outpace adaptive response are the fundamental driver of extinctions. In the case of KRB adult Chinook, as the rate of change increases and migratory windows shrink, the margin of error in run-timing decreases resulting in the risk of catastrophic failures of certain runs or stocks. The margin of error in management actions, in particular decisions regarding water quantity and timing, will also decrease thus managers need to account for these changing dynamics and compensate for detrimental changes. What works today will not necessarily be sufficient in the future, especially given the inertia of global climate change. Thus it is critical that biologists, managers, and policy makers in the KRB devise strategies to improve migration success in the near term and meet the coming challenge of global climate change in the long term.

4.3.2 Travel Rates

Travel rates of migrating salmon are determined by water velocities, swim speeds, and swimming duration over a given distance. Thus two equal travel rates over a given reach could be the result of different combinations of water velocities and swim speeds with resulting differences in energetic expenditures even with equivalent water temperatures (Hinch and Rand 1998). Conversely, different travel rates can require the same energetic demand due to equivalent swim speeds under different water velocities or water temperatures. Flow volume and channel characteristics (i.e. gradient, channel width, and roughness) control water velocities and swim speed is a function of fish swimming behavior. Swimming behavior is determined by a suite of potential factors including distance of migration, stage of maturation, water volume and velocity, water temperature, photoperiod, and fish energy density. Thus travel rates provide an excellent metric of behavioral response to a suite of interacting variables for migrating adult Chinook. For the purpose of this study, travel rates are displayed as movement histories (location via RKM versus date).

Migrating adult salmon have been shown to minimize energy expenditures by using advantageous currents such as eddies, micro-velocity breaks, and boundary layers (Rand and Hinch 1998, Hinch and Rand 2000). Salmon populations undertaking long or difficult migrations (e.g. upper Yukon, Fraser, and Columbia Rivers) are the most efficient with energetic swimming expenditures due to the high risk of energy exhaustion, whereas populations that have shorter and easier migrations are relatively inefficient swimmers (Bernatchez and Dobson 1987). KRB Chinook stocks appear to qualify for the latter category (especially since their range has been truncated by dams), which should allow them greater flexibility with swim speeds and swimming behaviors such as swimming rapidly through reaches of adverse conditions, retreating downriver extensively if needed, or delaying upriver migration until better migratory conditions develop. All of these behaviors have been observed among tagged adult Chinook during the course of this study.

Results from the 2004 study show that travel rates were highly variable among migrants and for a given migrant and ranged from zero during periods of holding to values in excess of 50 km/d in certain reaches. However, several general movement patterns did emerge: 1) Moderate travel rates typically consisted of periods of relatively swift upriver movement followed by periods of restful holding (such as at night or mid-day). Evidence for this behavior was provided by highly variable travel rates at finer temporal and spatial scales. Also numerous observations were made during manual tracking of tagged Chinook holding a stationary position but would kilometers upriver by the next day. 2) The highest travel rates (e.g. summer Chinook migrants) were accomplished by both swimming fast and foregoing rest stops. Such relatively continuous swimming only occurred during brief cooling events when water temperatures were otherwise above the thermal threshold for migration inhibition. 3) Extremely slow travel rates (i.e. <5.0 km/d) were due to extended periods of holding in reaches such as the estuary or lower Klamath River, or were due physically demanding passage in high gradient reaches such as the Burnt Ranch Gorge of the Trinity River (gradient of 100 ft/mile). 4) Travel rates (magnitude and longitudinal patterns) were consistent for a given migrant group, with the exception of migrants tagged at the Blue Creek thermal refuge. Since migrant groups are subject to similar environmental conditions during migration and are presumably genetically similar, examination of travel rates (movement histories) within these groups is highly informative in determining causative factors of migration behavior.

Spring Chinook Migrants – Movement Histories

Spring Chinook migrants (n=3) all exhibited a pattern of increasing travel rates that peaked (13.0 to 19.3 km/d) in the vicinity of Weitchpec followed by a gradual decrease to a steady moderate pace (7.5 to 11.5 km/d) until arrival to over-summering reaches (Figure 22). The difficult passage through Burnt Ranch Gorge slowed all Trinity River migrants, but spring Chinook migrants to a greater extent due to the higher flows. This movement pattern matches the constraints imposed by their run-timing strategy, which results in the need to travel rapidly (but not at maximum sustained swimming speeds) through downriver reaches in order to access headwater holding and spawning areas during the closing window of passable river conditions. Spring Chinook over-summer holding and spawning areas remain cool throughout the summer, functionally serving as thermal refuges when viewed on the watershed scale.

Summer Chinook Migrants – Movement Histories

After initiating upriver migration from the estuary with the onset of the early August cooling event, this group of migrants (*n*=7) traveled through the lower Klamath and Trinity Rivers at the fastest rate (i.e. 20-35 km/d) observed among all 2004 migrants (Figure 23). Travel rates dropped precipitously upon entering the steep Burnt Ranch Gorge but were still the fastest observed for all Trinity River migrants in 2004. After clearing Burnt Ranch Gorge, travel rates remained relatively high until reaching pre-spawning holding areas or spawning grounds. In simple terms these migrants held in the estuary/nearshore until a window of opportunity presented itself in the form of sharply falling water temperatures, at which point they sprinted upriver with little rest until reaching cool holding areas in the upper Trinity River (starting around RKM 187). These migrants passed numerous thermal refuges along the way, deciding instead to continue onward without stopping. This strategy paid off given that falling water temperatures only lasted for approximately six days (minima of 20.0^{o}C at RKM 102 on 8/6 at 9am for example). Despite the high temperatures endured by these migrants during their upriver sprint (e.g. body temperatures up to 24.8^{o}C), their high rates of travel served to greatly reduce their overall thermal experience during migration from the estuary to the upper Trinity River. For example, the mean thermal experience of a typical spring Chinook migrant (149.204) from the estuary to the upper Trinity River (RKM 183) was 16.8^{o}C compared to a mean thermal experience of 18.7^{o}C over the same migration path for a typical summer Chinook migrant (149.413). This is a difference of only 1.9^{o}C despite a difference of 4.4^{o}C in the maximum temperature experienced. Adjustment of travel rates and the ability to swim rapidly through reaches of high temperatures is thus an important tactic for minimizing thermal exposure and accommodating a summer run-timing.

Klamath Fall Chinook Migrants – Movement Histories

This group of migrants (*n*=10) exhibited a pattern of slow movement (2.0 to 10.9 km/d, mean of 4.9 km/d) through the lower Klamath River with a sharp rise (approximately 260%) in travel rates after entering the mainstem Klamath River above Weitchpec, which steadily increased to a peak (5.4 to 26.7 km/d, mean of 12.8 km/d) just before reaching spawning grounds in the Iron Gate/Bogus Creek area (Figure 24). This movement pattern was profoundly different than spring or summer Chinook migrants. At first glance the slow travel rates through the lower Klamath River are perplexing, but a closer examination of the environmental context under which these stocks evolved provides important explanatory clues.

Klamath fall Chinook travel approximately 300 km to reach spawning grounds, the longest in the KRB (although historically Chinook migrated much further in the KRB, such as those that spawned in the tributaries to Upper Klamath Lake). Klamath fall Chinook like all KRB salmon must reach their spawning grounds at a certain date and in sufficient fitness to spawn successfully, but unlike other KRB stocks, the distance to their spawning grounds and its thermal regime results in the need to begin migration earlier and to be more careful in conserving energy than other fall stocks (e.g. Trinity). For these Chinook, the timing of initiation of upriver migration is constrained by high water temperatures (≥22^{o}C), which typically prevail throughout the KRB until the first week of September, and their spawning date is constrained by stock specific incubation requirements with the goal of having optimal fry emergence timing. Thus spawning usually peaks during mid-October with emergence occurring in late-March in the Iron Gate/Bogus Creek area. Between these constraints, Klamath fall Chinook must migrate 300 km from the mouth of the Klamath to their spawning grounds, thus the need to begin migration as soon as possible after water temperatures cool below the migration inhibition threshold. As expected these Chinook generally commence upriver migration once this occurs, as evidenced by the peak run-timing of Iron Gate Hatchery fall Chinook as determined by coded wire tag recoveries and the movement timing of tagged Klamath fall Chinook migrants. Subsequent upriver movement would be expected to be steady and rapid to spawning grounds; however this was not the case. After initiating upriver migration, travel rates between the estuary and Weitchpec for this group were on average the lowest observed (mean 3.7 km/day) among all migrant groups in 2004, primarily due to extended periods of holding in areas with deep pools above Blue Creek such as the vicinity of Moore's Rock (RKM 43).

Several additional constraints provide possible explanations for this unexpected behavior. First, advanced maturation must occur in freshwater or gonads will be damage (Wertheimer 1984). This constraint provides an incentive not to linger in the ocean too long, and the high concentration of predators in the estuary provides an incentive to migrate upriver beyond the estuary perhaps as far as Blue Creek. Second, an incentive not to continue migrating beyond the Klamath River below Weitchpec is provided by the fact that water temperatures in the mainstem Klamath River increases upriver with a maxima midway between the mouth and Iron Gate Dam (Bartholow 2005). Fish that migrate upriver of Weitchpec too early run the risk of migration delays and greater thermal stress as evidenced by Chinook 149.270, which migrated approximately two to three weeks earlier than any other Klamath fall Chinook migrant and did indeed experience higher temperatures and migration delays before and after passing Weitchpec. While Chinook 149.270 ultimately arrived to spawning grounds, it was passed enroute near RKM 170 by three Klamath fall Chinook migrants that commenced upriver migration from the estuary later (~9/1/04) and passed Weitchpec later (~9/16/04) than Chinook 149.270 (Figure 24). Thus it may be bioenergetically less demanding to hold in the lower Klamath River until basin-wide season cooling occurs around mid-September.

The slow movement through the lower Klamath River displayed by Klamath fall Chinook migrants could not have been entirely driven by upriver trends in temperature however because Chinook 150.923, which was tagged on 10/1/04, displayed the same general movement pattern including extended holding in the lower Klamath River. This suggests that a physiological component relating to state of maturation and or energetic content may also be involved in this holding behavior. This fact also suggests that the

Trinity fall pulse flow was not responsible for the slow movement in the lower Klamath River observed among these migrants.

Regardless of the ultimate reasons, this behavior appears to be a strategy that makes the best of competing constraints given their migration path and maximizes survival in the face of the long term average conditions. One important negative implication of this behavior is that it increases the risk of fish-to-fish pathogen transmission and disease outbreaks for this stock of fall Chinook, such as occurred in 2002 with *Ich*. Fortunately this risk can be managed by increasing river discharge (e.g. greater than 2002 flows) starting in mid-August when these fish begin entering the estuary because increasing water velocities and turnover rates has been shown to be the most effective method for preventing or reducing *Ich* infection and mortality (Bodensteiner et al. 2000).

Trinity Fall Chinook Migrants – Movement Histories

Travel rates for these migrants (*n*=5) were overall the most moderate of all migrant groups. Movement was relatively steady with three potential exceptions: the lower Klamath River between Blue Creek and Weitchpec, the Willow Creek weir, and Burnt Ranch Gorge (Figure 25). The amount of detection for most of these migrants was insufficient to determine finer scale movement through these reaches (e.g. constant moderate travel versus extended holding with brief rapid travel). However, one migrant (150.654) had sufficient detections at the Willow Creek weir area and was delayed for a period of nine days, and another migrant (150.274, female) had sufficient detections in the lower Klamath River to determine that it held extensively (approximately two weeks) from Blue Creek to Moore's Rock in manner similar to Klamath fall Chinook migrants.

The fact at least some Trinity fall Chinook migrants also exhibited slow movement with extended holding in the lower Klamath River provides supporting and refuting evidence for various explanations of this behavior. First, it shows that the driver of this behavior is common to Trinity and Klamath fall Chinook, which implies it could be related to conditions in the lower Klamath River below Weitchpec, to possible similarities in the spawning grounds of these stocks, or common to fall Chinook in general. Bioenergetics in terms of swimming expenditures at different temperatures coupled with maturation thresholds and predator avoidance are still possible drivers of this behavior, even if an upriver warming trend is not.

Combining these elements produces the following theory consistent with this behavior: 1) Fall Chinook have a threshold of maturation which motivates entry into freshwater in order to avoid damage to gonads from advanced maturation in salt water; 2) Predation (pinnipeds and humans) in the estuary and lowermost Klamath River propels fall Chinook past Blue Creek where numerous deep pools and poor water clarity provide excellent holding habitat; 3) An incentive to hold in this area (Blue Creek to Weitchpec) is provided by the reduced energetic costs of waiting to continue the active swimming of upriver migration until water temperatures cool further (this component could be especially important to females); and, 4) Once a certain threshold of maturation is reached, fall Chinook can delay no longer and need to resume upriver migration in order to reach spawning grounds in time to successfully spawn. This theory is consistent with the observed variation in the amount of holding and travel rates in the lower Klamath River because the stage of maturation varies among individuals within a given run of salmon (Groot and Margolis 1991). It is also consistent with the fact that this behavior occurs among both Klamath and Trinity fall Chinook migrants, as this theory does not depend on stock specific migration paths. Additionally, fall Chinook have greater flexibility in travel rates (i.e. passage duration) than spring or summer Chinook through the lower Klamath River: spring Chinook must reach pre-spawn holding area before the window of passable river conditions closes, summer Chinook must sprint upriver during brief cooling events, whereas fall Chinook are constrained only by the need to arrive before they are too ripe and before the window of acceptable spawning dates closes. Indeed the only times spring or summer Chinook have been observed holding in the lower Klamath River was in thermal refuges during periods when water temperatures exceed the migration inhibition threshold, whereas no use of thermal refuges has been documented among fall Chinook holding in the lower Klamath River.

Flow in the lower Klamath River cannot be considered a significant factor in producing this behavior because holding among fall Chinook in the lower Klamath River has been observed at variety of flows, including during (e.g. 2004 mean 3,615 cfs) and after (e.g. 2004 mean 2,685 cfs) the Trinity fall pulse flows for both 2003 and 2004.

Flows in the Trinity River might have had an evolutionary influence on Trinity fall Chinook migration strategies in the lower Klamath river as extremely low flows prevailed in the pre-dam upper Trinity River during the summer and fall until autumn rains produced significant runoff.

Travel Rate Summary

Travel rates are an excellent metric of migration behavior since they reflect behavioral response to a suite of influencing variables and capture multiple tactics of interest including holding and variation in swim speeds associated with specific reaches of difficult or stressful passage. Travel rates observed among tagged Chinook were consistent within migrant groups and are generally explained within an evolutionary context by the constraints imposed by run-timing and the associated environmental conditions. High travel rates accomplished via increasing swim speeds and reducing the length and frequency of rest stops are an important tactic for reducing thermal stress and compensating for migration delays, both of which were especially important for summer Chinook.

The theory set forth herein for the extended holding and associated slow travel rates in the lower Klamath River exhibited by both Klamath and Trinity fall Chinook migrants can be tested with future study results, especially with data from a non-fall pulse flow year, but regardless of the details, slow migration through the lower Klamath River by fall Chinook appears to be part of a strategy that makes the best of competing constraints and maximizes survival and reproductive success in the face of the long term average conditions. This behavior does have negative ramifications in the form of increasing the risk of fish-to-fish transmission of disease pathogens such as *Ich*, however this risk can be managed by increasing river discharge in order to dilute pathogen concentrations and reduce infectivity. This was the primary unintended positive consequence of the Trinity fall pulse flow.

The Trinity fall pulse flow was, however, ineffective in triggering upriver migration among adult Chinook as evidenced by equivalent movement histories for fall Chinook before and after the Trinity pulse flow and by comparisons of run-timing in 2004 to longer-term averages. The only exceptions were the two migrants tagged at the

Blue Creek thermal refuge, for which the Trinity fall pulse flow provided cooler temperatures allowing resumed upriver migration. The general non-response of adult Chinook to the Trinity fall pulse flow is consistent with the long-term average conditions to which these fish are adapted, conditions that do not include pulse flows of this magnitude or duration.

4.3.3 Behavioral Thermoregulation

Adult Chinook have physiological limits of temperature exposure due to thermal stress, increased metabolic demand, and immune system suppression; factors which reduce the probability of successful migration and spawning (Brett 1979; McCullough 1999). The upper limit of exposure is governed by the physiological limits of a population or species. Adult Chinook have been observed tolerating temperatures as high as 25-27^{o}C for brief periods in other rivers (as cited in Bartholow 1995); however, at a certain threshold of temperature migratory movements become too costly and the majority of individuals will hold and/or seek cooler water. This threshold represents is based on behavioral decisions of individual fish. Thus the thermal threshold for migration inhibition will vary among individuals within a population, most likely following a normal distribution.

Like all poikilotherms, Chinook salmon have no physiological mechanisms to control their body temperature and therefore will be the same temperature as their surrounding environment. Thus Chinook salmon can only control their body temperature by physically locating themselves in bodies of water with specific temperatures. Termed behavioral thermoregulation, one form of this is residing in pockets of cold water in areas of high water temperature, such as during periods of migration inhibition or over-summer holding. Such pockets of cold water are termed thermal refuges and are formed by a variety of physical processes.

In the KRB, use of thermal refuges by adult Chinook has been previously observed via direct snorkel observations and telemetry results from previous study years. Consistently used thermal refuges consisted of cold water tributary confluences with mainstem rivers. Popular thermal refuges have favorable characteristics of temperature and depth, plus morphologic features that deflect river currents and minimize mixing.

The later in the most commonly shared characteristic among popular thermal refuges in the KRB. Notable examples include Blue, Hopkins, Bluff, Crapo, Horse Linto, and Madden Creeks. This is consistent with the findings of McIntosh and Li (1998) who conducted a search for cold water pockets in the mid-Klamath River in 1997 and found them only in conjunction with tributary confluences. Other types of thermal refuges frequently used include the salt wedge of the estuary, the hyporheically fed Blue Hole associated with Blue Creek, and cool water reaches such as occurs in mountainous headwaters and below Lewiston Dam. Stratified pools only occur in extremely low flow setting with large volume pools such as in the South Fork Trinity River.

In 2004 the most used thermal refuge by tagged Chinook was the estuary/nearshore. Cold water in the estuary is provided by the salt wedge, which is formed by tidal, hydrologic, and morphologic characteristics common to lagoon type estuaries and is most extensive during the summer, providing the largest volume of cold water holding habitat in the KRB aside from headwater areas in mountainous tributaries and the upper Trinity River.

Eighty two percent of the 33 Chinook for which definitive data was available resided in the estuary/nearshore residence for longer than 48 hours (Figure 58). Estuary/nearshore residence times determined in this study are minimums since adult Chinook could have been already been in and out of the estuary prior to tagging, and is defined as the period from tagging until movement past the Wakel station at RKM 7, which is just above the upriver terminus of the estuary. Residence in the estuarine salt wedge versus the nearshore ocean can be sometimes be determined by examining archival temperature tag data since each physical habitat has a distinct thermal signature (e.g. see Figure 31). There has been a high level of variability in the temperatures experienced by tagged Chinook holding in these habitats, and how much variability is due to fish movements versus tidal movements of water cannot be determined without direct information of fish locations and movements which is lacking due to the non-detectability of radio transmitters in high salinities. Switching to ultrasonic transmitters for the 2005 study year will hopefully provide data to answer that question.

Based on the telemetry data, the longest estuary/nearshore residence documented was 31.2 days by Chinook 149.114, which was tagged on 7/21/04 but missed the window of opportunity to migrate during the early August weather-induced cooling event and finally commenced upriver migration on 8/21/04 when temperatures began dropping again. Such extended residence in the estuary/nearshore behavior is not anomalous given the substantial percentages of Trinity River Hatchery 'spring' Chinook (i.e. summer Chinook) caught in the estuary into late August (Table 4). Mean estuary/nearshore residence times for the four migrant groups were: 11.7 days for spring migrants, 13.9 days for summer migrants, 9.7 days for Klamath fall migrants, and 3.0 days for Trinity fall migrants. Thus estuary/nearshore residence is greatest during the hottest months of the year as expected but is not entirely driven by thermal migration inhibition as evidenced by the residence times for spring versus Klamath fall Chinook migrants (Figure 58). Holding in the estuary/nearshore prior to commencing upriver migration is due to a suite of potential reasons; such as osmotic transformation, homing, extension of feeding, monitoring of river conditions, and behavioral thermoregulation.

Behavioral thermoregulation at enroute thermal refuges has been documented previously for KRB adult Chinook, including all previous study years. In 2004, brief use (<24 hours) of enroute thermal refuges was documented by primarily summer Chinook migrants at Blue Creek (149.424, 149.714), Mill Creek (149.743), and Tish Tang Creek (149.392, 149.494). Two fall Chinook migrants were documented briefly residing in cooler water at the confluence of Blue Creek (150.274 <4 hours, 149.973 <2 hours). From 2001 to 2003, direct snorkel observations documented large numbers (>500) of adult Chinook seeking refuge in Blue Hole, a hyporheically fed side-channel pool associated with Blue Creek at RKM 26 (Figure 2), during periods of high water temperatures in July and August. This was not the case in 2004, apparently due to a reduction in depth of the already shallow entrance to Blue Hole. During the low flows of summer, the long stretch (~30 m) of water no deeper than 20 inches at the entrance apparently behaviorally inhibited adult Chinook movement into Blue Hole as evidenced by the lack of Chinook in Blue Hole coupled with observations of schools of adult Chinook holding below the entrance in slightly deeper water. Adult Chinook were also observed residing in the thermal refuge at the mouth of Blue Creek.

All spring and summer Chinook migrants that survived to reach holding areas in the upper Trinity River relied upon cool water reach that extends downriver from

Lewiston Dam (RKM 253) to the vicinity of Pigeon Point (RKM 187) for pre-spawn holding (see water temperatures in Figure 17). Besides allowing a summer run timing for a portion of 'spring' Chinook, this cool water reach is critical to the success of Trinity River spring Chinook stocks and is a topic that needs further evaluation to determine the adequacy of the quantity of quality of holding habitat in this reach.

In summary, thermal refuge use among 2004 migrants was concentrated to the estuary/nearshore along with brief visits to several enroute cold creek confluences. Holding in the estuary/nearshore until physiological or riverine conditions are acceptable for migration is a cornerstone of the migration strategies of KRB Chinook, in particular for fish entering during the hot summer months of July and August. Estuarine residence provides numerous benefits but is not without tradeoffs such as increased predation risk. The limited enroute use of thermal refuges occurred primarily at tributary confluences in the lower Klamath and Trinity Rivers and is analogous to the use of emergency trail shelters. Use of such thermal refuges obviously allows for a reduction thermal stress and energetic demand but can also increase the risk of predation and pathogen transmission. The cool water reach below Lewiston Dam provides one of the largest thermal refuges in the KRB when viewed at the watershed scale and allows migrating summer Chinook migrants to reduce thermal stress by traveling rapidly through the hot lower reaches with assurance of thermal refuge upriver.

Thermal Migration Inhibition Threshold

Unpublished results from the 2002 and 2003 study years indicated that adult Chinook migration in the KRB was inhibited when MDTs ≥22^{o}C, at which point adult Chinook would seek out and reside in thermal refuges or delay migration and continue to hold in the estuary/nearshore. Based on the timing of tagged Chinook movements in comparison to their body temperatures and ambient river temperatures, this relationship generally held true in 2004 except that tagged Chinook were observed migrating at substantially higher real-time body temperatures (up to 24.8^{o}C) and MDTs up to 23.6^{o}C, but also choose not to commence migration at MDTs as low as 20.9^{o}C. These seemingly contradictory results were explained by examining trends in river temperatures during these observations; the steeper the decline in river temperatures the more aggressive adult

Chinook will be in deciding when to migrate, and conversely they will be more conservative the faster river temperatures are rising.

For example, seven tagged Chinook had been holding in the estuary for up to 22.6 days in July during which time river temperatures in the lower Klamath River had been steadily increasing since 7/12/04 to a seasonal maximum on 7/27/04 (Figure 13). At the end of July and into early August a cold front moved over the KRB resulting in decreasing water temperatures beginning on 7/29/04. All seven tagged Chinook holding in the estuary/nearshore commenced migration during this cooling event. Six of these seven Chinook commenced upriver migration between 8/1/04 00:45 and 8/5/04 09:01 (shaded box A in Figure 59). MDT on 8/1/04 was 23.1^{o}C compared to 23.6^{o}C for 7/31/04 and 24.0^{o}C for 7/30/04. All six migrants successfully completed their migration through the lower Klamath River passing Weitchpec into the Trinity River between 8/2/04 19:00 and 8/8/04 02:32. An interesting related fact is that the last three of these fish to reach Weitchpec (149.743, 149.392, and 149.494) were the only Chinook of these six migrants documented using enroute thermal refuges (in the Hoopa Valley). The seventh tagged Chinook (149.114) commenced upriver migration from the estuary on 8/6/04 at 00:00 but had not yet reached Blue Creek before temperatures began to rise again on 8/7/04 (MDT of 22.0^{o}C); thus this fish subsequently turned around and returned to the estuary on 8/9/04 at 09:03 (shaded box B Figure 59).

A similar situation occurred in late August when this same tagged Chinook (149.114) plus another (Klamath fall Chinook migrant 149.714) commenced upriver migration from the estuary in response to a second cold front that caused river temperatures to begin falling again on 8/21/04. These fish left the estuary on 8/21/04 at 17:21 and 16:45 respectively (shaded box A Figure 60). Mean daily river temperature on 8/21/04 was 23.6 and 23.0 on 8/22/04. It should be noted that all of these migratory events up to this point occurred during periods of stable flows. River flow influences river temperatures and therefore may have had an indirect affect, however flow did not appear to be a causative factor in triggering or impeding upriver migration.

Three other tagged Chinook migrants were holding in the estuary at this time (149.173, 149.564, and 149.622), and two others had recently been tagged at the Blue Creek thermal refuge (149.063 and 149.270), however none of these fish immediately commence upriver migration. The two Blue Creek migrants and Chinook 149.173 commenced upriver migration between 8/25/04 and 8/27/04 at 05:44, which coincided with the arrival of the Trinity fall pulse flow and the tail end of the declining temperature trend (shaded box B Figure 60). All remaining tagged Chinook plus those tagged after 8/21/04 commenced migration no sooner than 8/30/04 at 00:07, at which point river temperatures in the lower Klamath River had begun to decline again (shaded box C Figure 60). MDTs on 8/28/04 and 8/29/04 when no tagged Chinook commenced upriver migration were 20.9°C and 21.2°C respectively.

Migration Threshold Summary

During this study tagged Chinook were observed migrating at surprisingly high real-time temperatures (resulting in body temperatures up to 24.8°C) and commenced upriver migration at MDTs up to 23.6°C, but also choose not to commence migration at MDTs as low as 20.9°C. This is because the thermal threshold for migration inhibition for KRB adult Chinook is trend dependent; the steeper the decline in temperature the more aggressive adult Chinook will be in deciding when to migrate, and conversely they will be more conservative the faster temperatures are rising. Based on all pertinent observations, it can be concluded that the thermal migration inhibition threshold occurs at MDTs of 23.5°C during declining temperature trends and at MDTs of 21.0°C during rising temperature trends. A period of stable water temperatures of MDT of ≥22.0°C are expected to inhibit migration. The upper thermal limit of migration (i.e. 23.5°C) is likely controlled by inflexible physiological constraints, whereas as the range in the trend dependent thermal migration threshold (2.5°C) represents individual behavioral flexibility and is likely an adaptive trait under some degree of genetic control.

Thus this study provides evidence to the contrary (for KRB stocks at least) of the commonly accepted 21ºC definition of the upper limit for adult Chinook migration (McCullough 1999). At least two other studies have identified a migration threshold for adult Chinook higher than 21ºC (22ºC by Fresh 1999; up to 23.9ºC by Fish and Hanavan 1948), and another study identified a trend specific thermal migration inhibition threshold for adult salmonids; specifically 20ºC during rising temperatures and 21.3ºC during falling temperatures for Okanagan sockeye salmon (Hyatt et al. 2003). Thus results from this study are not entirely unprecedented but do show a considerably higher maximum migration threshold than has been previously reported for adult Chinook.

While numerous studies of Chinook migration in other river systems have identified 21^{o}C as the upper thermal limit for migration (McCullough 1999), it is not surprising that KRB Chinook have a higher limit given the thermal regime of the Klamath River, which provides selective pressures for salmonids to extend their physiological and behavioral limits of temperature tolerance. Salmonids are capable of evolving stock specific thermal tolerances (Groot and Margolis 1991), and while numerous biologists have hypothesized that this is the case for Klamath Chinook stocks, Bartholow (1995) found no data to support this hypothesis. Thus the results of this study provide the first empirical evidence that this could be a valid hypothesis, but more importantly provide definitive quantification of the thermal threshold for migration inhibition for KRB adult Chinook.

4.4 Thermal Experience

Behavioral tactics served to reduce the duration and magnitude of high body temperatures experienced by migrating adult Chinook in comparison to ambient river temperatures. This reduces the amount of thermal stress and energy expenditures during migration which provides evidence that the migration strategies of KRB adult Chinook do help to compensate for the high thermal regime and are vital adaptive traits.

The degree to which various behavioral tactics influenced the actual thermal experience of specific fish is best determined by comparing their thermal experience to ambient river temperatures and flow along with the history of their migratory movements on a common axis of date/time. These variables have been graphed for a representative fish from each migrant group in Figures 61 to 64. These graphs generally show that delayed commencement of upriver migration while holding in the estuary/nearshore and adjustment of travel rates were the two most important behavioral tactics influencing thermal experience. Descriptive statistics of temperatures experienced during migration to spawning grounds excluding pre-spawn holding for each of these fish is summarized in Table 6. These numbers should be viewed as approximate values for the purpose of relative comparisons due to differences in migratory routes and the lack of comprehensive statistical analysis for all migrants. The typical spring (149.204) and Trinity fall (150.274) Chinook migrants are very similar in thermal experience for all categories as expected given that the run-timing of both groups avoids seasonal periods of high water temperatures. Typical summer (149.413) and Klamath fall Chinook (149.714) migrants were distinctly different as expected given that these fish entered the river during the summer (July and August), and thus do not avoid of high water temperatures via run-timing adaptations. There are tradeoffs that produce the run-timing for these latter two migrant groups, and the value of behavioral tactics employed is shown by the large difference between maximum versus mean thermal experience. This difference is especially impressive for summer Chinook migrants (e.g. 149.413) and demonstrates the effectiveness of their behavioral tactic in reducing exposure to high water temperatures while migrating during the hottest part of the year.

4.5 Summary of Major Findings

- The fates and destinations of 2004 tagged adult Chinook matched run-timing, harvest, and escapement data for the entire 2004 Chinook run remarkably well.
- The thermal migration inhibition threshold for KRB adult Chinook is trend dependent and occurs at mean daily river temperatures of approximately 23.5^{o}C during declining temperature trends and at mean daily river temperatures of approximately 21.0^{o}C during rising temperature trends. Mean daily temperatures ≥22^{o}C during a stable trend are expected to inhibit migration.
- The most heavily used thermal refuges in the KRB are the Klamath River estuary (i.e. salt wedge and nearshore ocean), cool-water reaches such as the upper Trinity River from Lewiston Dam to the confluence of the North Fork Trinity River, and the Blue Creek refuge complex in the lower Klamath River.
- Enroute use of thermal refuges at other cold-water tributary confluences was minimal, but such tributaries still offer important thermal refuge for migrating salmonids.
- Holding in the estuary and/or nearshore ocean until physiological or riverine conditions are optimal or acceptable for migration is a cornerstone of migration

- Adjustment of travel rates in order to delay migration or speed migration through specific reaches with desirable or adverse conditions is perhaps the other most critically important migration strategy employed by KRB adult Chinook.
- Trinity River ‘spring’ Chinook are compromised of two distinct groups based on run-timing and migration behavior: 1) spring-run fish (May and June) that display classic “springer” behavior by migrating upriver prior to the onset of high water temperatures (i.e. $\geq 20^{o}$C); and 2) summer-run fish (July and August) fish that enter the estuary after the onset of high water temperatures, where they hold until weather-induced cooling allows a brief opportunity to sprint upriver to the upper Trinity River. The extent to which the summer-run group is a product of environmental conditions versus hybridization of spring with fall Chinook is unknown.
- The Trinity River spring bench release delayed the onset of mean daily water temperatures $\geq 22^{o}$C by approximately two weeks in the lower Klamath River below Weitchpec, which extended the migratory window for spring Chinook. The Trinity River spring bench release did not, however, match the timing or ramp down rates of natural snowmelt from unregulated tributaries, which has the potential to miscue biota including adult Chinook.
- Fall Chinook migrated slowly through the lower Klamath River below Weitchpec with slow travel rates and periods of extended holding deep pools from Blue Creek to Weitchpec. This was especially distinctive for Klamath fall Chinook and appears to be an important component of their normative migration behavior but also increases their vulnerability to pathogen (i.e. *Ich*) infection.
- The Trinity River fall pulse flow had a negligible affect on adult Chinook migration behavior, with the possible exception of Chinook holding at enroute thermal refuges, and did not accomplish stated goals of reducing fish densities by inducing upriver migration.
- The Trinity fall pulse flow and higher base flows did reduce the risk of pathogen (i.e. *Ich*) transmission by increasing turnover rates and water velocities. No

repeat of the 2002 fish kill occurred and disease monitoring by the YTFP in the lower Klamath River revealed almost no *Ich* infections.

4.6 Recommendations

- Further explore the relationship between migration rate, thermal experience, environmental conditions and migration success or failure.
- Determine the details of estuarine and nearshore ocean habitat use prior to commencing upriver migration.
- Understand the causes and implications of the Trinity River summer 'spring' Chinook run.
- Refine data collection and knowledge of wild Chinook (e.g. Salmon, South Fork Trinity, Scott, and Shasta Rivers) run-timing and harvest rates.
- Continue to monitor adult Chinook migration behavior in the KRB especially for different water year types, flow prescriptions, and run sizes.
- Protect thermal refuges and the watershed of the tributaries that form them.
- Evaluate the adequacy of the quantity and quality of holding habitat for adult Chinook in the upper Trinity River from the North Fork Trinity confluence to Lewiston Dam.
- Ensure adequate flows during the fall Chinook migration season in the lower Klamath River starting in late August in order to provide turnover rates and water velocities sufficiently high enough to significantly reduce the probability of *Ich* infection and mortality.
- Develop strategies to mitigate for the regional affects of accelerating global climate change.

5.0 TABLES AND FIGURES

Table 1. Radio listening station locations, dates of deployment, and radio telemetry equipment model or vendor for the 2004 adult Chinook telemetry study.

Location	River	RKM	Date In	Date Out	Type
Wakel	Klamath	7.25	5/1/2004	12/6/2004	Orion/ATS
Blue Creek	Klamath	26.0	5/2/2004	12/6/2004	Orion
Lower Weitchpec	Klamath	67.5	5/5/2004	11/3/2004	Orion
Klamath/Trinity Confluence	Klamath	69.25	10/1/2004	12/15/2004	Orion
Bluff Creek	Klamath	80.0	5/7/2004	12/15/2004	Orion
Salmon River at Wooley Creek	Salmon	114	5/10/2004	12/1/2004	Orion
Upper Ishi Pishi Falls	Klamath	108.25	8/27/2004	12/8/2004	Lotek
Happy Camp	Klamath	177.5	8/28/2004	12/8/2004	Lotek
Blue Heron	Klamath	234.25	8/28/2004	12/8/2004	Lotek
Mouth of Shasta River	Klamath	288.5	8/29/2004	12/8/2004	Lotek
Horse Linto Creek	Trinity	101.75	5/5/2004	12/16/2004	Orion
Hawkins Bar	Trinity	132.5	10/15/2004	12/16/2004	Orion
Upper Gray's Falls	Trinity	139.5	5/17/2004	9/20/2004	Orion
China Slide	Trinity	146.0	5/15/2004	10/30/2004	Orion
Junction City Weir	Trinity	207.5	8/31/2004	12/16/2004	Orion

Table 2. Tagging data and the fate or last observation for all tagged Chinook that successfully migrated to tributaries or spawning areas during 2004 (n=25), excluding the 19 Chinook that died, disappeared, or were harvested in the lower Klamath River or estuary. Fish are separated by run timing/stock groups.

Tag Frequency	Tagging Date	Max River Temp C Tagging Day	Fork Length (cm)	Tagging Location	Sex	Fate/Last Observation	River of Fate	Archival Data Recovery
149.204	3-Jun-04	17.0	74.5	Mouth of Klamath	?	sport caught in Browns Canyon RKM 213 on 8/31	Trinity	yes
149.424	8-Jun-04	15.5	80	Mouth of Klamath	?	sport caught at Bucktail RKM 241.5 on 7/27	Trinity	yes
149.093	14-Jun-04	18.6	81	Mouth of Klamath	?	died below Grays Falls RKM 140 by 7/24	Trinity	yes
149.413	9-Jul-04	21.7	83	Mouth of Klamath	?	spawned at Lewiston Hatchery RKM 252 on 9/30	Trinity	yes
149.722	15-Jul-04	22.7	65	Mouth of Klamath	?	spawned at Lewiston Hatchery on 10/4, entered ~9/30	Trinity	no
149.743	15-Jul-04	22.7	74	Mouth of Klamath	?	Tribal caught Hoopa RKM ~90 on 8/6	Trinity	yes
149.392	22-Jul-04	24.9	72	Mouth of Klamath	?	caught Hoopa RKM 86 on 8/7	Trinity	yes
149.494	26-Jul-04	25.8	85	Mouth of Klamath	?	spawned out in Junction City RKM 207 by 10/22	Trinity	yes
149.515	26-Jul-04	25.8	75	Mouth of Klamath	?	tag found near Steelbridge RKM 231 on 11/3	Trinity	yes
149.173	16-Aug-04	23.9	83	Mouth of Klamath	male	spawned out in lower Bogus Cr RKM 309 by 10/29	Klamath	yes
149.564	16-Aug-04	23.9	81	Mouth of Klamath	?	tag found at mouth of Walker Creek RKM 219 on 11/22	Klamath	yes
149.063	18-Aug-04	23.9/18.5	79	Blue Cr. Refuge	?	spawned out lower Junction City RKM 192 by 10/26	Trinity	yes
149.270	18-Aug-04	23.9/18.5	95	Blue Cr. Refuge	?	MIA above Shasta River RKM 288.5 on 10/7	Klamath	no
149.622	19-Aug-04	24.2	75	Mouth of Klamath	?	MIA Iron Gate Dam RKM 310 on 10/5 - hatchery?	Klamath	no
149.714	19-Aug-04	24.2	78	Mouth of Klamath	male	spawned at Iron Gate Hatchery RKM 310 on 10/11	Klamath	yes
149.732	24-Aug-04	22.5	91	Mouth of Klamath	male	spawned out below R Ranch RKM 302 on 10/29	Klamath	yes
149.843	31-Aug-04	22.2	91	Mouth of Klamath	?	spawned below Iron Gate Dam RKM 307 by 11/22	Klamath	no
149.872	6-Sep-04	21.2	67	Mouth of Klamath	?	spawned at Iron Gate Hatchery RKM 310 on 10/13	Klamath	yes
149.973	6-Sep-04	21.2	93	Mouth of Klamath	male	spawned at Iron Gate Hatchery RKM 310 on 10/25	Klamath	yes
150.133	16-Sep-04	20.7	65	Mouth of Klamath	?	Tribal caught in Hoopa RKM 96.5 on 9/9	Trinity	yes
150.274	20-Sep-04	18.4	69	Mouth of Klamath	female	ad clip 1162uu, spawned out Lewiston R1 RKM 249 by 11/23	Trinity	yes
150.654	22-Sep-04	18.3	76	Mouth of Klamath	?	MIA above Junction City Weir RKM 207.5 on 10/26	Trinity	no
150.793	1-Oct-04	18.6	66	Mouth of Klamath	?	above JC RKM 207.5 11/9; returned 11/24, dead RKM 179 12/14	Trinity	no
150.923	1-Oct-04	18.6	72	Mouth of Klamath	?	spawned near Blue Heron RKM 235 in early Dec	Klamath	no
149.453	22-Oct-04	13.4	66	Mouth of Klamath	?	last observed in Burnt Ranch Gorge on 12/8	Trinity	no

Table 3. Summary of several biologically important benchmarks in temperature for five locations in the Klamath River Basin during 2004.

Water Temperature Monitoring Location	First Day Over MDT 20C	Last Day Over MDT 20C	First Day Over MDT 22C	Last Day Over MDT 22C	# Days MDT 22C or >	Max MDT C & Date	Annual Max C & Date
Klamath River at RKM 26	6/28	9/16	7/18	8/24	37	24.5, 7/28	26.0, 7/27
Klamath River at RKM 81	6/24	9/13	7/4	9/1	38	25.2, 7/28	26.4, 7/26-7/28
Trinity River at RKM 102	7/16	8/24	7/21	8/22	30	24.4, 7/28	25.6, 7/27
Trinity River at RKM 187	NA	NA	NA	NA	0	19.0, 7/26	21.5, 7/26
Klamath River at RKM 153	6/17	9/13	6/29	9/1	58	25.9, 7/25-7/26	26.8, 8/12-8/13

Table 4. Percentage of the total Yurok Tribal harvest of adult Chinook in the Klamath River estuary comprised by Trinity River Hatchery spring Chinook based on expansion of coded wire tag recoveries. Source: YTFP.

Week Ending	2000	2001	2002	2003	2004
30-Jul	68%	96%	100%	100%	89%
6-Aug	94%	84%	86%	55%	44%
13-Aug	96%	82%	52%	37%	2%
20-Aug	NA	55%	27%	4%	NA

Table 5. Summary of descriptive statistics of thermal experience (body temperatures) during migration (excluding pre-spawn holding) for a representative Chinook from each migrant group.

Fish	Group	Mean C	Variance C	Max C	Max - Mean C
149.204	Spring	14.6	9.9	20.0	5.4
149.413	Summer	16.6	14.8	24.4	7.8
149.714	K Fall	18.8	4.5	24.0	5.2
150.274	T Fall	14.5	11.3	18.8	4.3

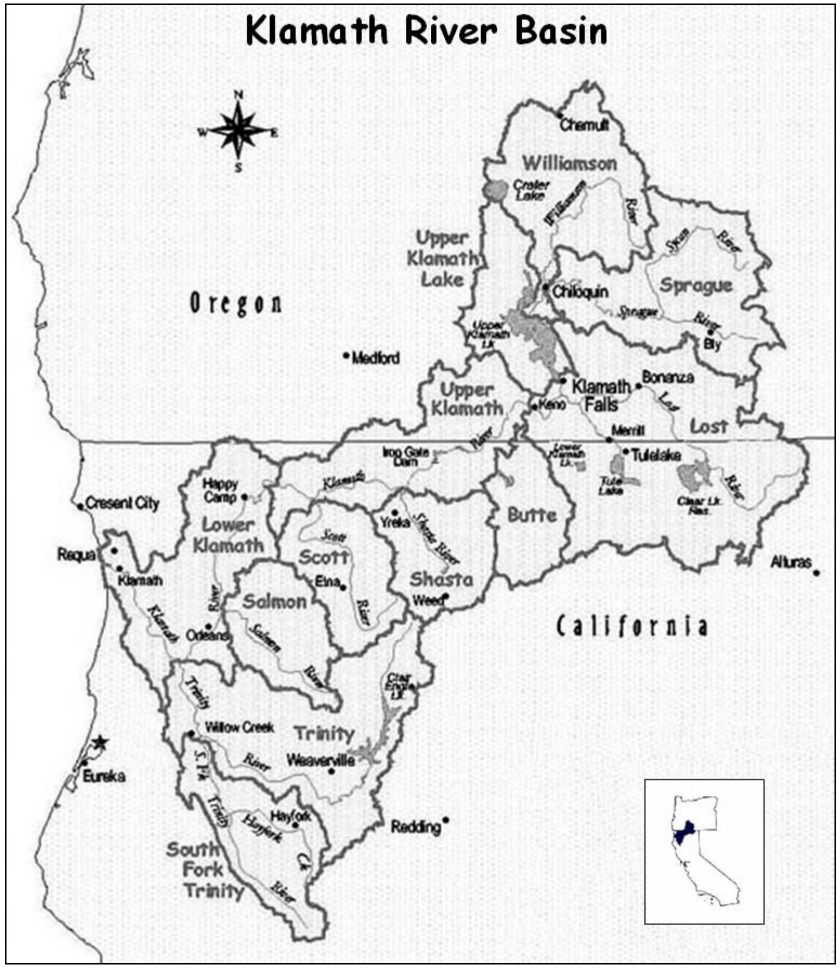


Figure 1. The Klamath River Basin of northern California and southern Oregon with sub-basins. Iron Gate Dam on the mainstem Klamath and Trinity Dam on the mainstem Trinity River both currently limit the upriver distribution of anadromous fishes within the watershed. Historically spring Chinook were distributed throughout large areas of the Basin, presently however, 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 September of 2004. The Klamath River is flowing from up to down with Blue Hole left of center and Blue Creek joining the Klamath River at the top center of the picture. The configuration in 2004 was very similar to 2003 and 2002, except that the outlet of Blue Hole was shallower in 2004. Photo by the author; pilot Rich Anthis CA Department of Fish and Game.

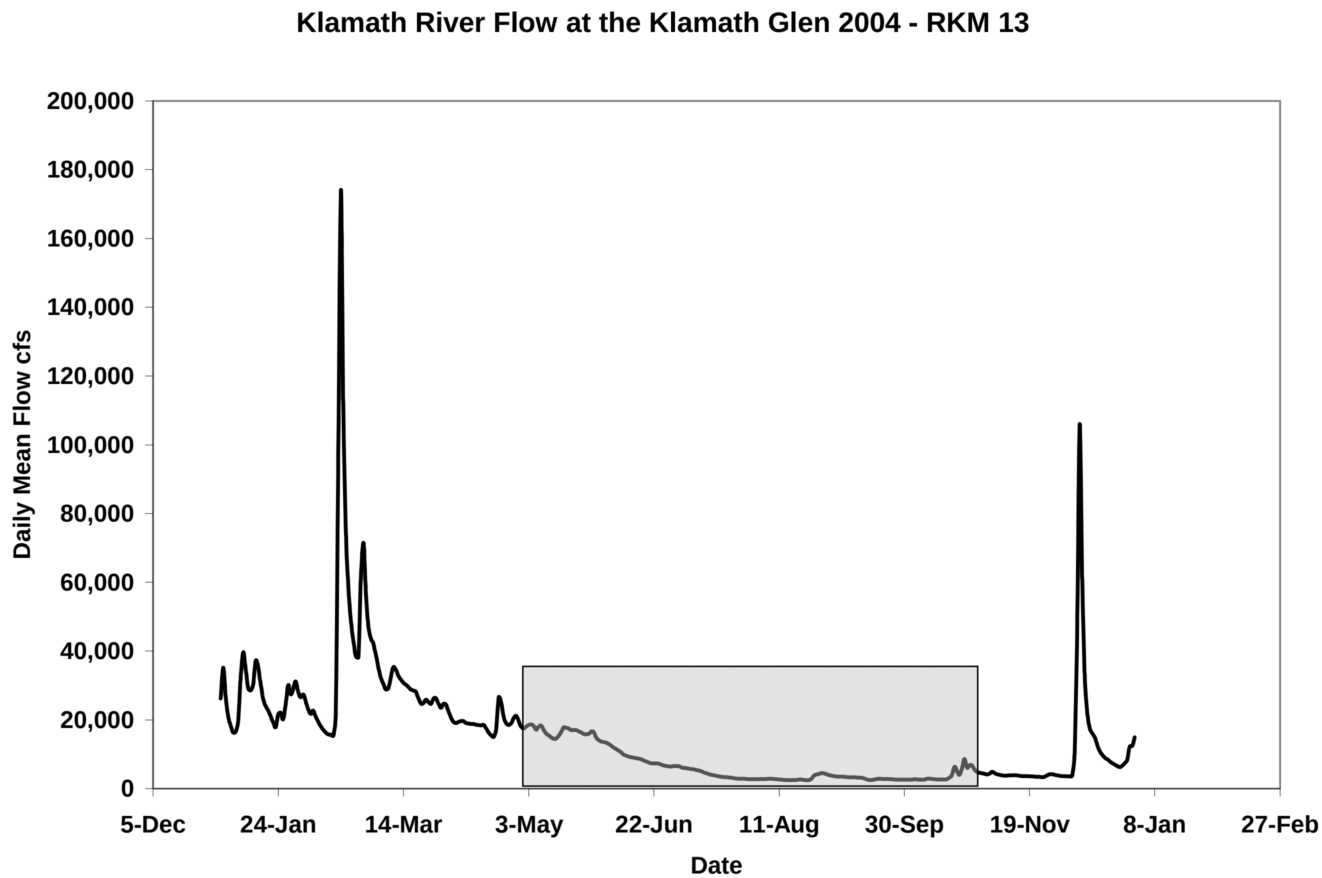


Figure 3. Flow (cubic feet per second – cfs) in the lower Klamath River during the 2004 calendar year. The shaded box highlights the months when tagged Chinook were holding or migrating through the lower Klamath River (defined as the reach from the estuary to the Trinity River confluence at Weitchpec RKM 69).

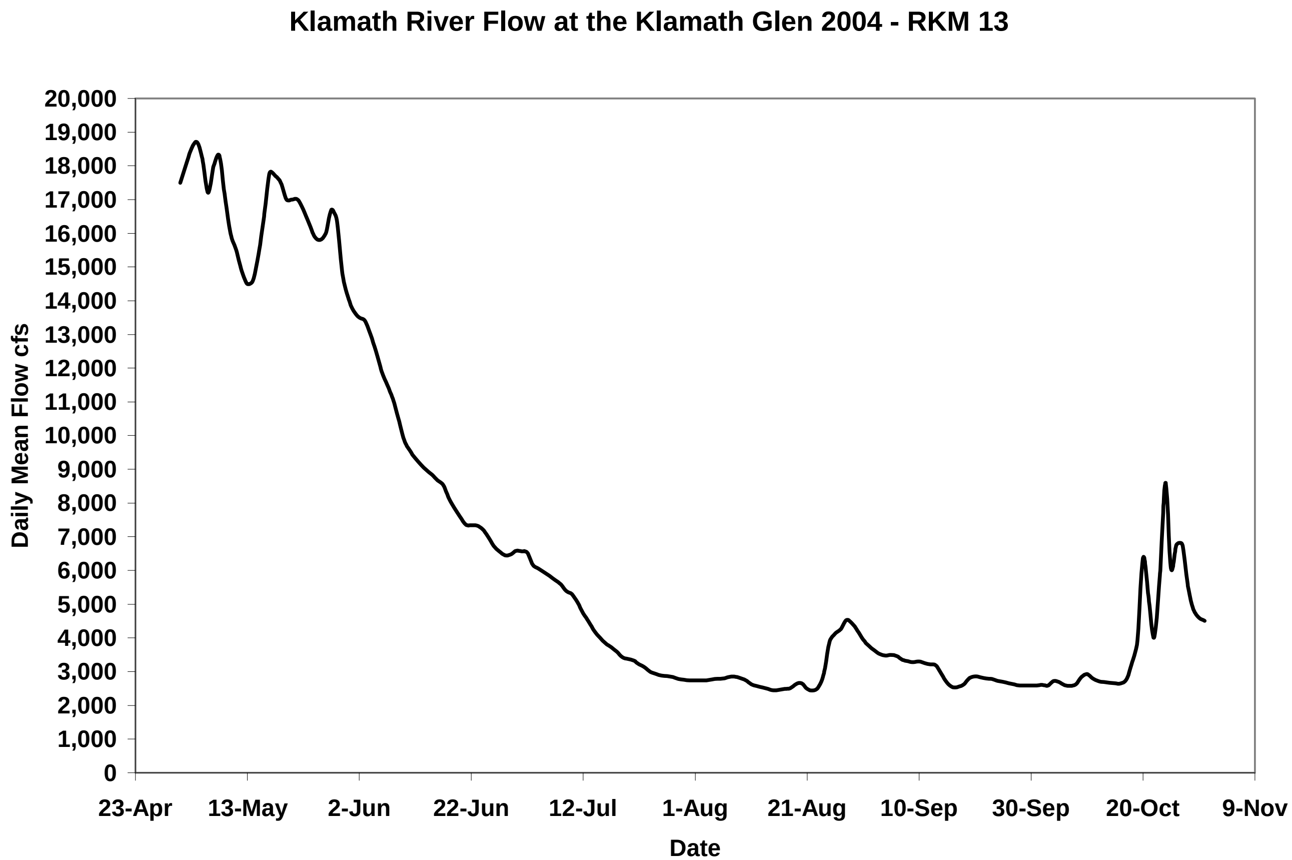


Figure 4. Flows in the lower Klamath River during the months when tagged Chinook were holding or migrating through the lower Klamath River. The spike in flows during late August was due to pulse flow releases from Lewiston and Iron Gate Dams.

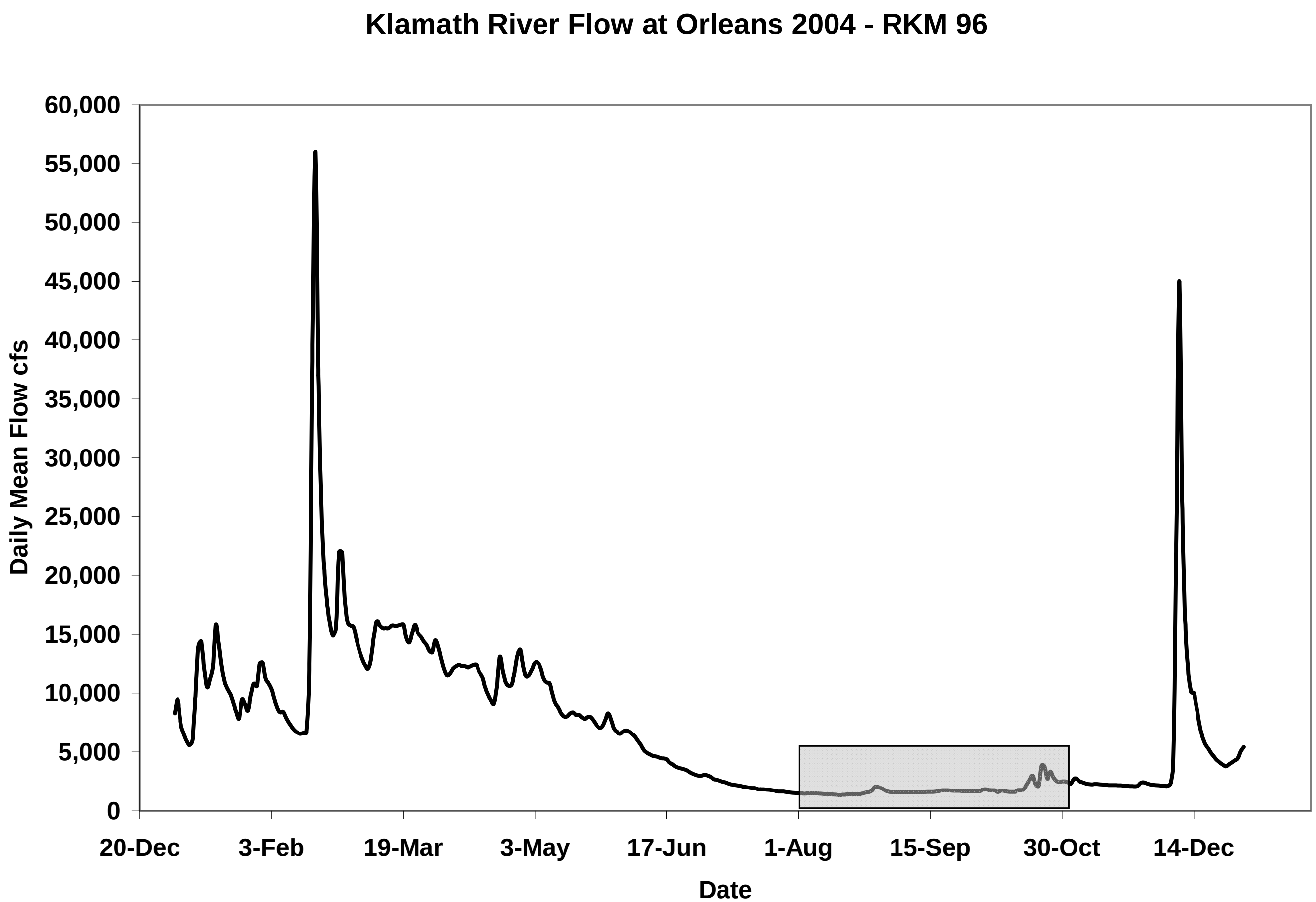


Figure 5. Flow for the mid-Klamath River at Orleans for the calendar year 2004. The shaded box highlights the months when tagged Chinook were migrating through the mid-Klamath River (Weitchpec to Somes Bar RKM 107). Salmon River spring Chinook generally migrate through this reach in May and early June, however none were tagged in 2004.

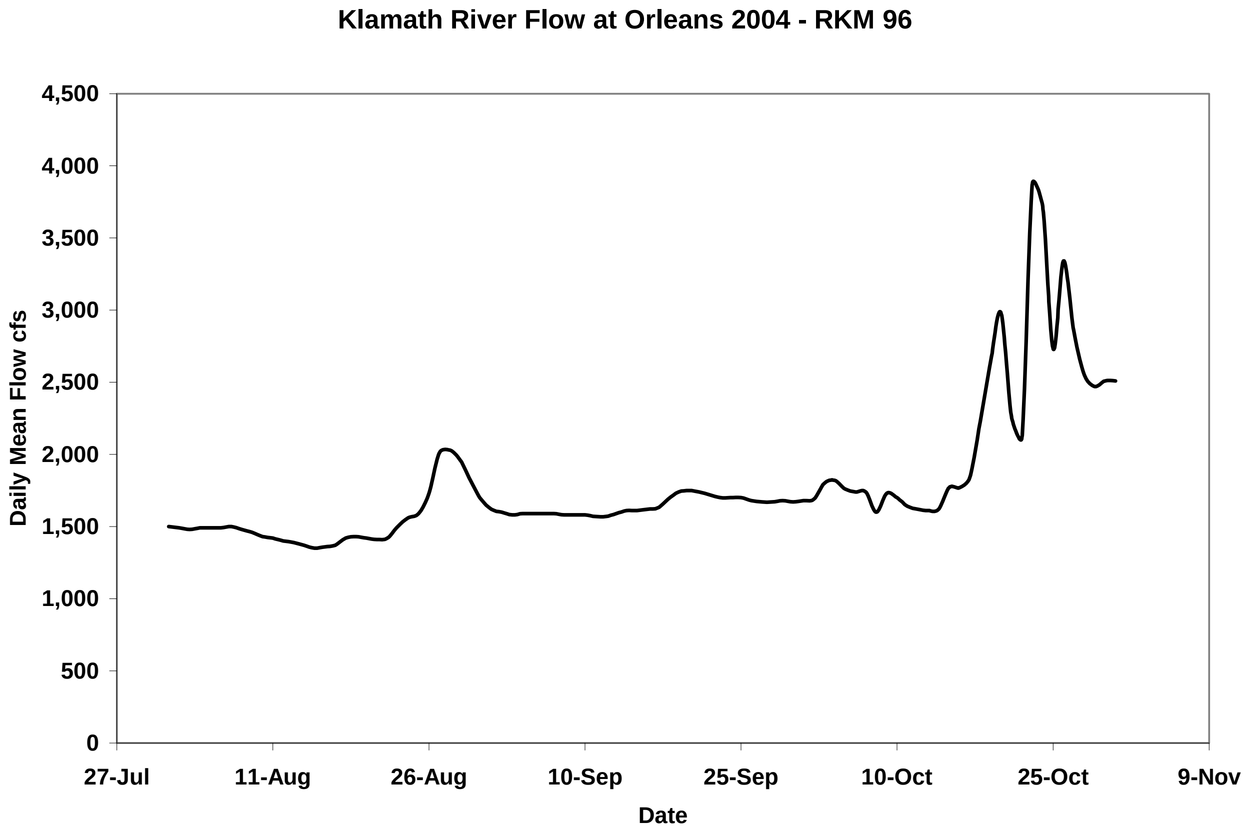


Figure 6. Flows in the mid-Klamath River during the months when tagged Chinook were holding or migrating through this reach. The majority of tagged Chinook that migrated through this reach did so from mid-September to mid-October. The spike in flows that occurred starting on 8/26 was due to the pulse flow release from Iron Gate Dam. The spikes in late October were caused by the first significant rainfall of the season.

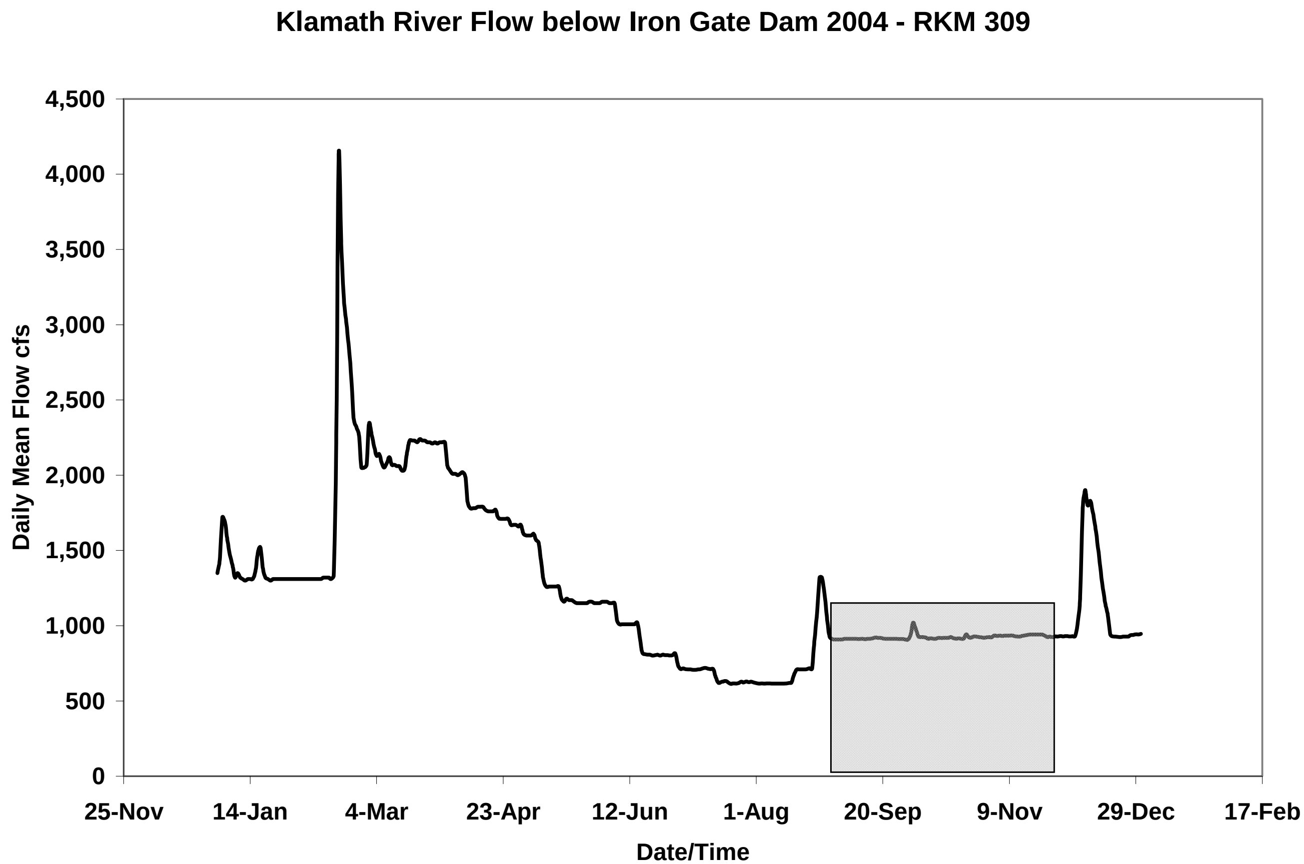


Figure 7. Flows releases from Iron Gate Dam during the 2004 calendar year. The shaded box highlights the months when tagged Chinook were migrating or spawning in the upper Klamath River (Somes Bar to Iron Gate Dam RKM 310). Flow in the Klamath River during the summer months are dominated by releases from Iron Gate Dam. Bogus Creek is the only accreation measured by this gauge besides releases from the dam.

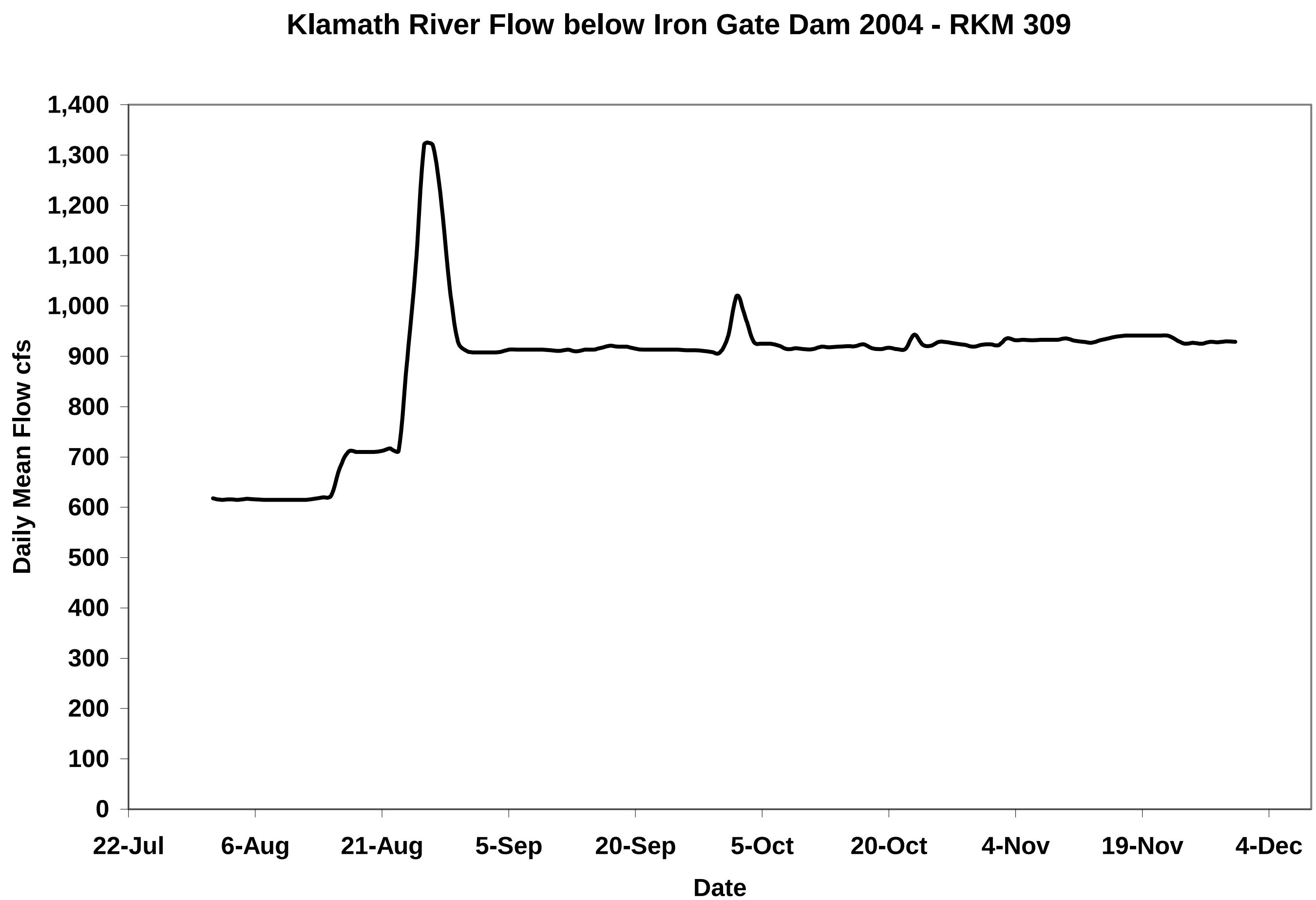


Figure 8. Flow releases from Iron Gate Dam during the period when tagged Chinook were migrating and spawning the Klamath River above Weitchpec. On 8/27 the first tagged Chinook of the season migrated into the Klamath River above Weitchpec.

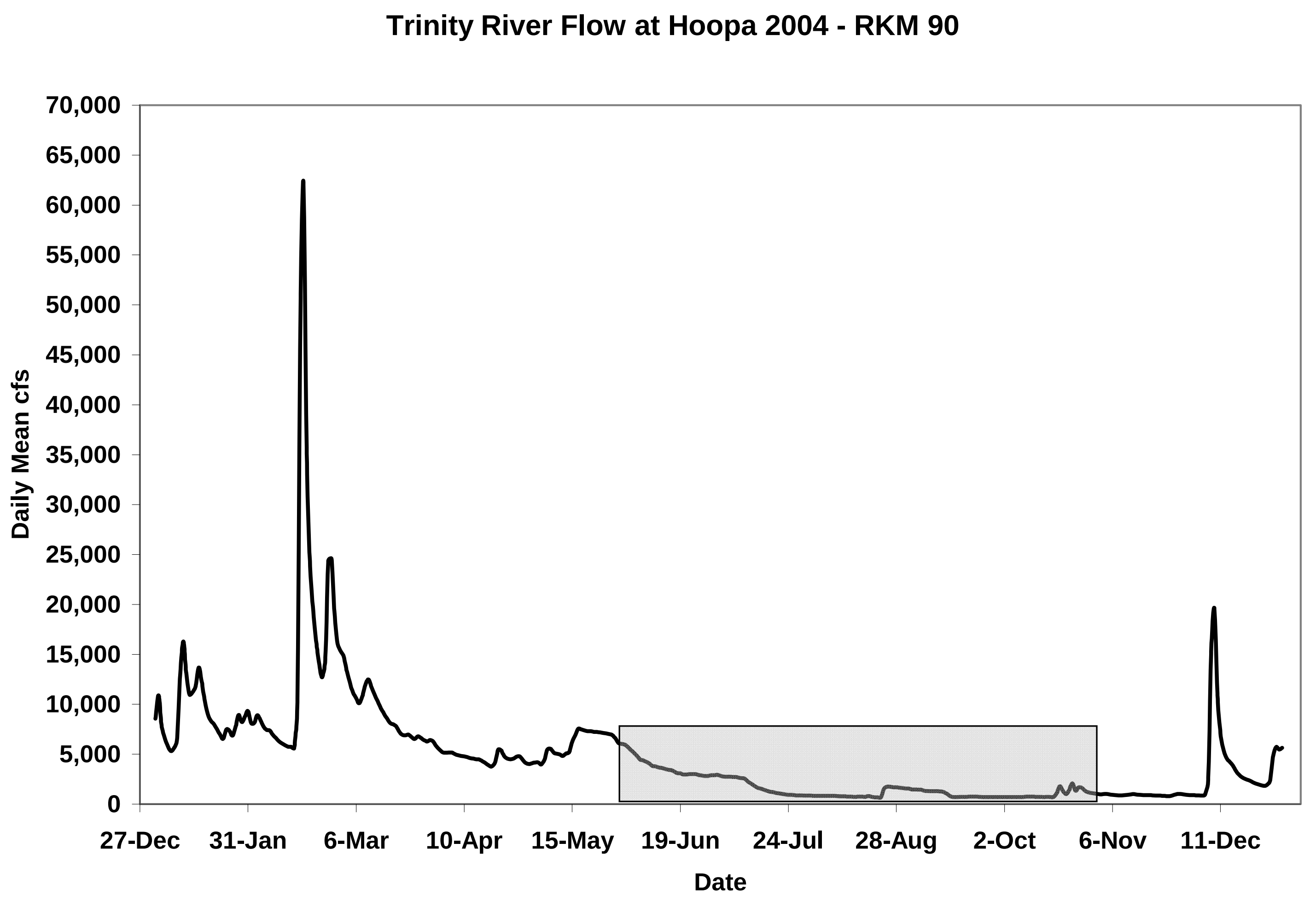


Figure 9. Flow in the lower Trinity River at Hoopa for the 2004 calendar year. The shaded box highlights the months when tagged Chinook were holding or migrating through lower Trinity River (Weitchpec to South Fork Trinity confluence at Salyer RKM 120).

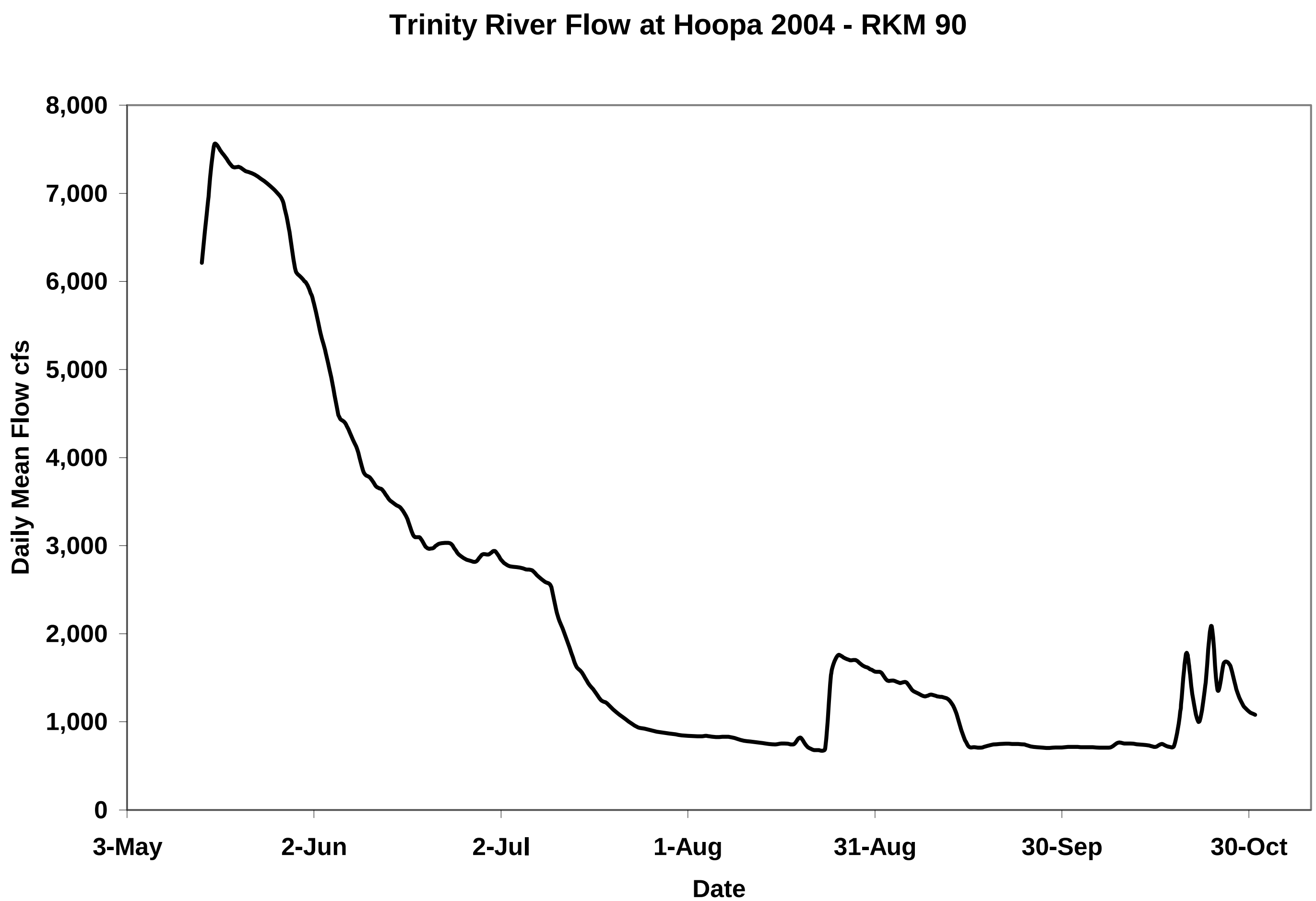


Figure 10. Flow for the lower Trinity River during the months when tagged Chinook were holding or migrating through this reach. The first tagged Chinook migrated into the Trinity River above Weitchpec on ~6/20; however flows during mid-May are shown for reference.

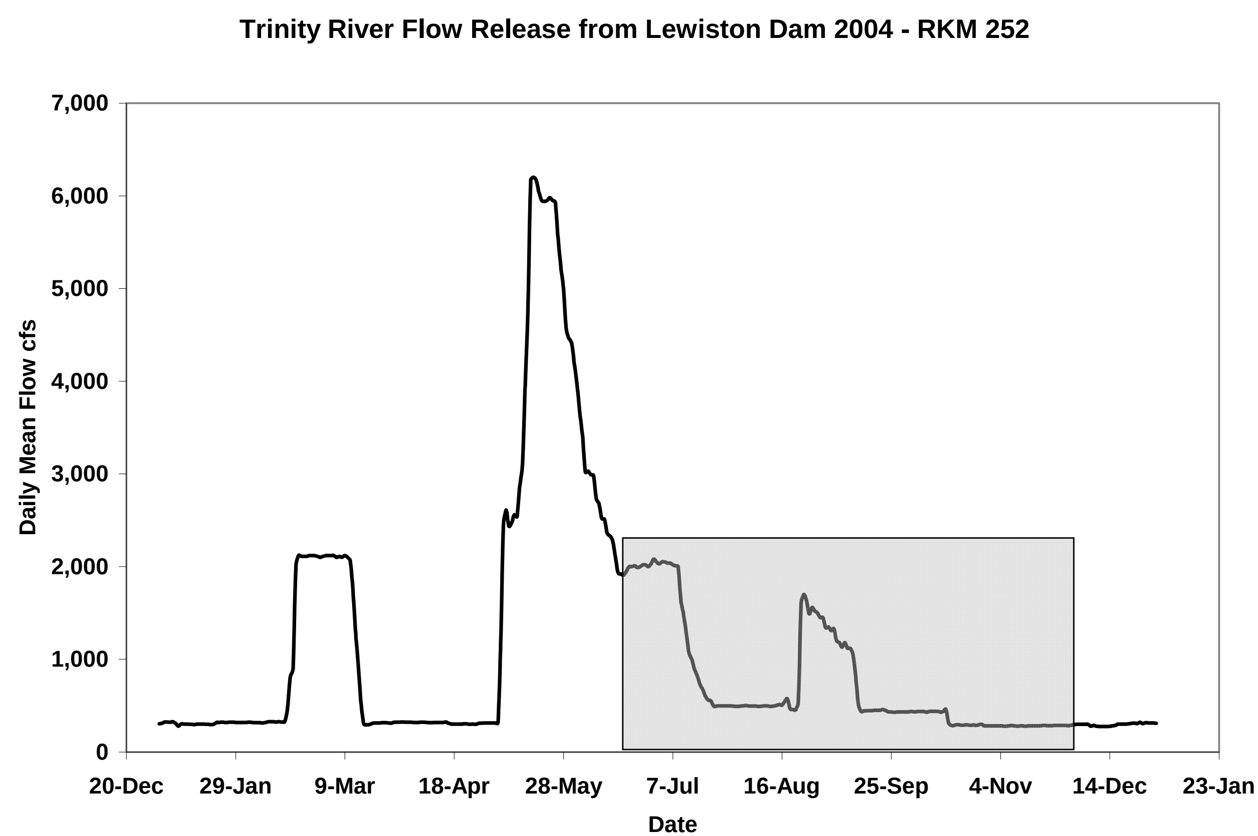


Figure 11. Flow for the upper Trinity River as controlled by releases from Lewiston Dam during the 2004 calendar year. The shaded box highlights the period of time when tagged Chinook were holding, migrating, and/or spawning in the Trinity River from Weitchpec to Lewiston. Flow releases from Lewiston Dam dominate the spring, summer, and fall portions of the Trinity River hydrograph all the way to Weitchpec.

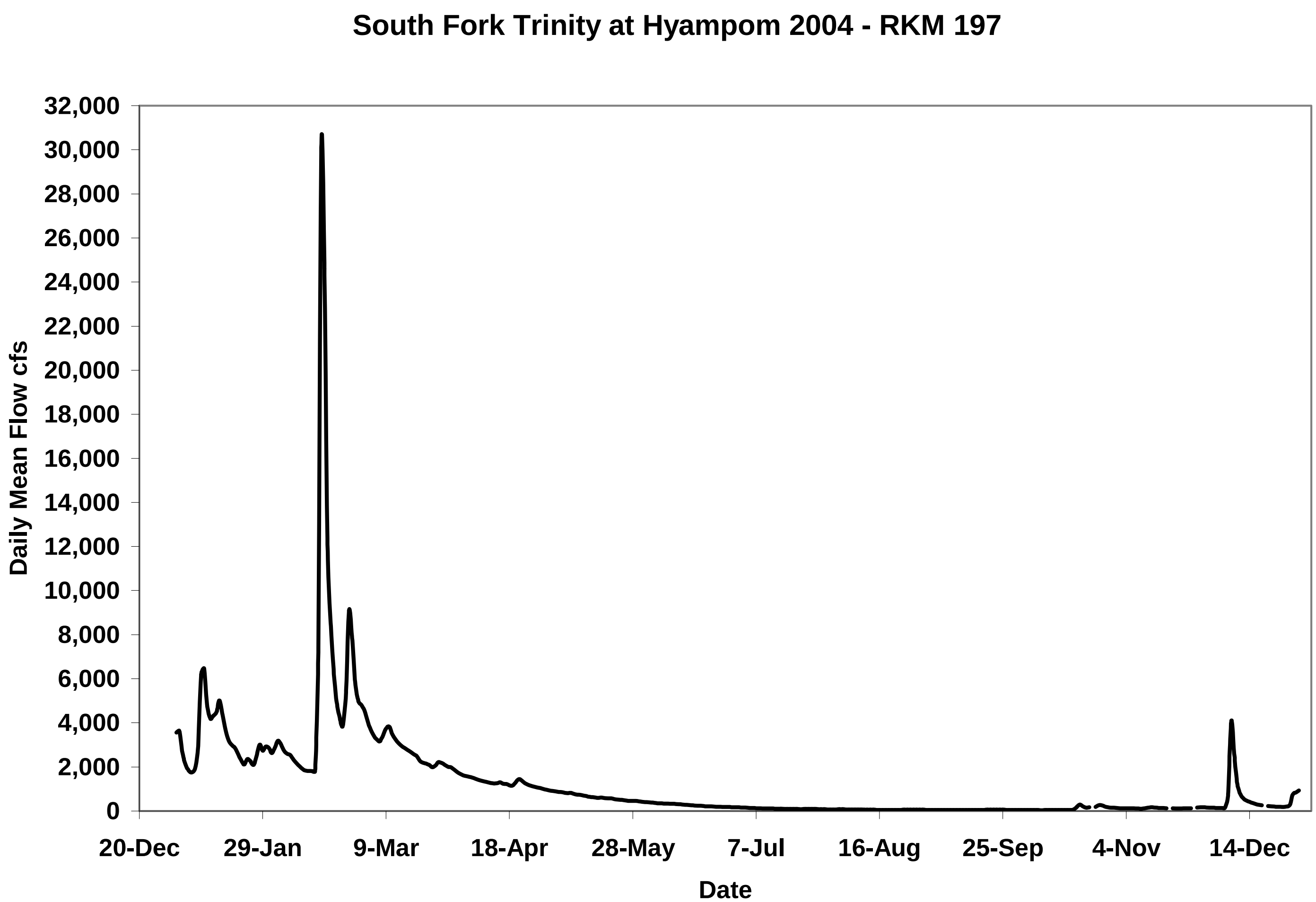


Figure 12. Flow for the lower South Fork Trinity River at Hyampom (below Hayfork Creek) for the 2004 calendar year. Summer base flows were approximately 50 - 100 cfs. The unregulated South Fork is the Trinity River's largest tributary.

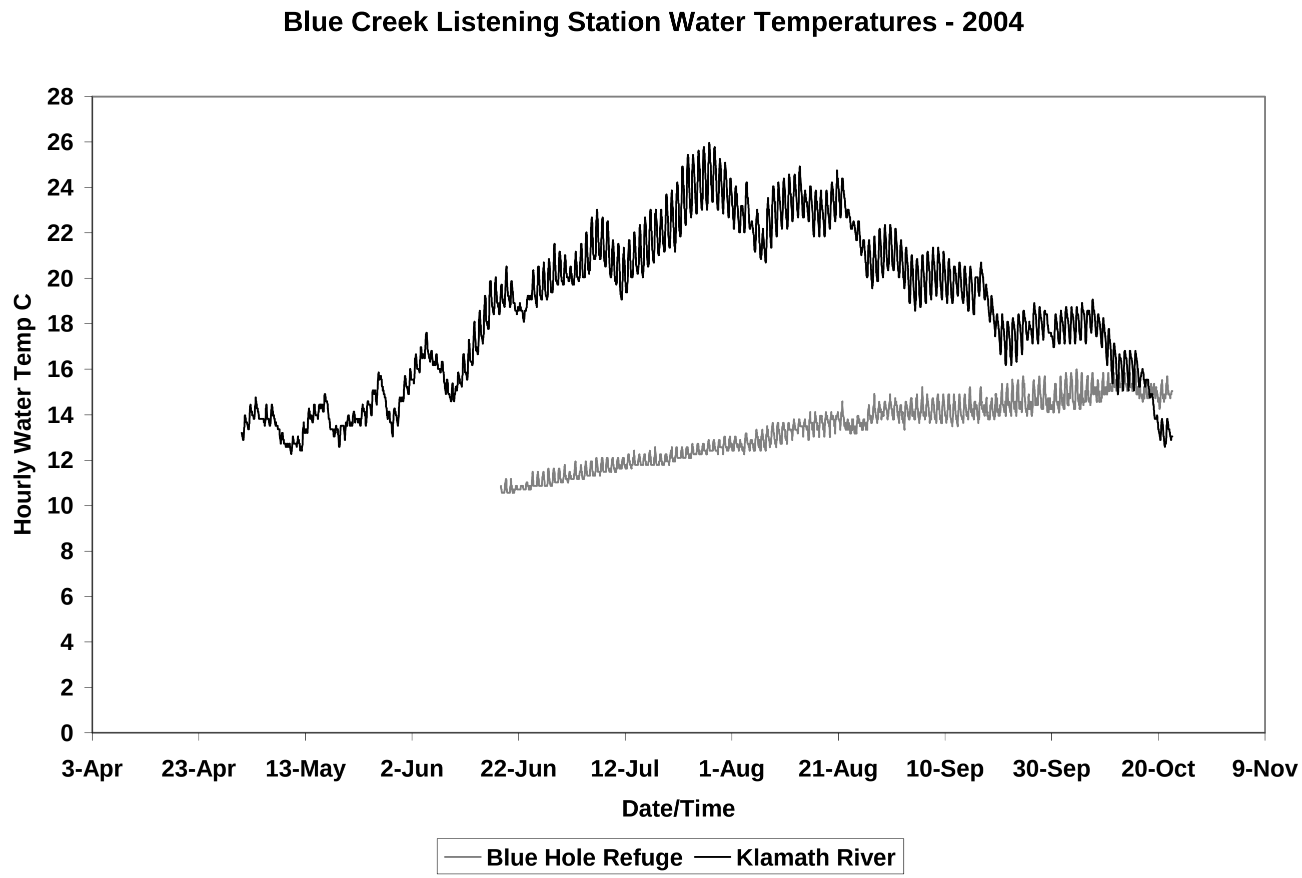


Figure 13. Hourly water temperatures for the mainstem Klamath River, Blue Creek, and the hyporheically fed Blue Hole during the study period at RKM 26, the location of the Blue Creek radio listening station.

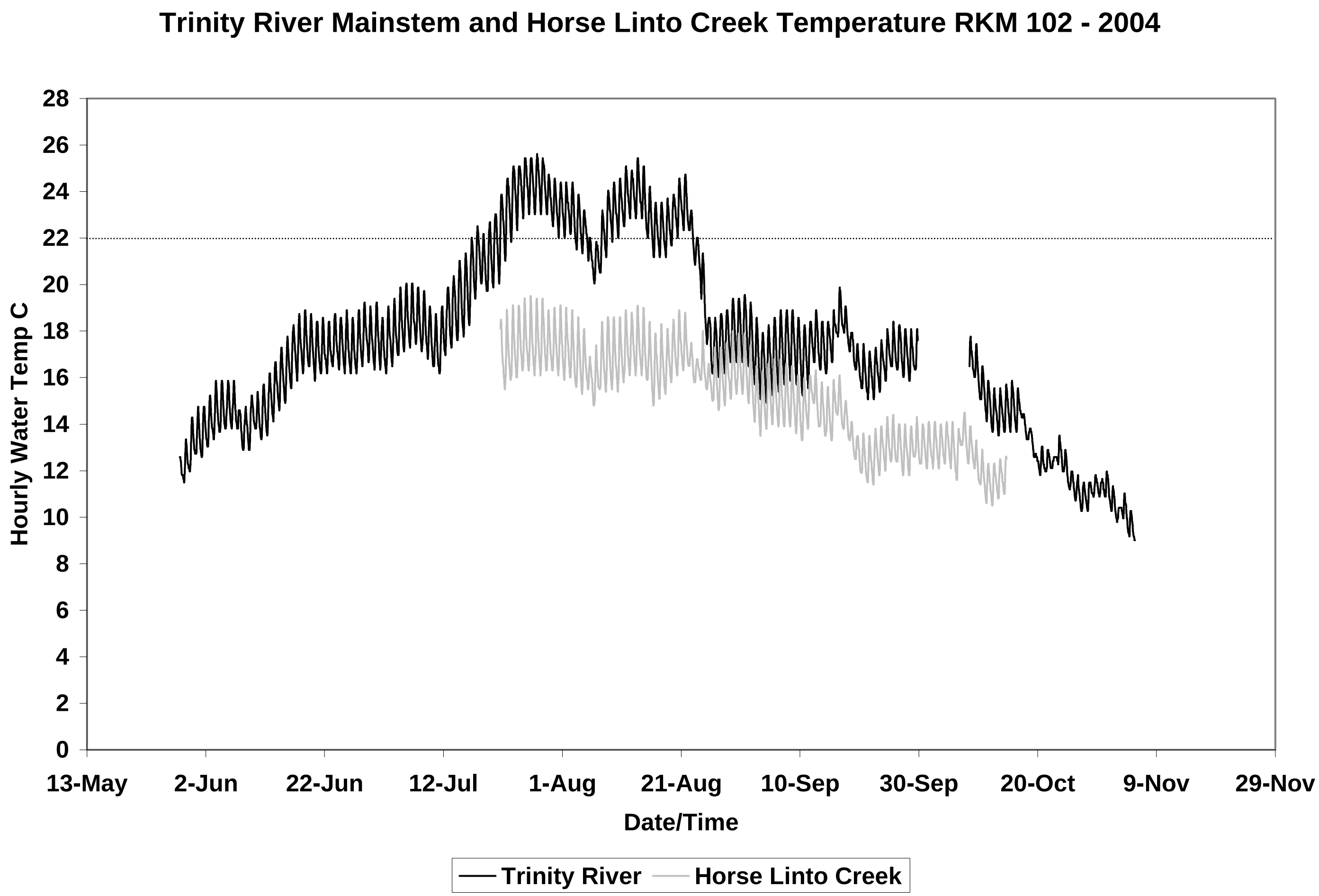


Figure 14. Hourly water temperatures for the mainstem Trinity River and the thermal refuge forming Horse Linto Creek during the study period at RKM 102, the location of the Horse Linto Creek radio listening station. The dotted line shows the 22°C threshold.

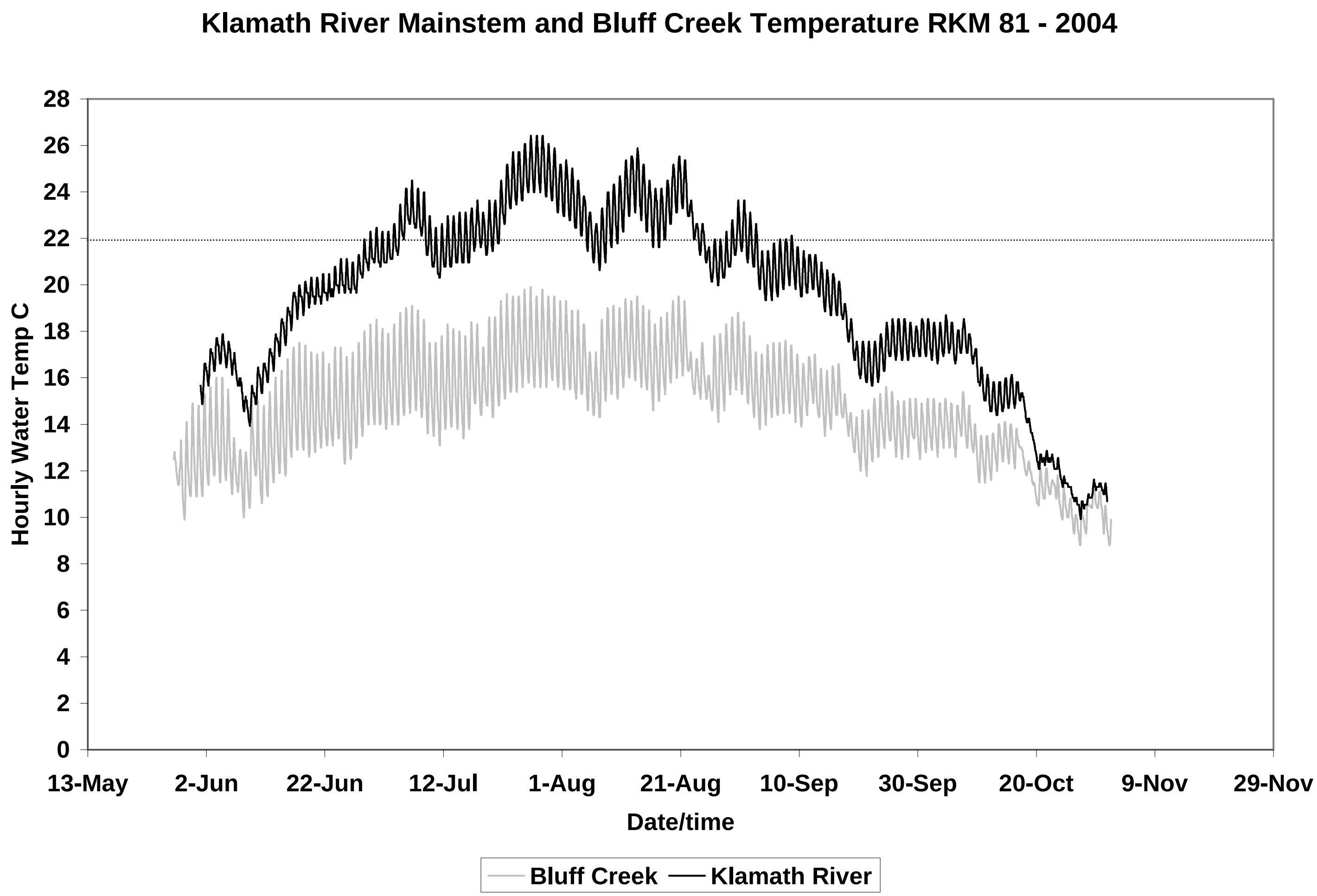


Figure 15. Hourly water temperatures for the mainstem Klamath River and the thermal refuge forming Bluff Creek during the study period at RKM 180, the location of the Bluff Creek radio listening station. The dotted line shows the 22°C threshold.

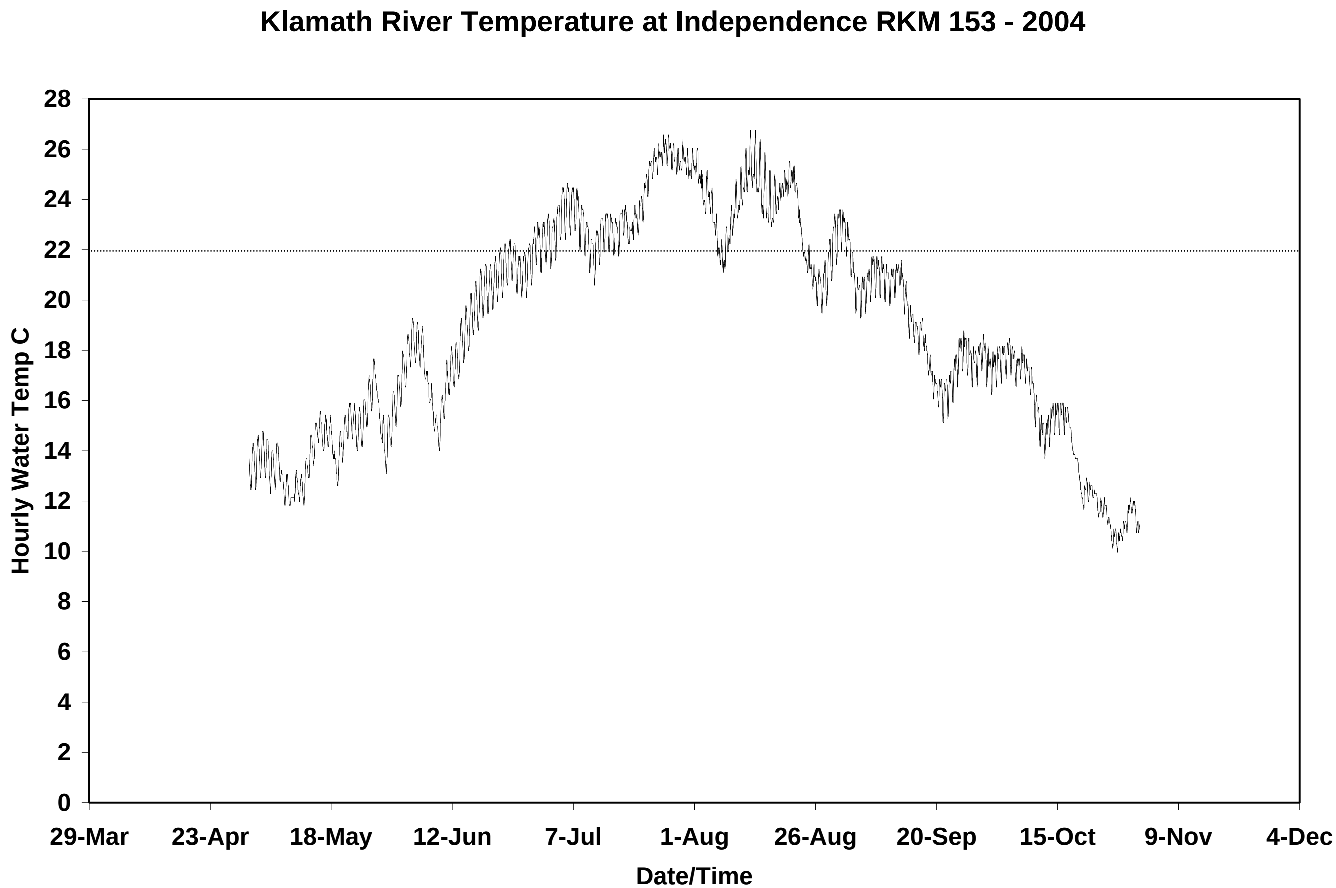


Figure 16. Hourly water temperatures for the Klamath River at Independence (RKM 153) during the 2004 study period. The dotted line shows the 22^{o}C threshold.

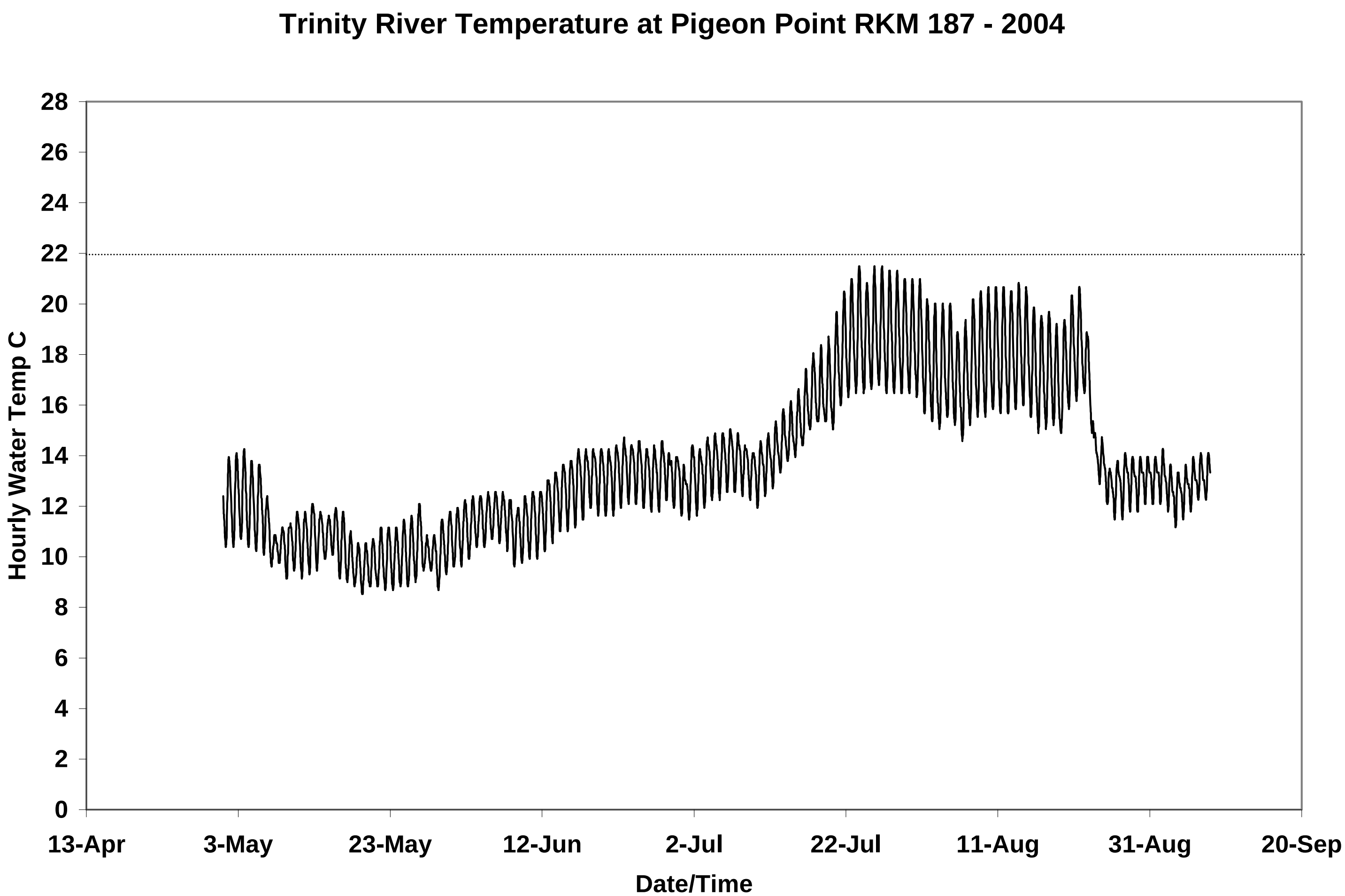


Figure 17. Hourly water temperatures for the Trinity River at Pigeon Point (RKM 187) during the 2004 study period. The dotted line shows the 22°C threshold.

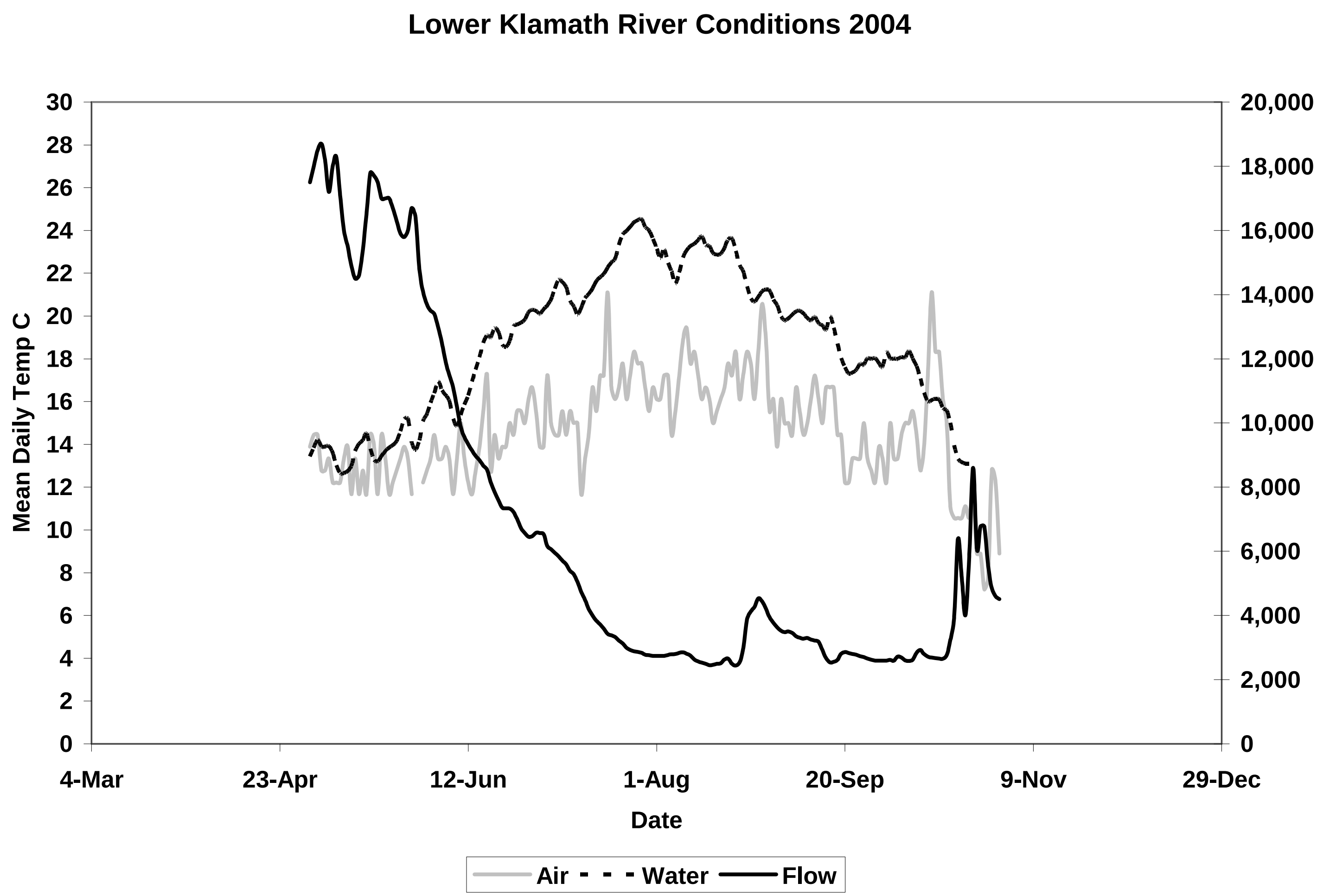


Figure 18. Comparison of mean daily air temperature (RKM 13), water temperature (RKM 26), and flow (RKM 13) for the lower Klamath River during the 2004 study period.

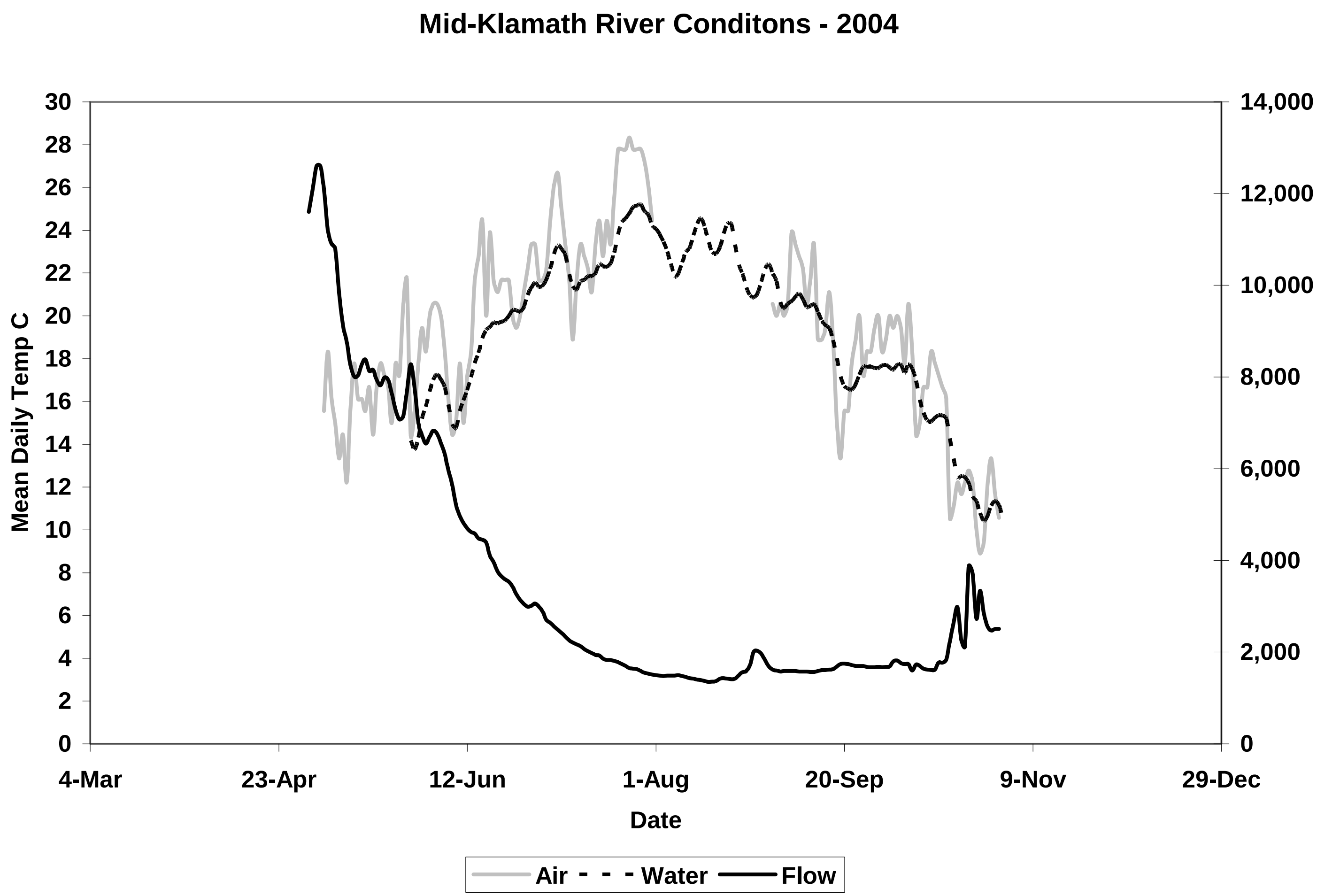


Figure 19. Comparison of available mean daily air temperature (RKM 95.5), water temperature (RKM 81), and flow (RKM 96) for the mid-Klamath River during the 2004 study period.

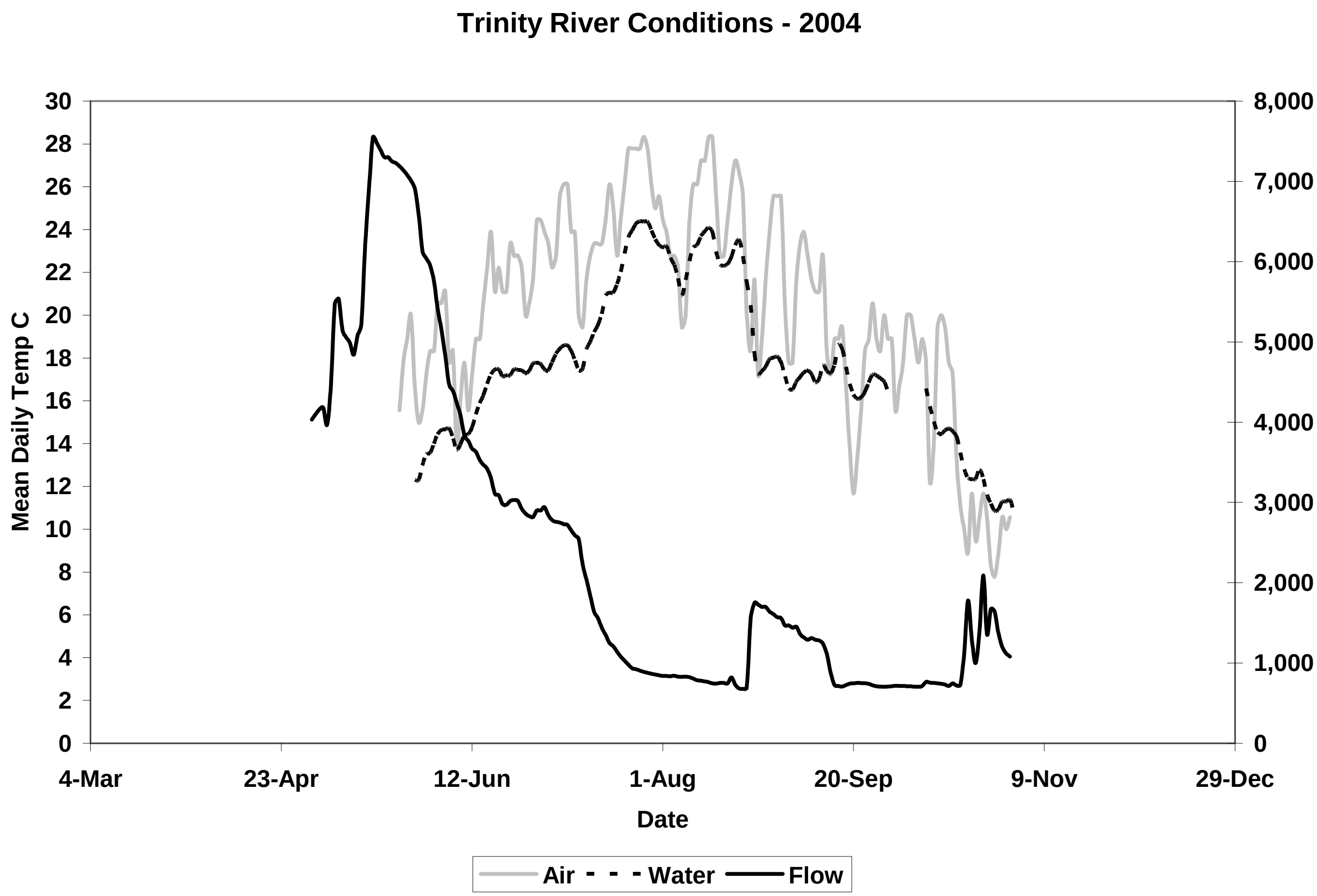


Figure 20. Comparison of mean daily air temperature (RKM 174), water temperature (RKM 102.5), and flow (RKM 90) for the lower Trinity during the 2004 study period. The air temperature record at RKM 174 was used because it was the most complete record while water temperature was used further downstream at RKM 102.5 in order to get beyond the strongest influences of cold water release from Lewiston Dam.

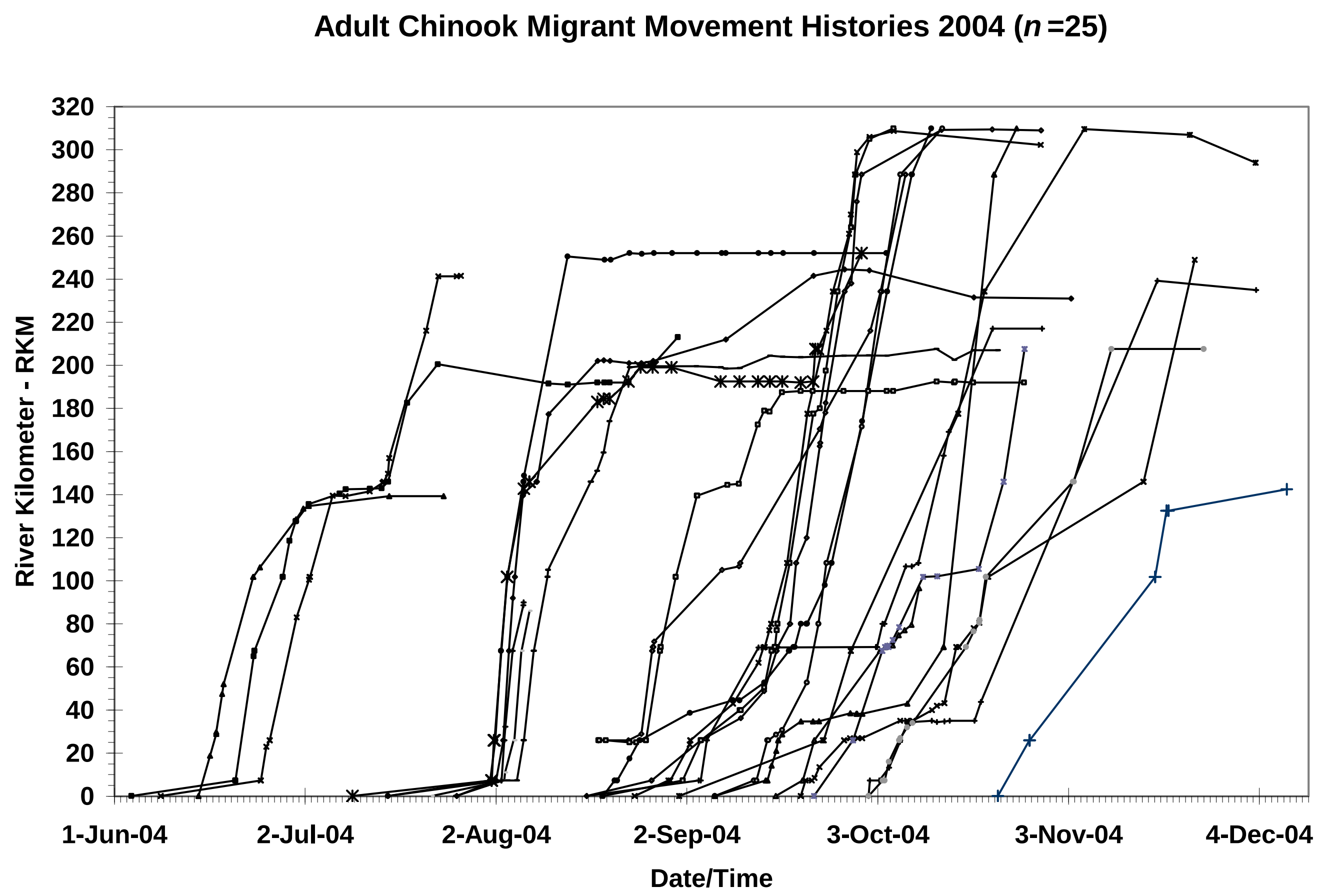


Figure 21. Movement histories (location versus date) for all 25 adult Chinook migrants tagged in 2004. The scale is set the same for all movement history graphs.

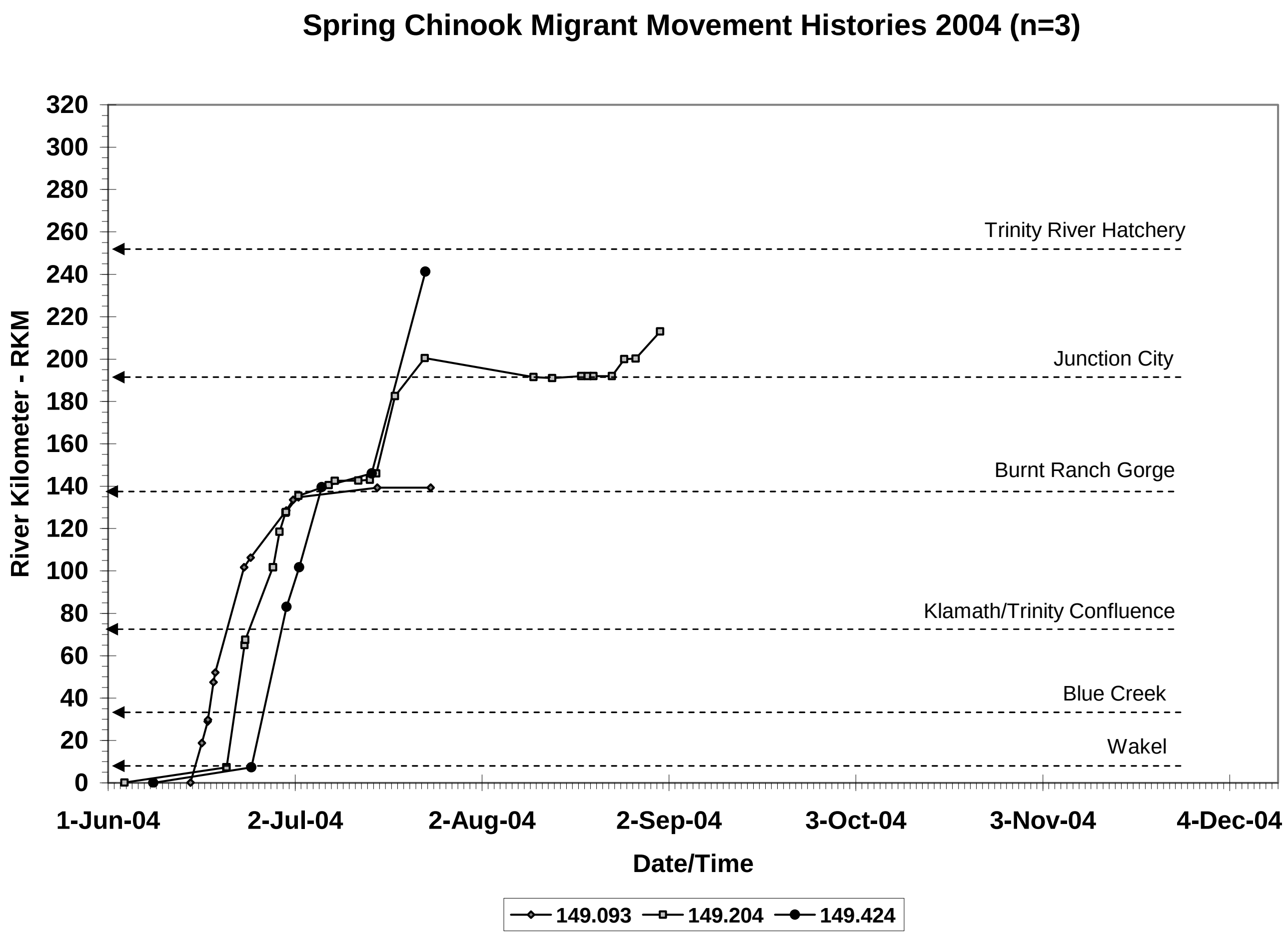


Figure 22. Movement histories (location versus date) for all three spring Chinook migrants tagged in 2004. The dotted lines mark the locations of applicable landmarks in the migration path. The scale is set the same for the movement histories for all migrant groups. Chinook 149.093 was not successful in passing Burnt Ranch Gorge.

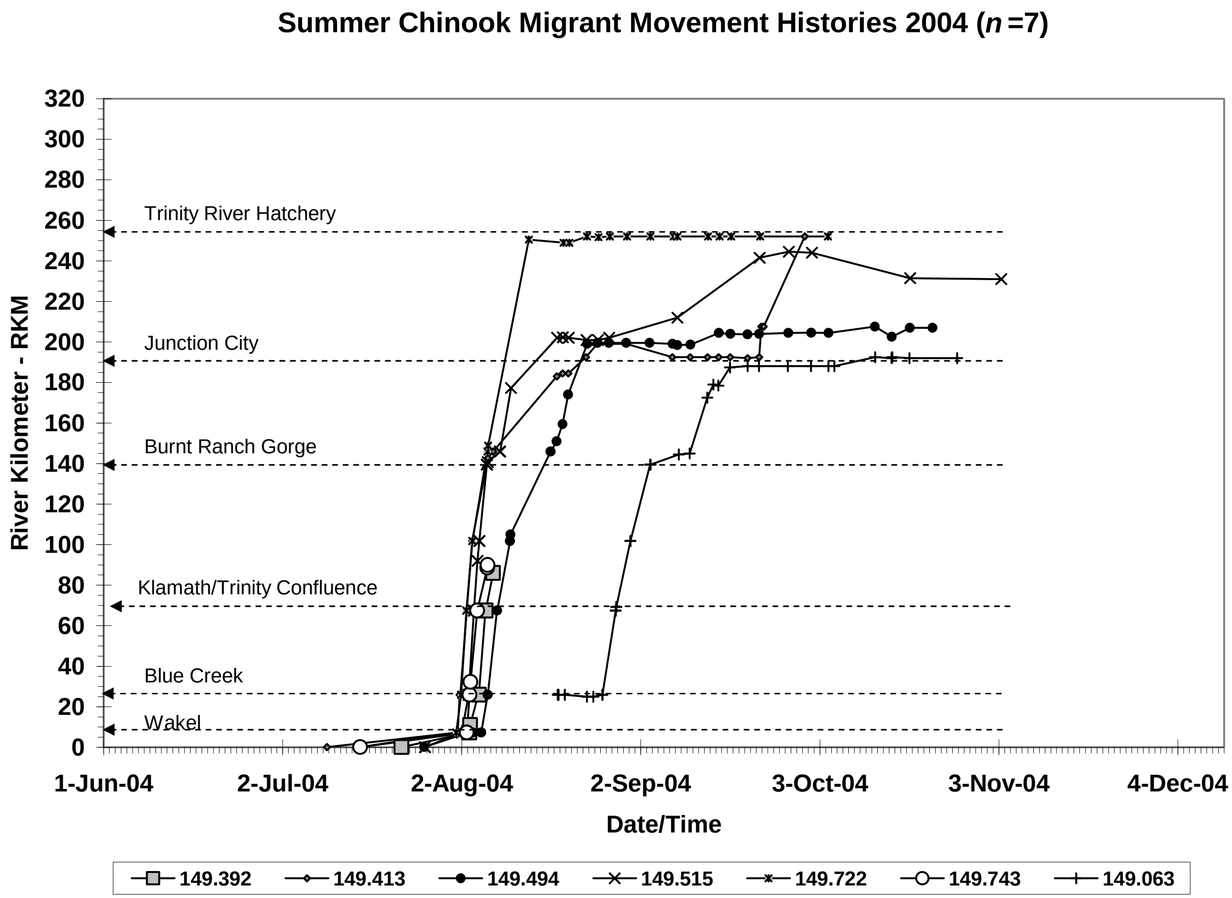


Figure 23. Movement histories (location versus date) for all seven summer Chinook migrants tagged in 2004. The dotted lines mark the locations of applicable landmarks in the migration path. The scale is set the same for the movement histories for all migrant groups. These fish would be considered Trinity River "spring' Chinook even though they have summer run-timing and behavior. Chinook 149.063 likely missed the opportunity to migrate upriver during the early August cooling event and sought refuge at Blue Creek until temperatures cooled again in conjunction with the Trinity fall pulse flow.

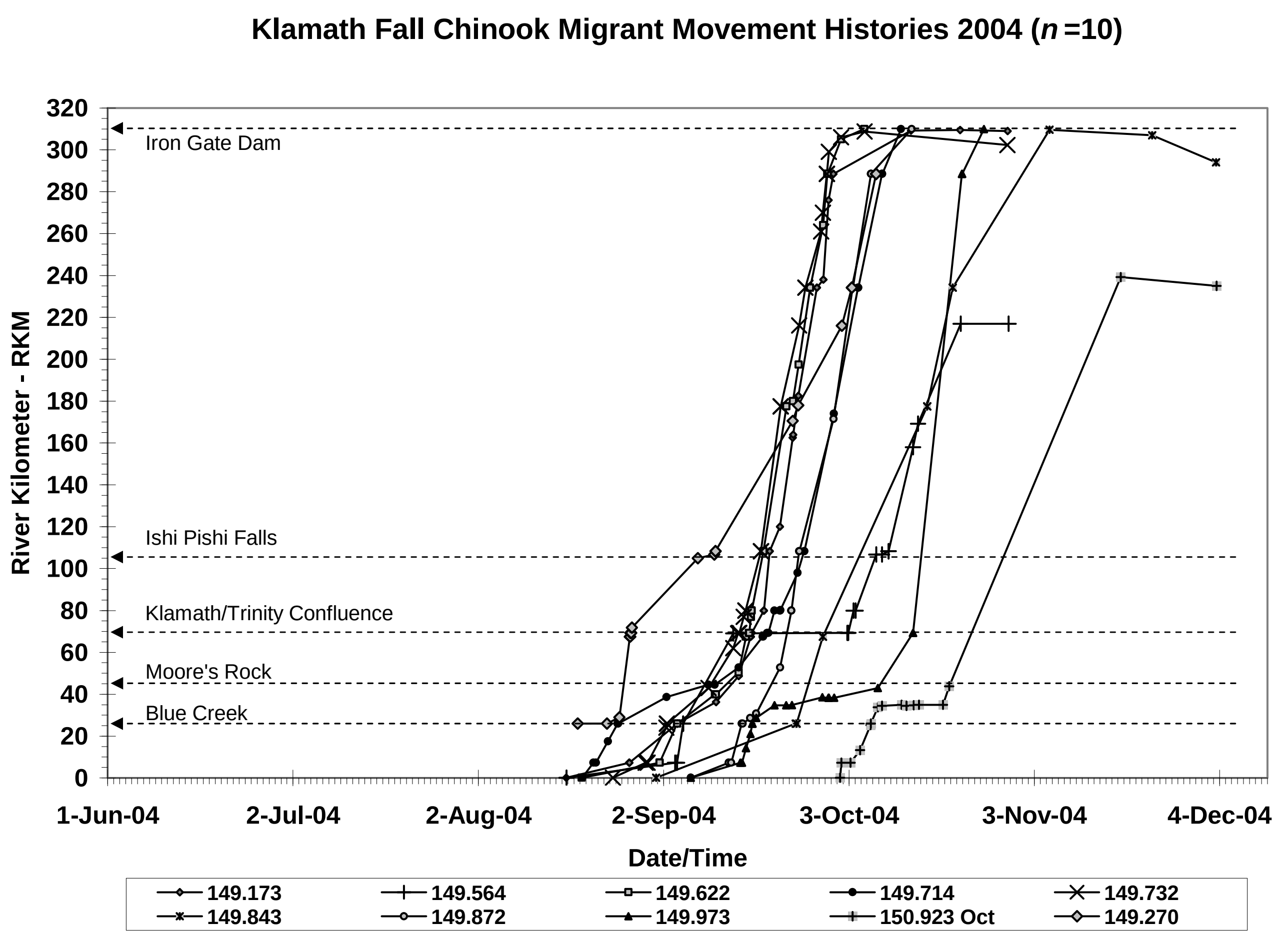


Figure 24. Movement histories (location versus date) for all ten Klamath fall Chinook migrants tagged in 2004. The dotted lines mark the locations of applicable landmarks in the migration path. The scale is set the same for the movement histories for all migrant groups. Chinook 149.270 was tagged at Blue Creek on 8/18/04 and is the earliest Klamath fall Chinook migrant tagged in all study years.

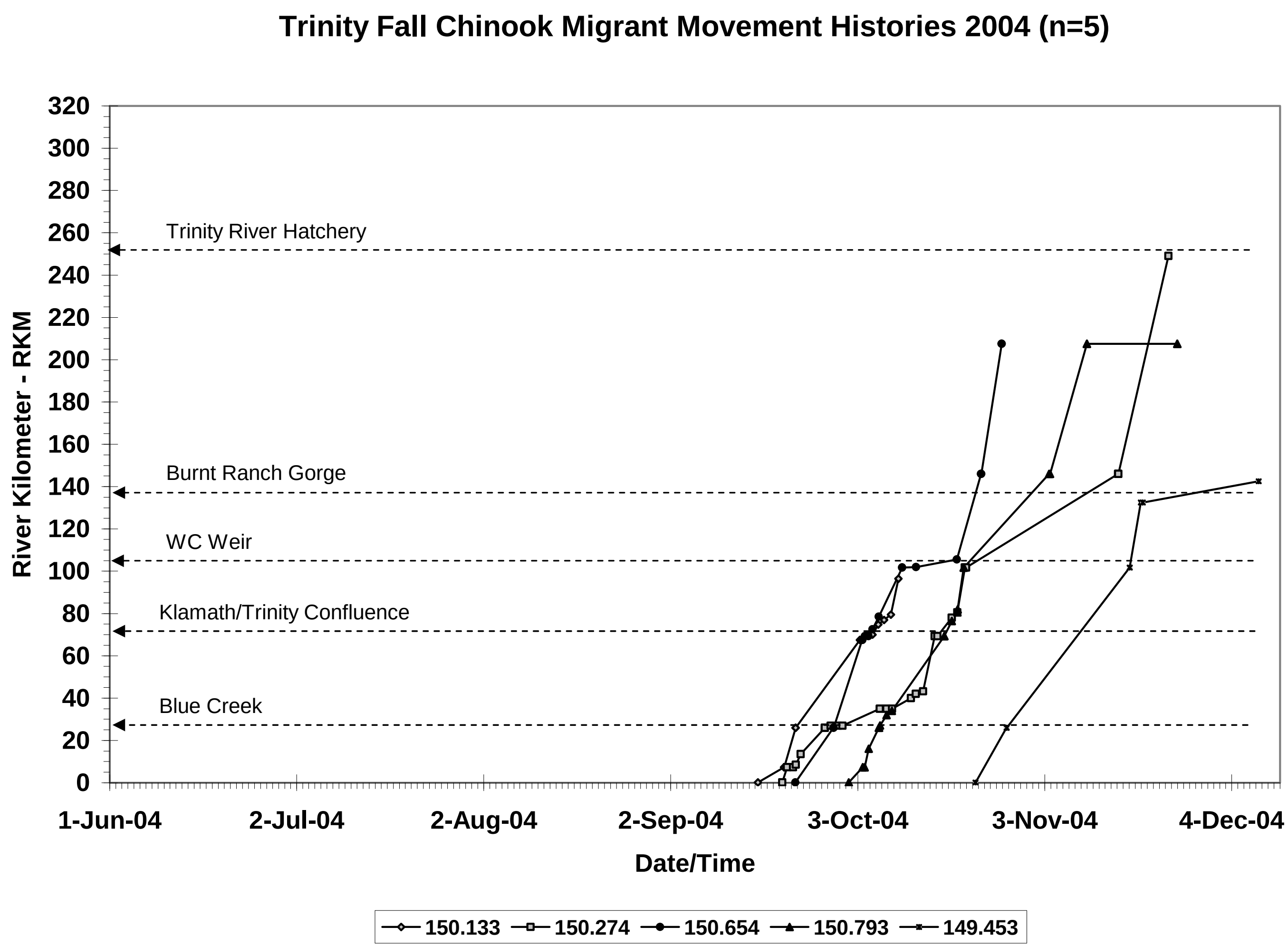


Figure 25. Movement histories (location versus date) for all five Trinity fall Chinook migrants tagged in 2004. The dotted lines mark the locations of applicable landmarks in the migration path. The scale is set the same for the movement histories for all migrant groups.

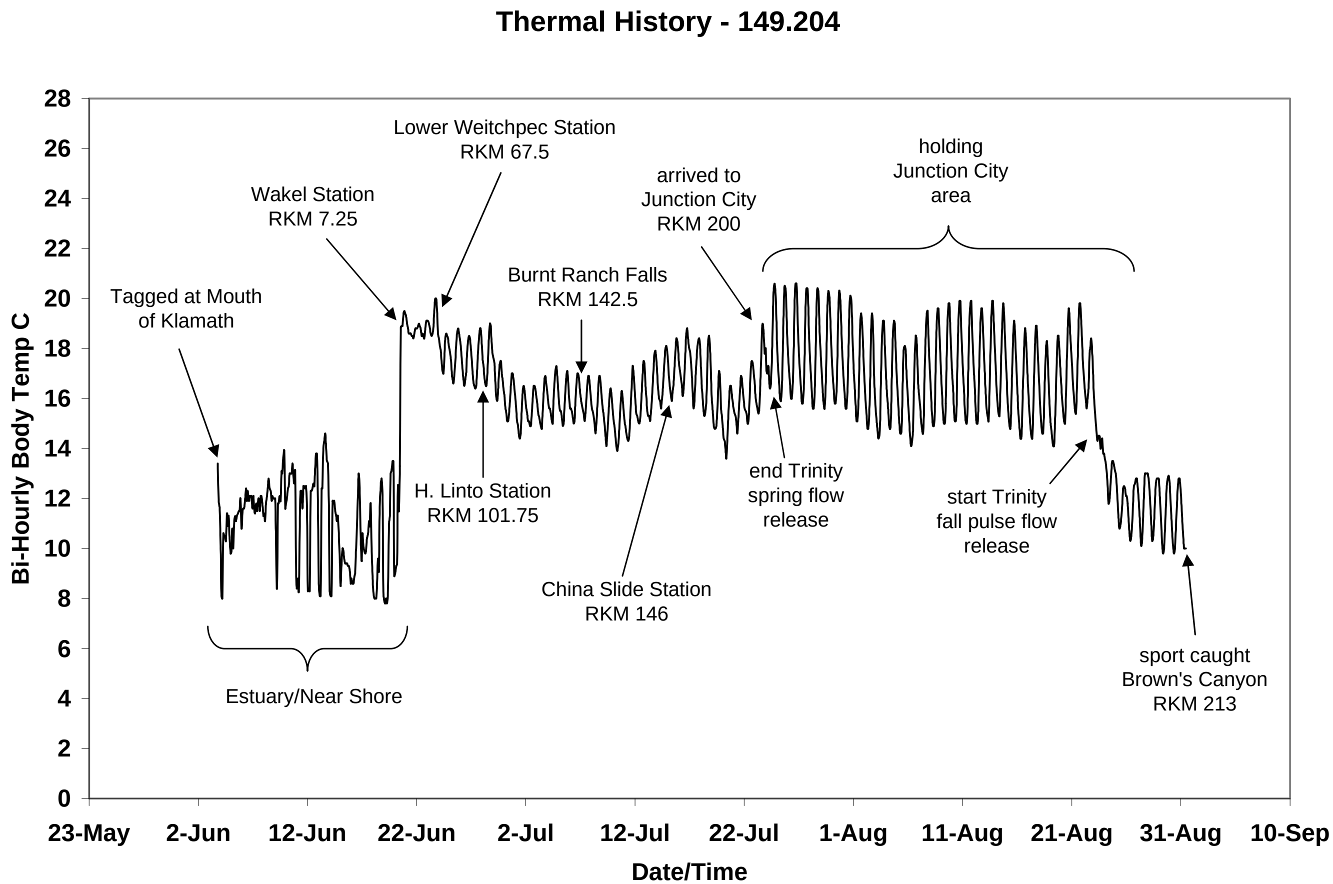


Figure 26. The thermal history (internal body temperature °C) for Chinook 149.204 during its upriver migration in the Klamath and Trinity Rivers, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

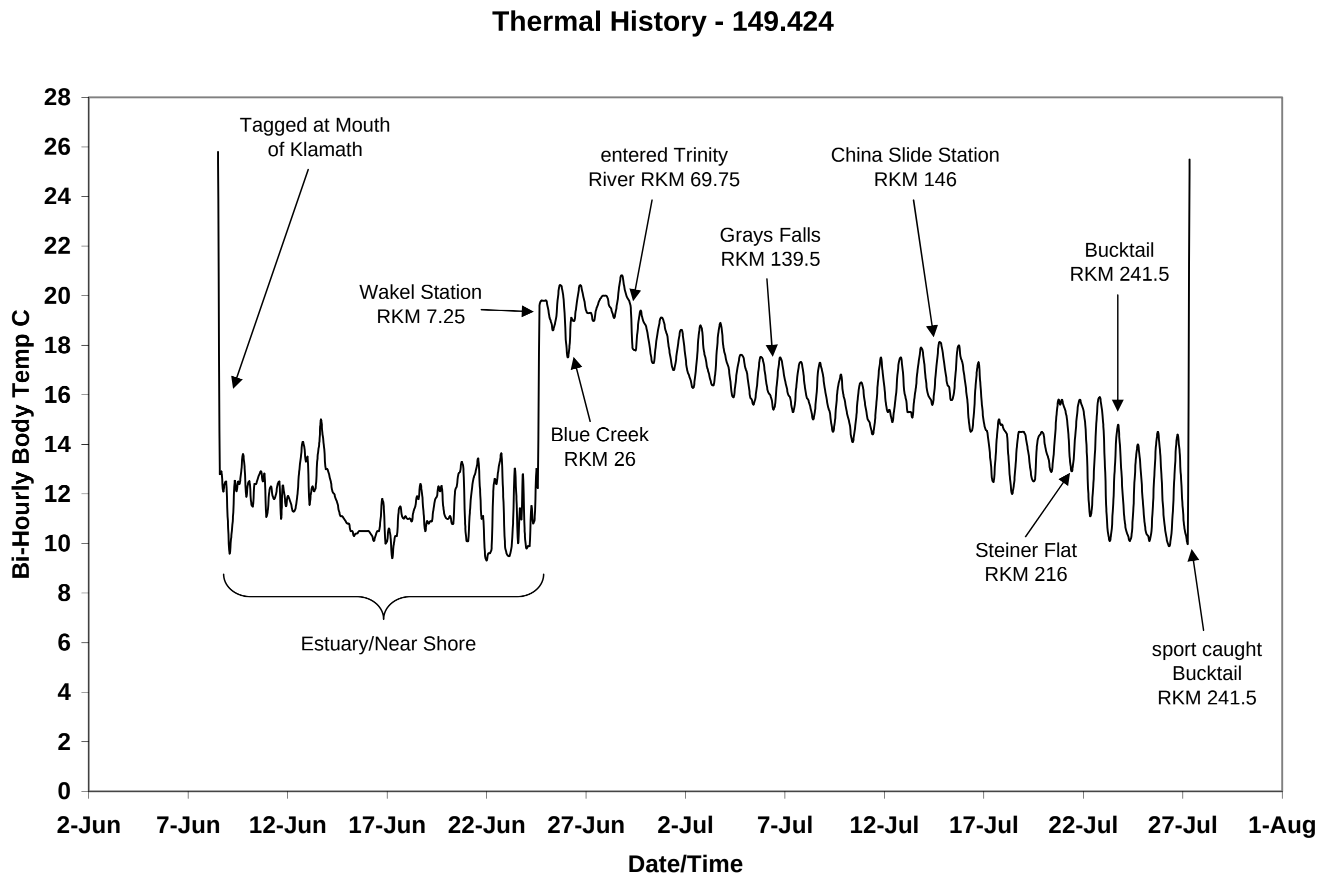


Figure 27. The thermal history (internal body temperature °C) for Chinook 149.424 during its upriver migration in the Klamath and Trinity Rivers, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

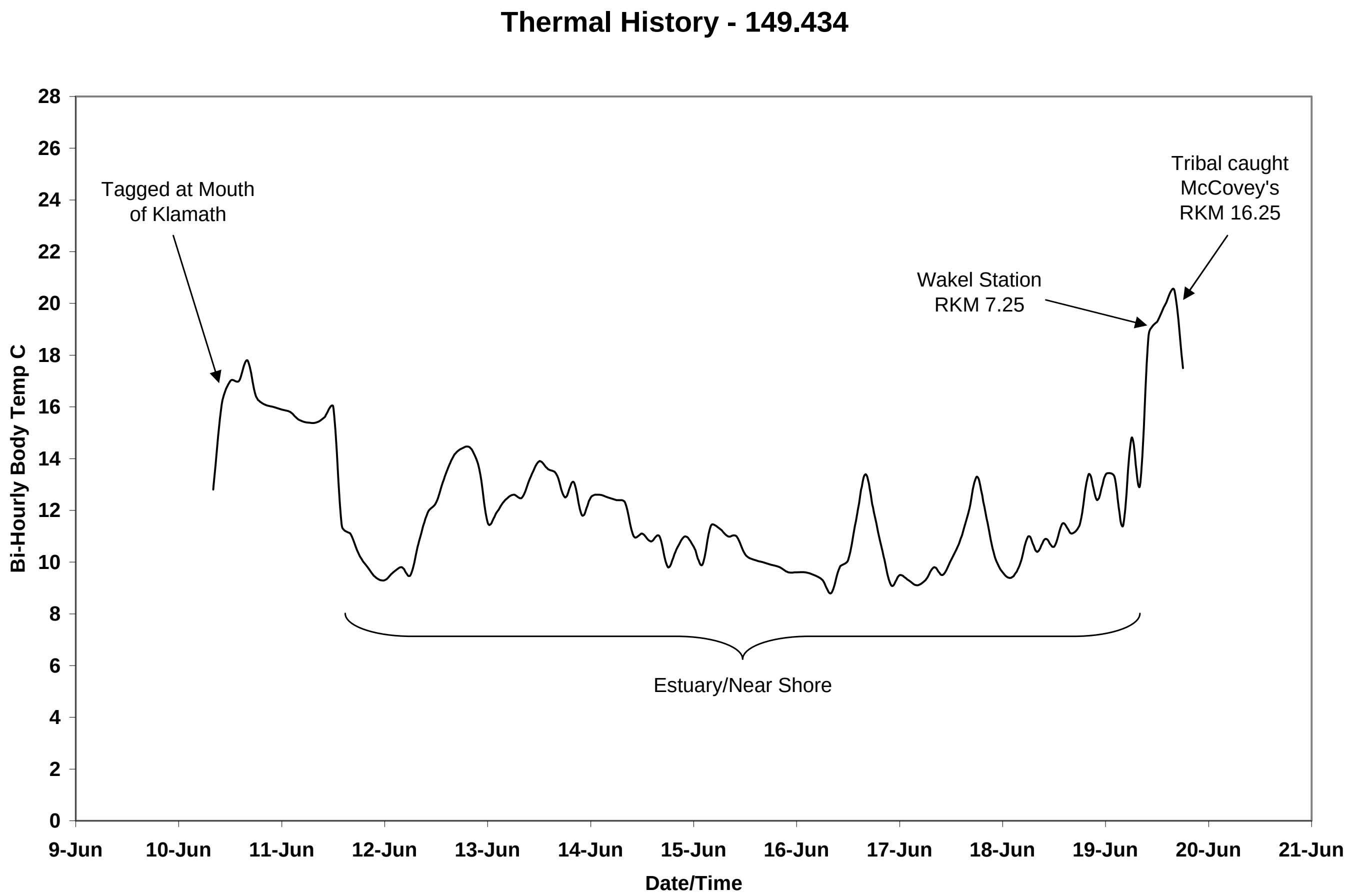


Figure 28. The thermal history (internal body temperature °C) for Chinook 149.434 during its upriver migration in the Klamath River, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

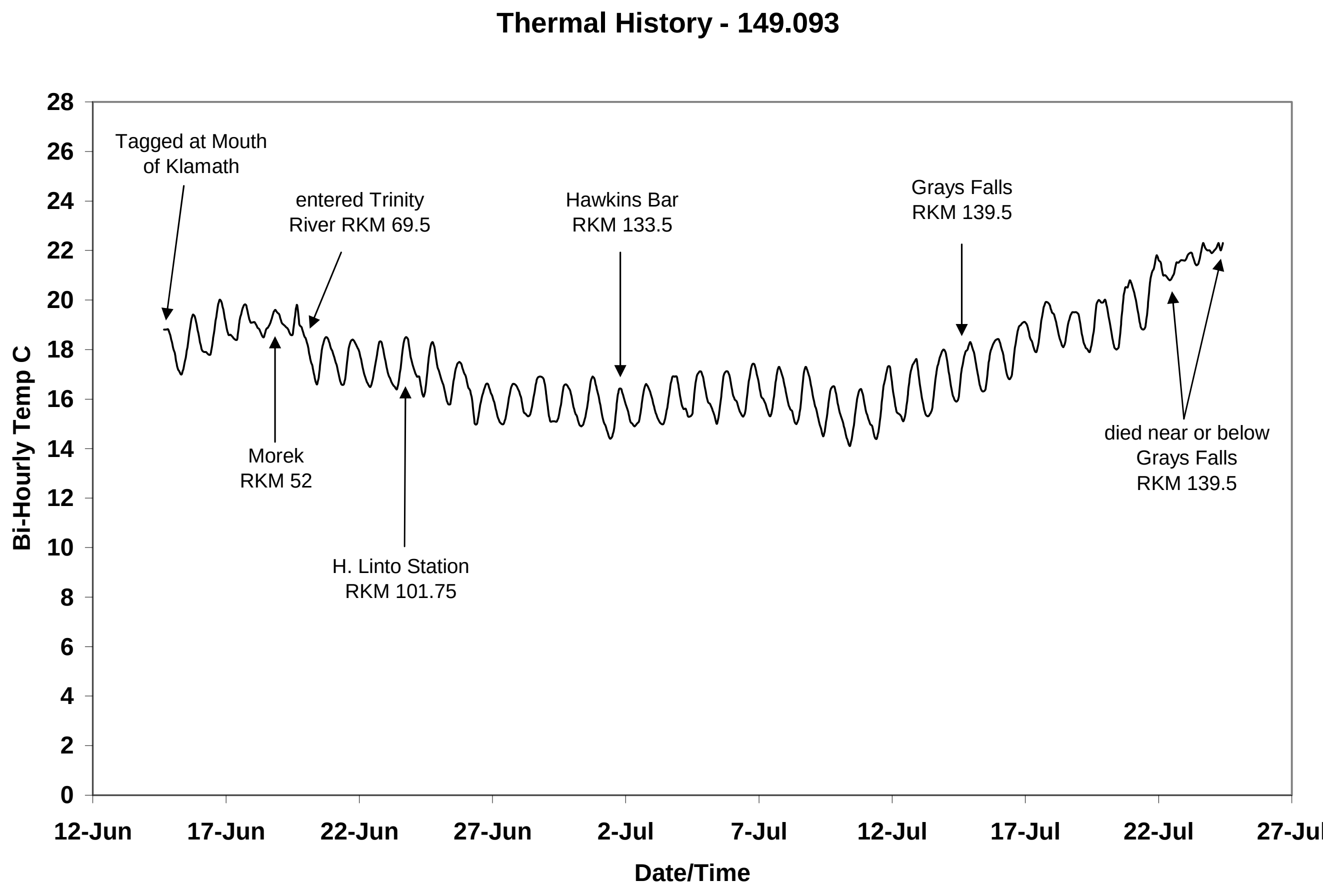


Figure 29. The thermal history (internal body temperature ^{o}C) for Chinook 149.093 during its upriver migration in the Klamath and Trinity Rivers, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

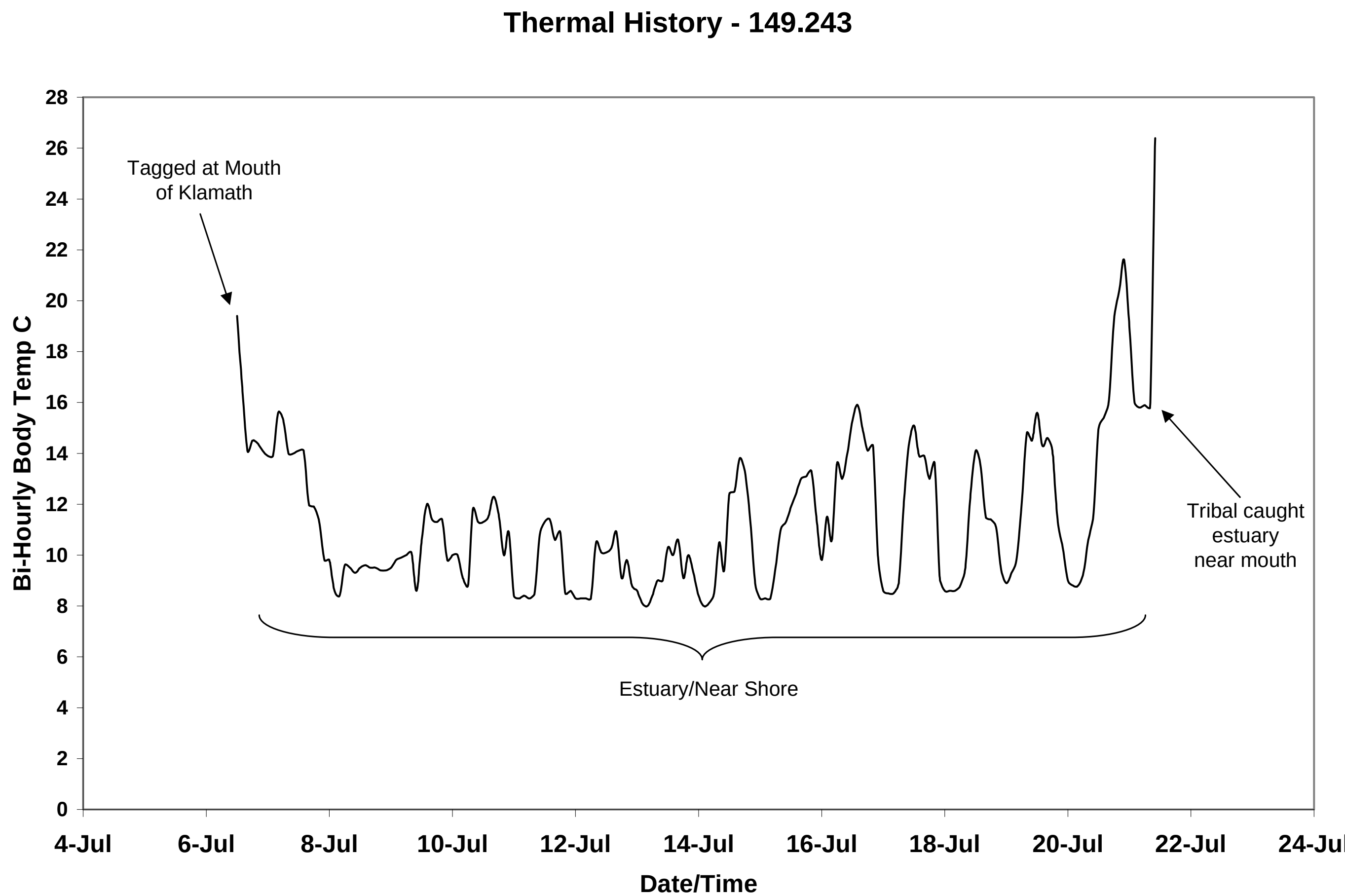


Figure 30. The thermal history (internal body temperature ^{o}C) for Chinook 149.243 during its upriver migration in the Klamath Rivers, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

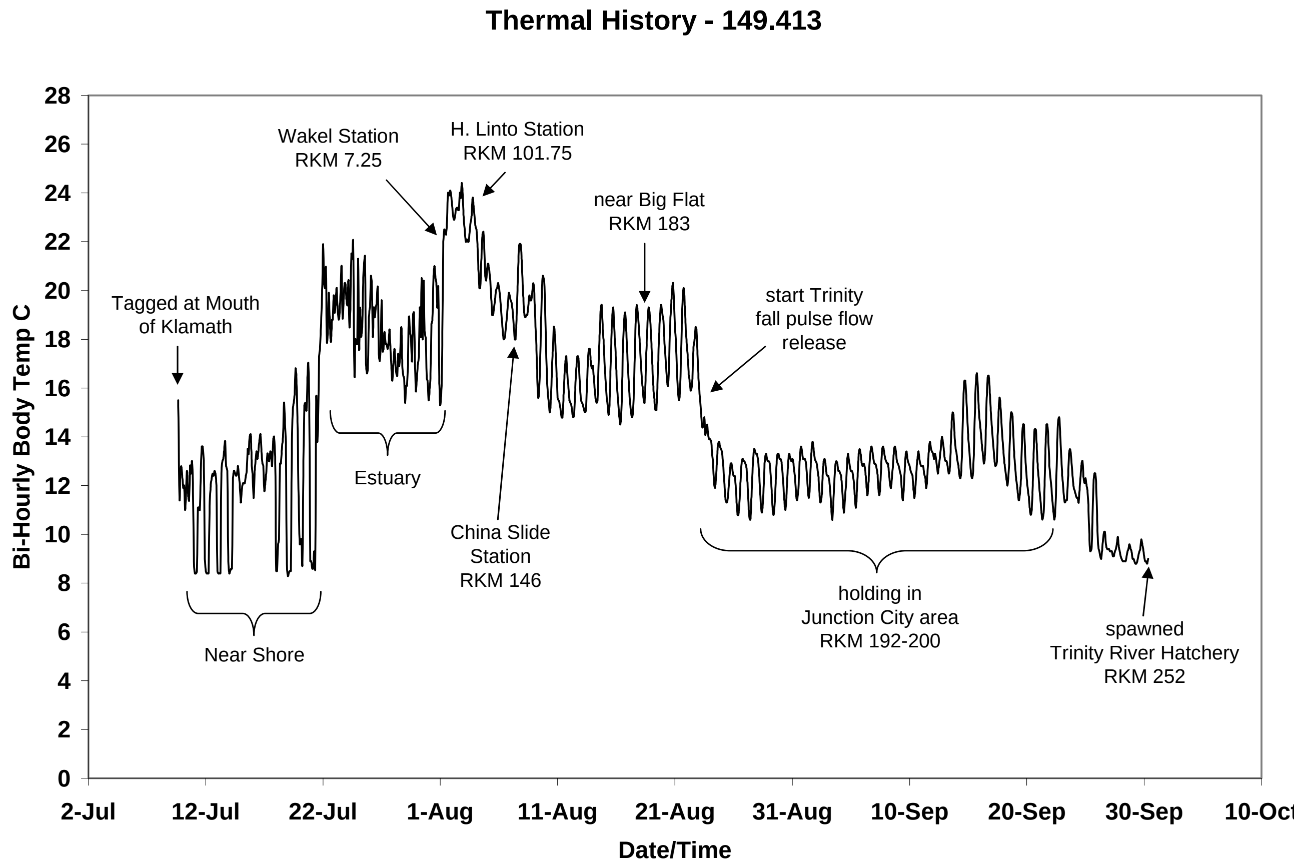


Figure 31. The thermal history (internal body temperature ^{o}C) for Chinook 149.413 during its upriver migration in the Klamath and Trinity Rivers, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation. This fish was not ad clipped but was spawned at the Trinity River Hatchery on 9/30/04 with the last group of "spring" Chinook of the season.

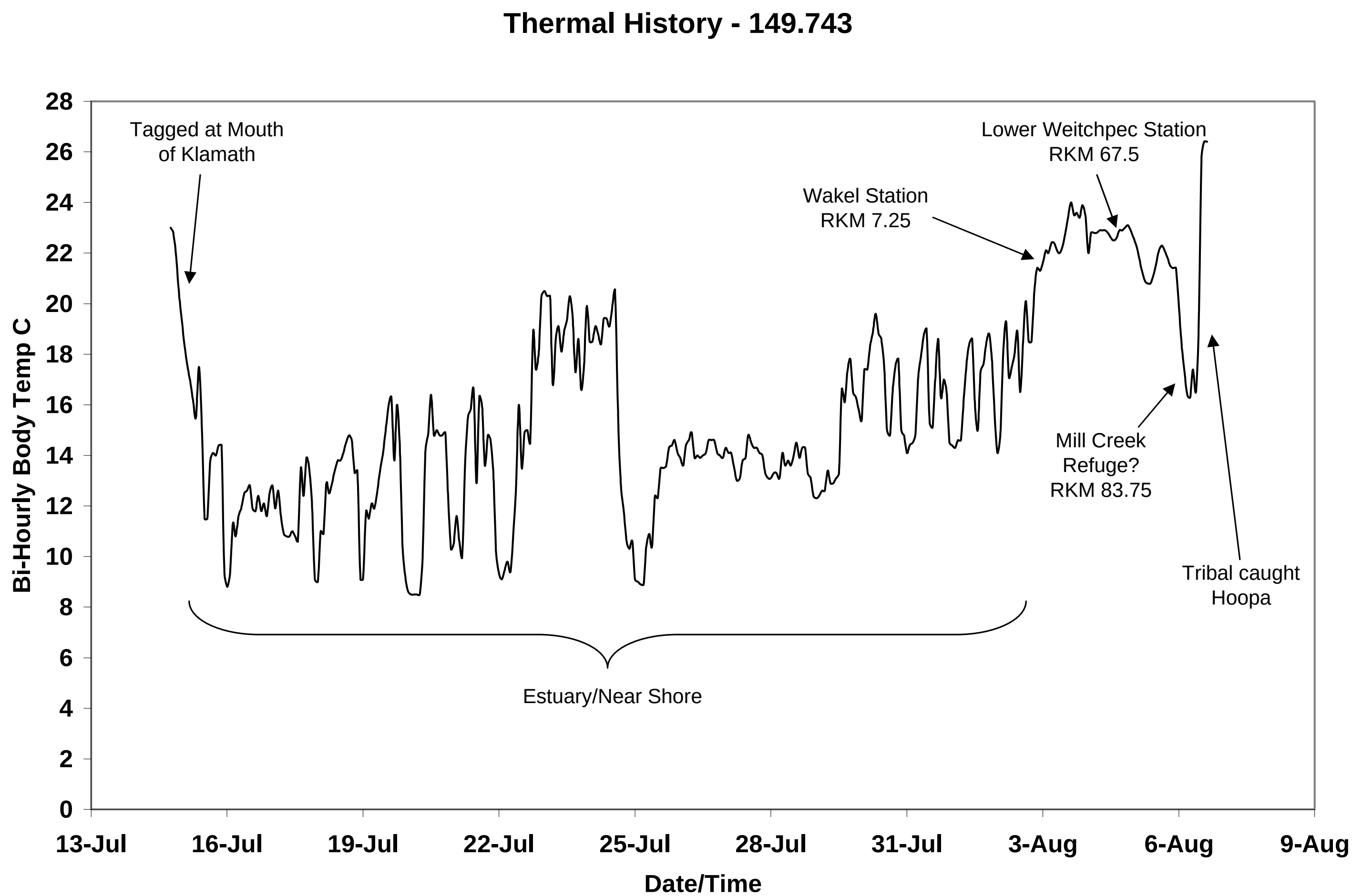


Figure 32. The thermal history (internal body temperature ^{o}C) for Chinook 149.743 during its upriver migration in the Klamath and Trinity Rivers, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

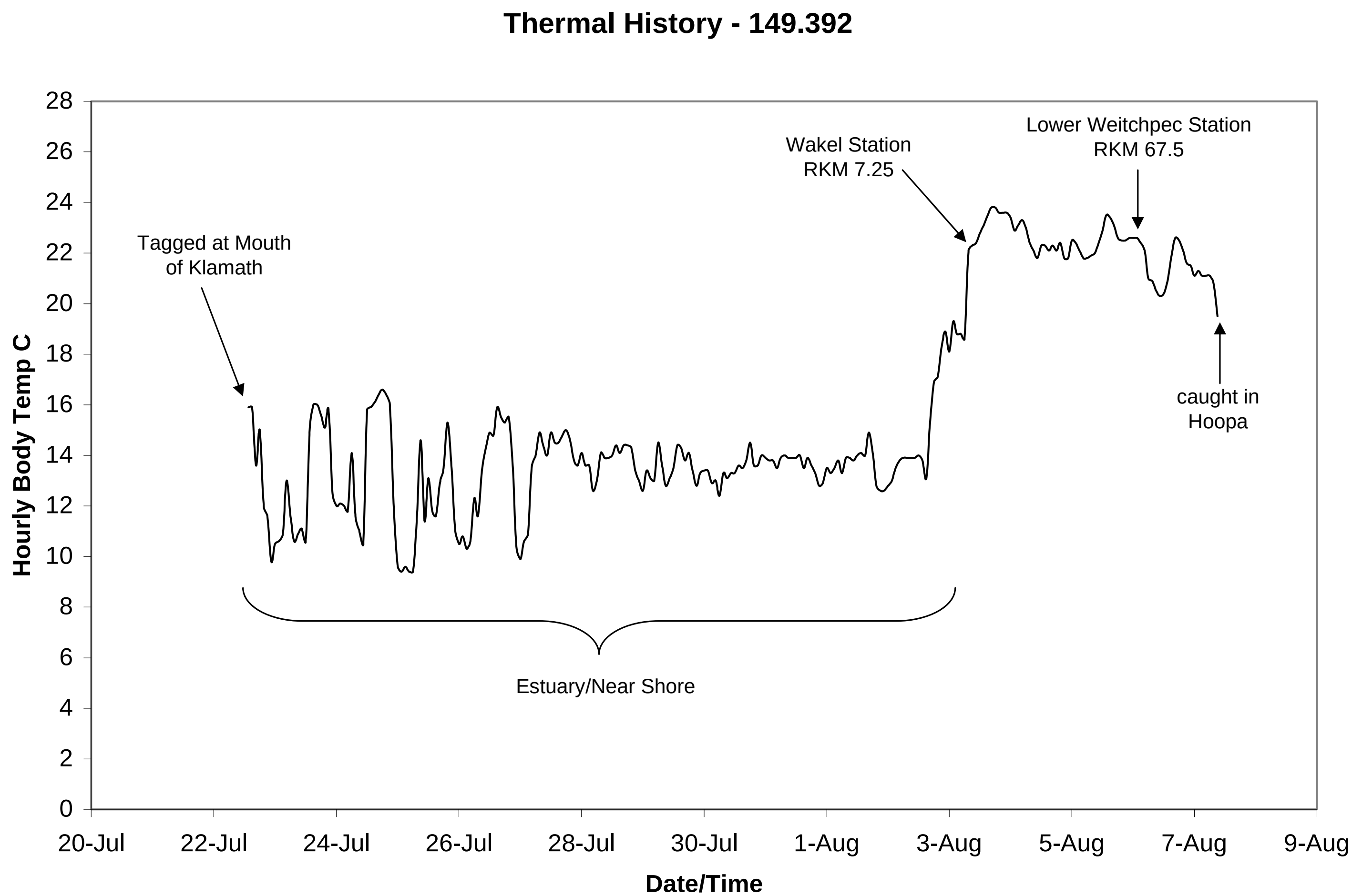


Figure 33. The thermal history (internal body temperature ^{o}C) for Chinook 149.392 during its upriver migration in the Klamath and Trinity Rivers, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

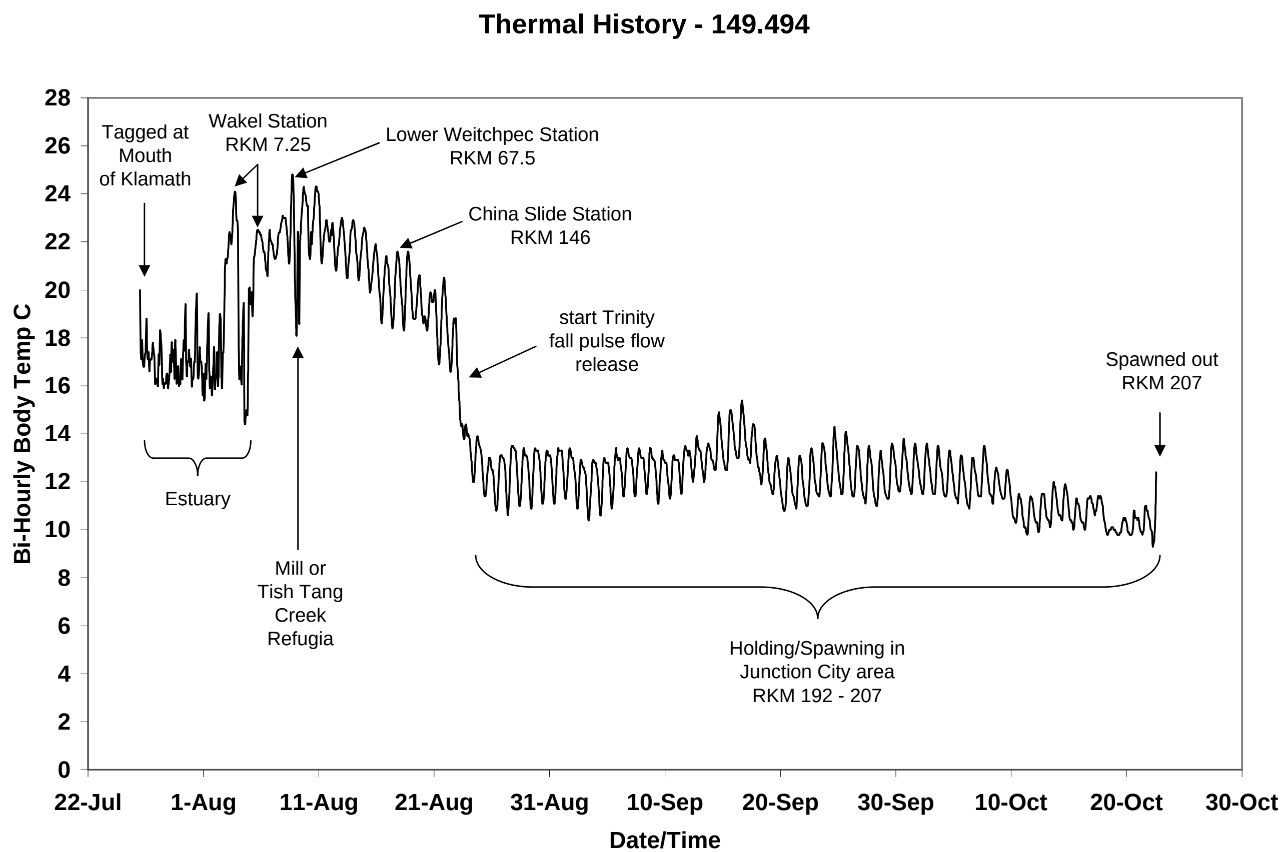


Figure 34. The thermal history (internal body temperature ^{o}C) for Chinook 149.494 during its upriver migration in the Klamath and Trinity Rivers, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

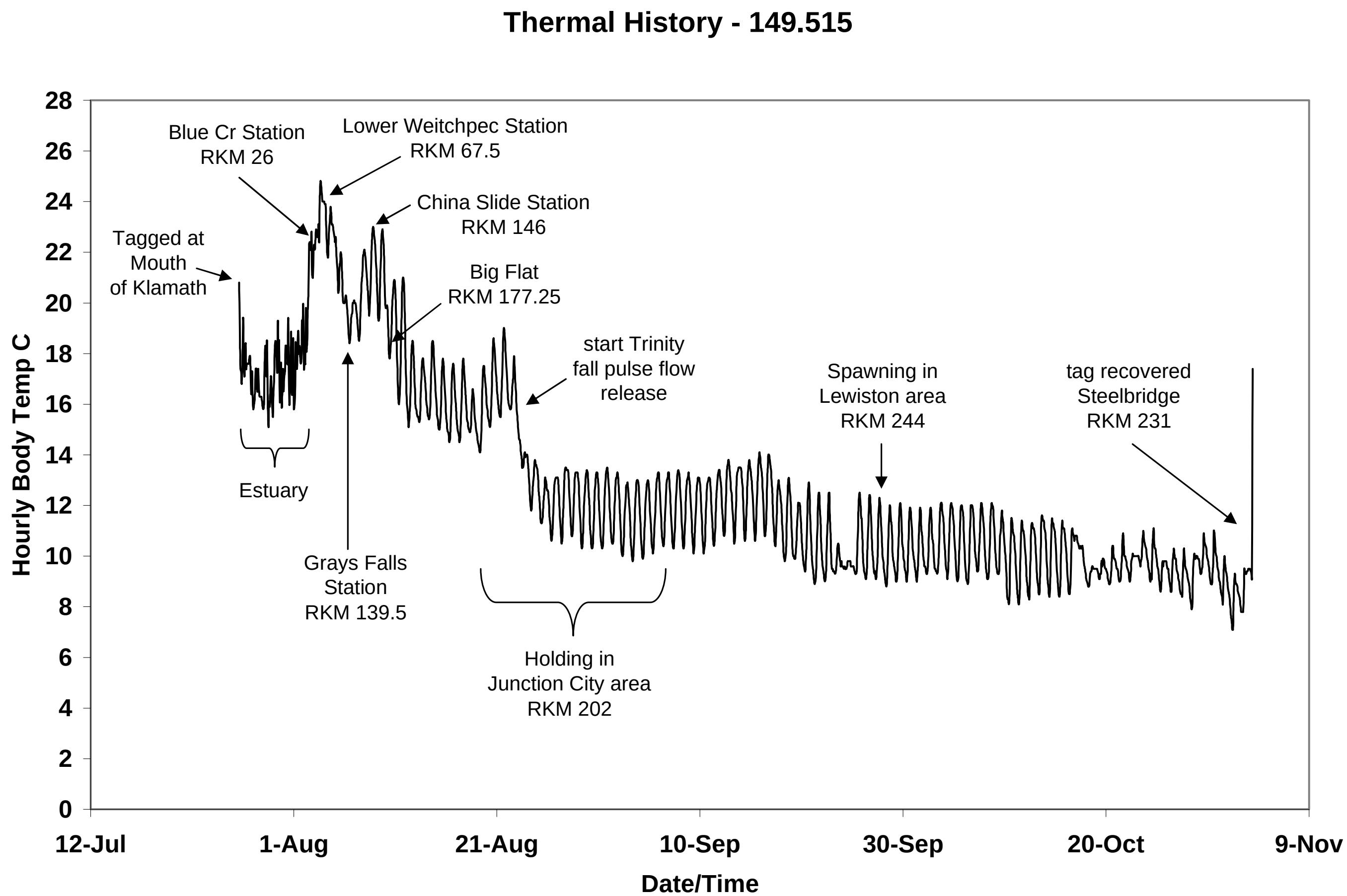


Figure 35. The thermal history (internal body temperature °C) for Chinook 149.515 during its upriver migration in the Klamath and Trinity Rivers, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

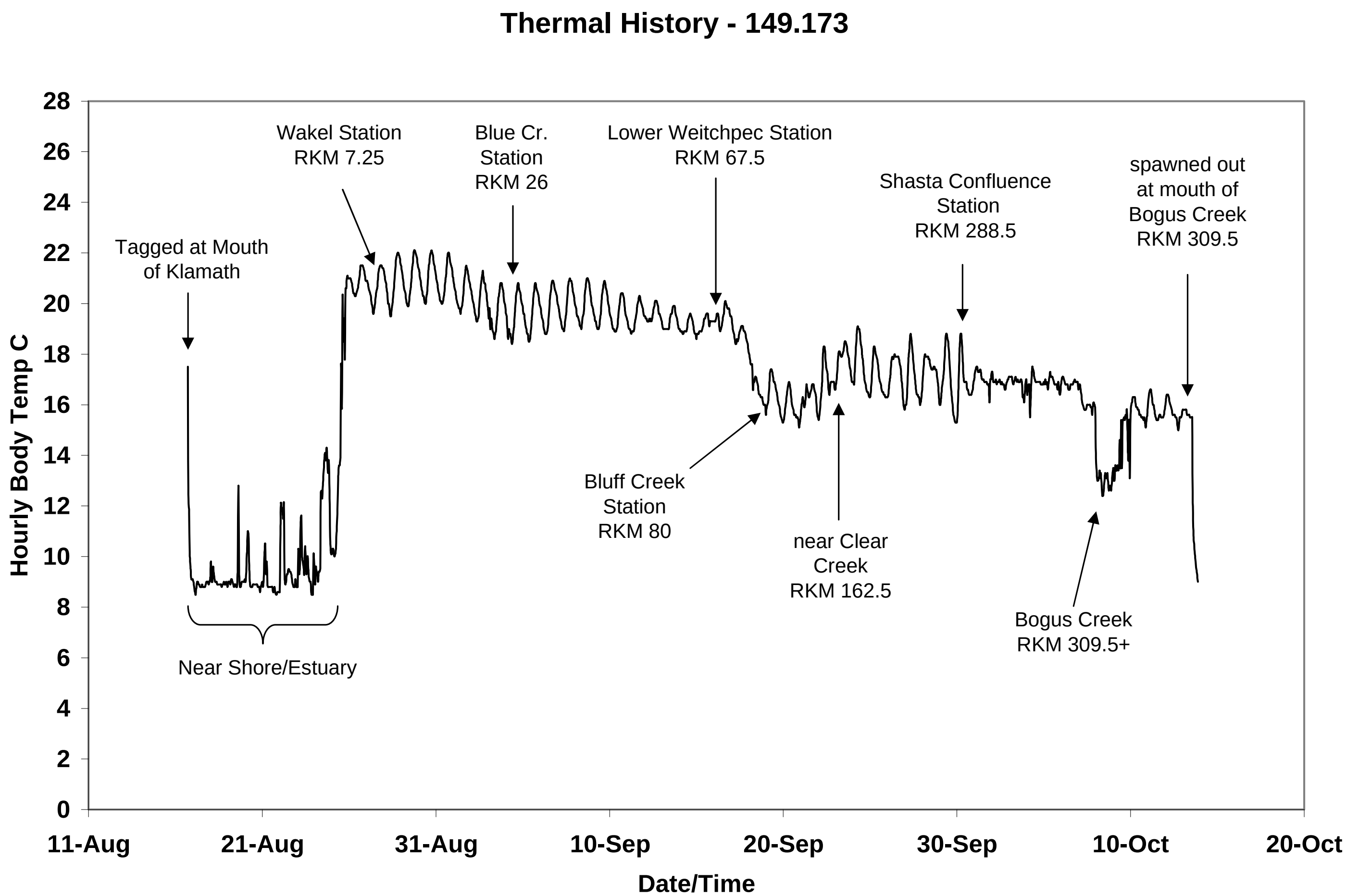


Figure 36. The thermal history (internal body temperature °C) for Chinook 149.173 during its upriver migration in the Klamath River, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

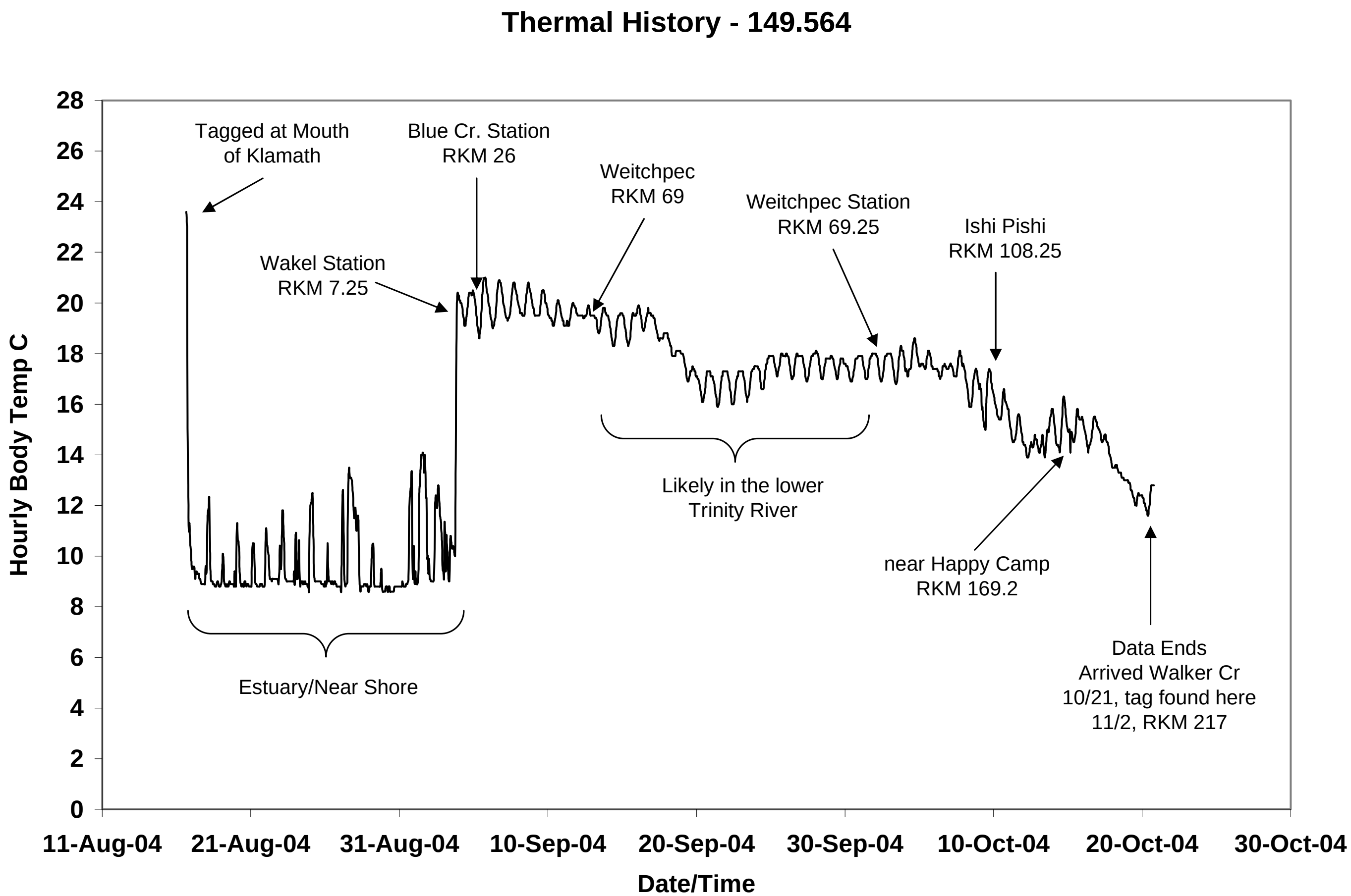


Figure 37. The thermal history (internal body temperature ^{o}C) for Chinook 149.564 during its upriver migration in the Klamath and Trinity Rivers, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

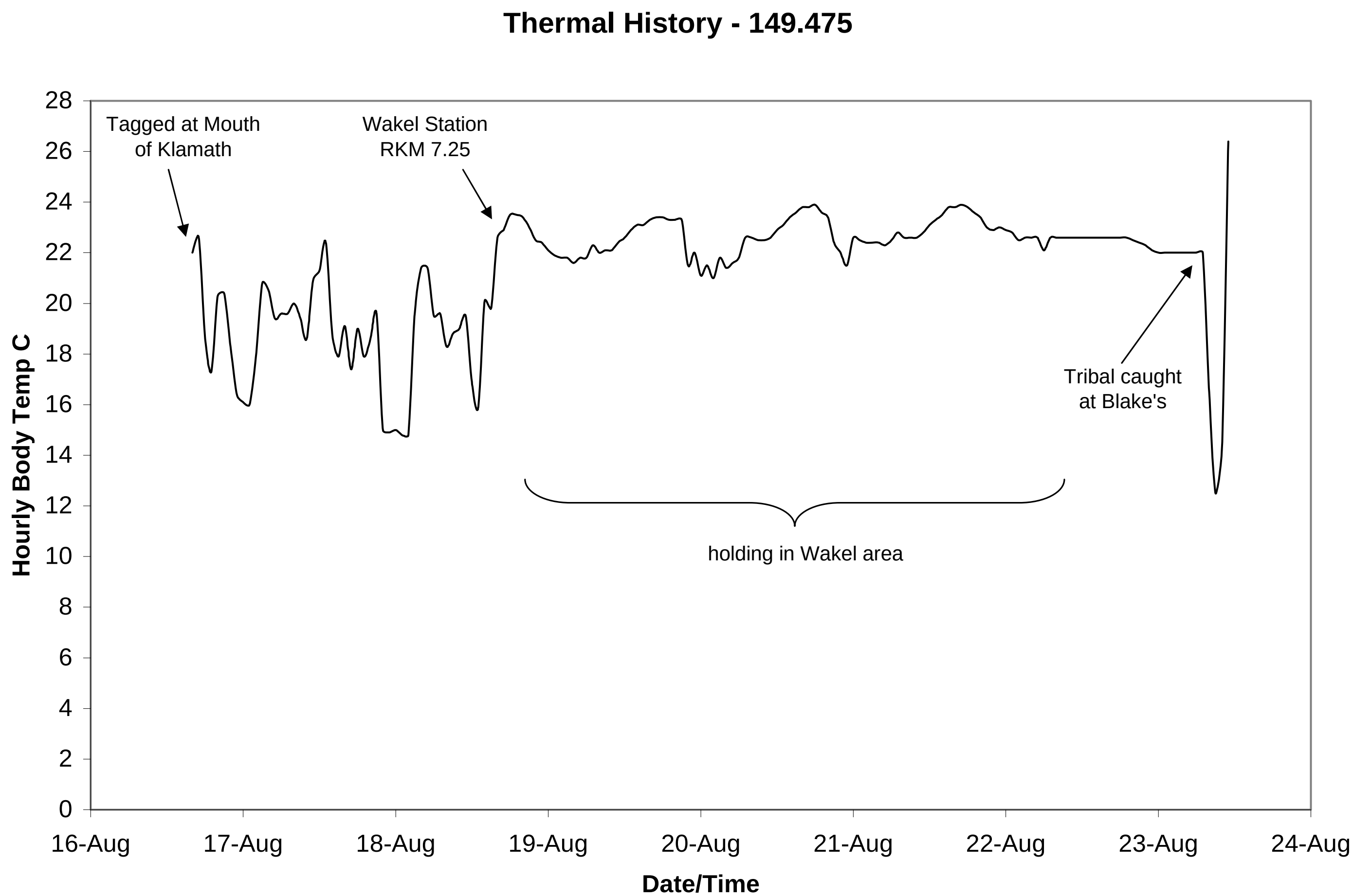


Figure 38. The thermal history (internal body temperature ^{o}C) for Chinook 149.475 during its upriver migration in the Klamath River, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

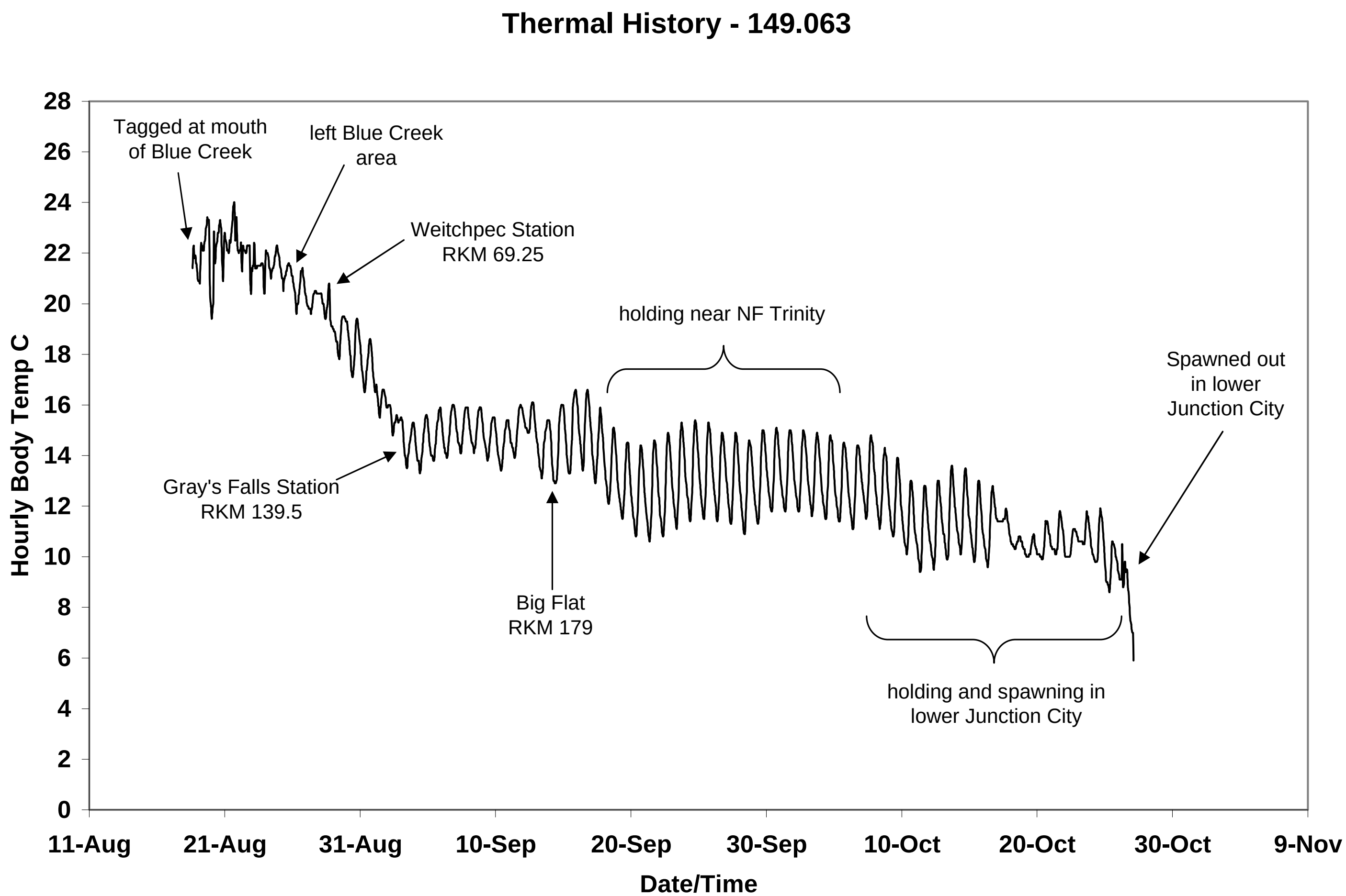


Figure 39. The thermal history (internal body temperature ^{o}C) for Chinook 149.063 during its upriver migration in the Klamath River, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

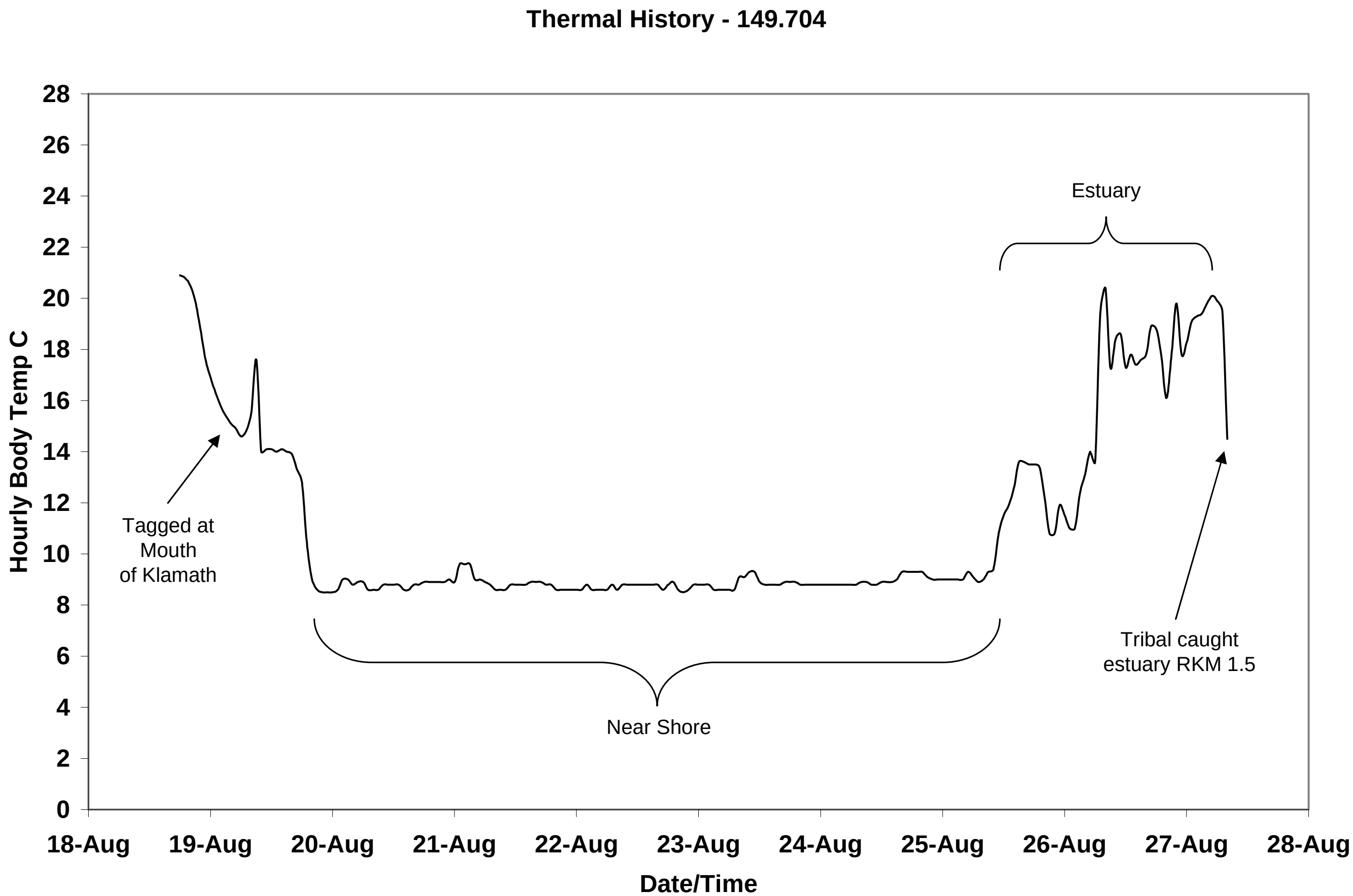


Figure 40. The thermal history (internal body temperature ^{o}C) for Chinook 149.704 during its upriver migration in the Klamath River, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

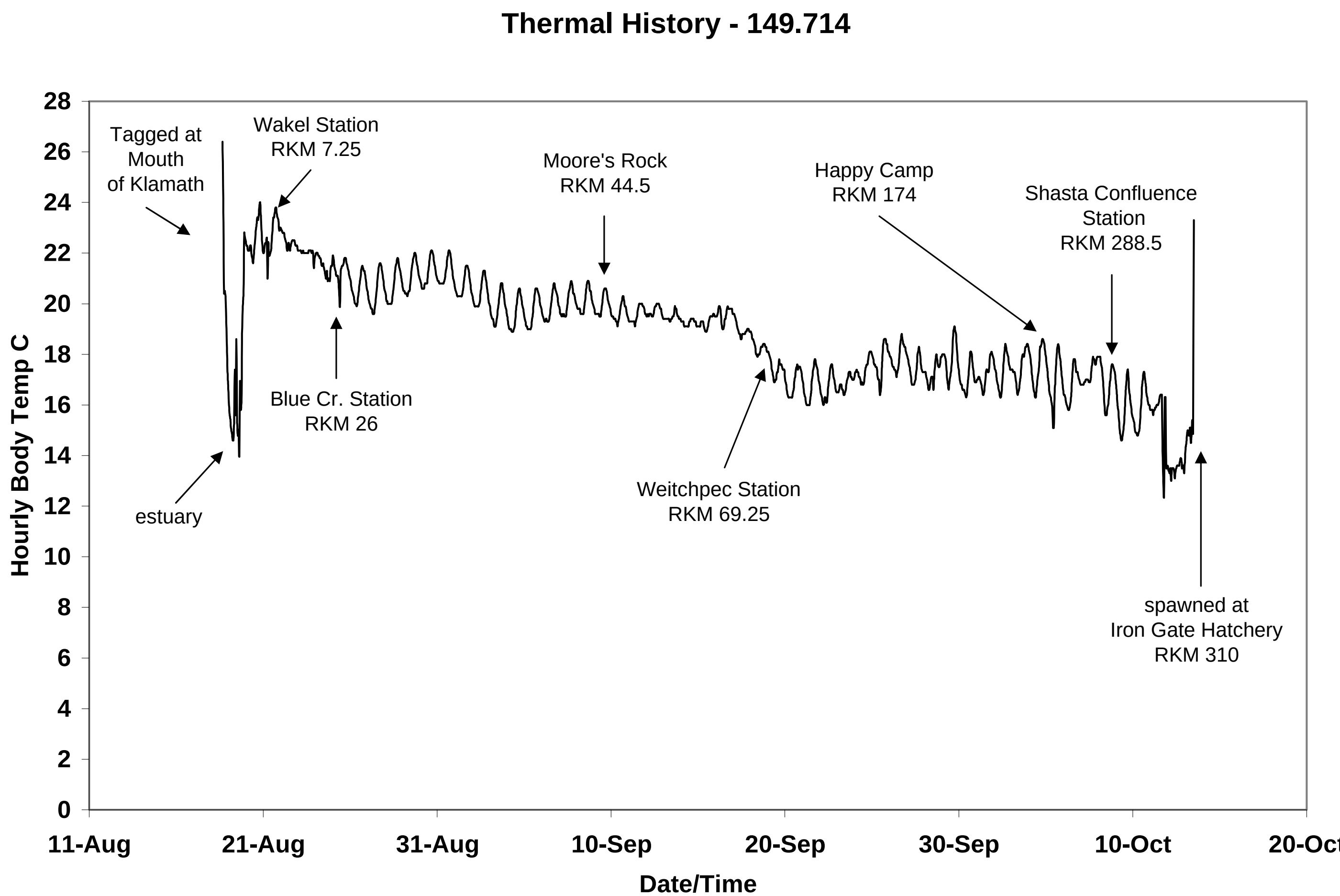


Figure 41. The thermal history (internal body temperature ^oC) for Chinook 149.714 during its upriver migration in the Klamath River, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

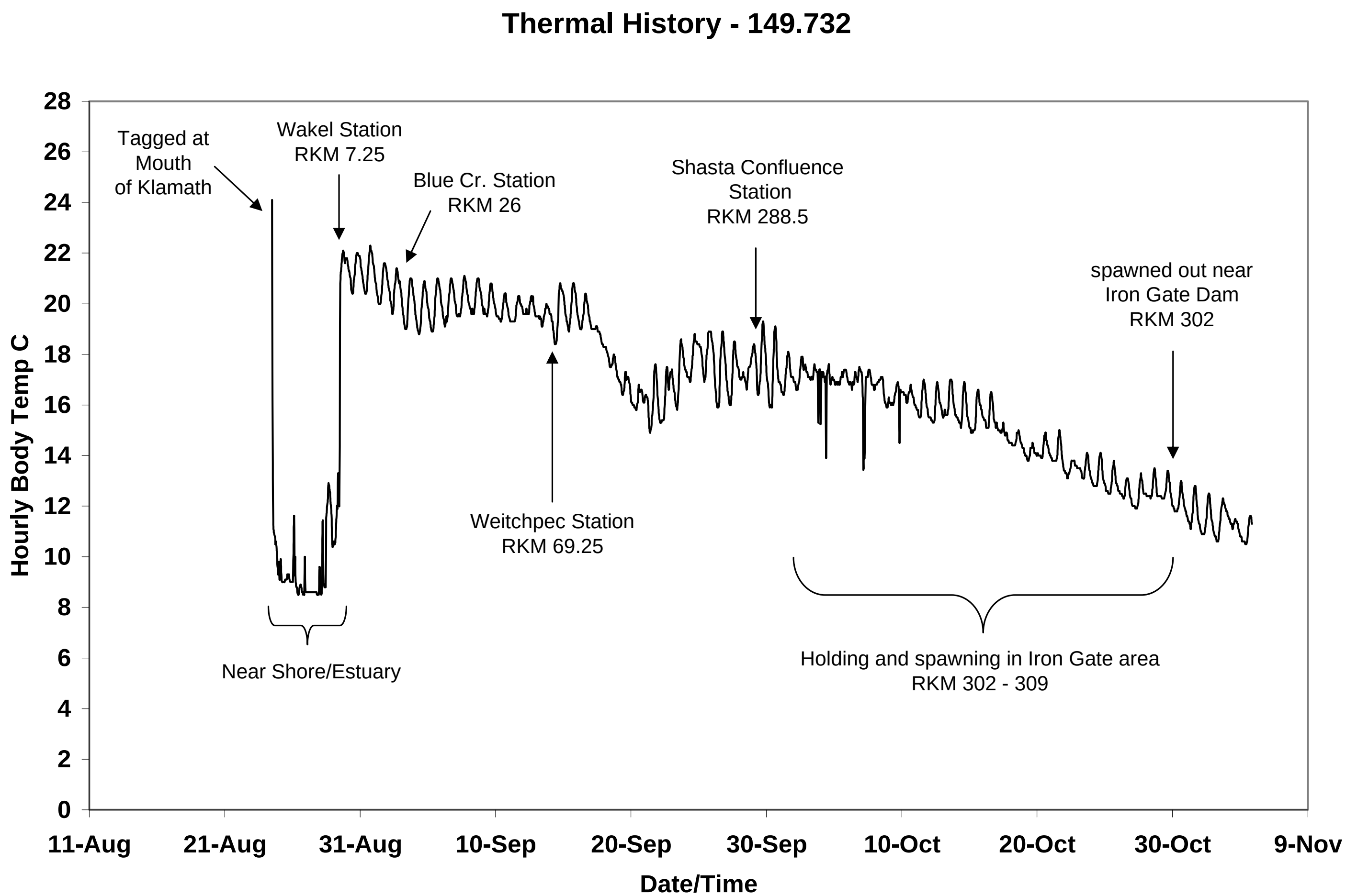


Figure 42. The thermal history (internal body temperature °C) for Chinook 149.732 during its upriver migration in the Klamath River, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

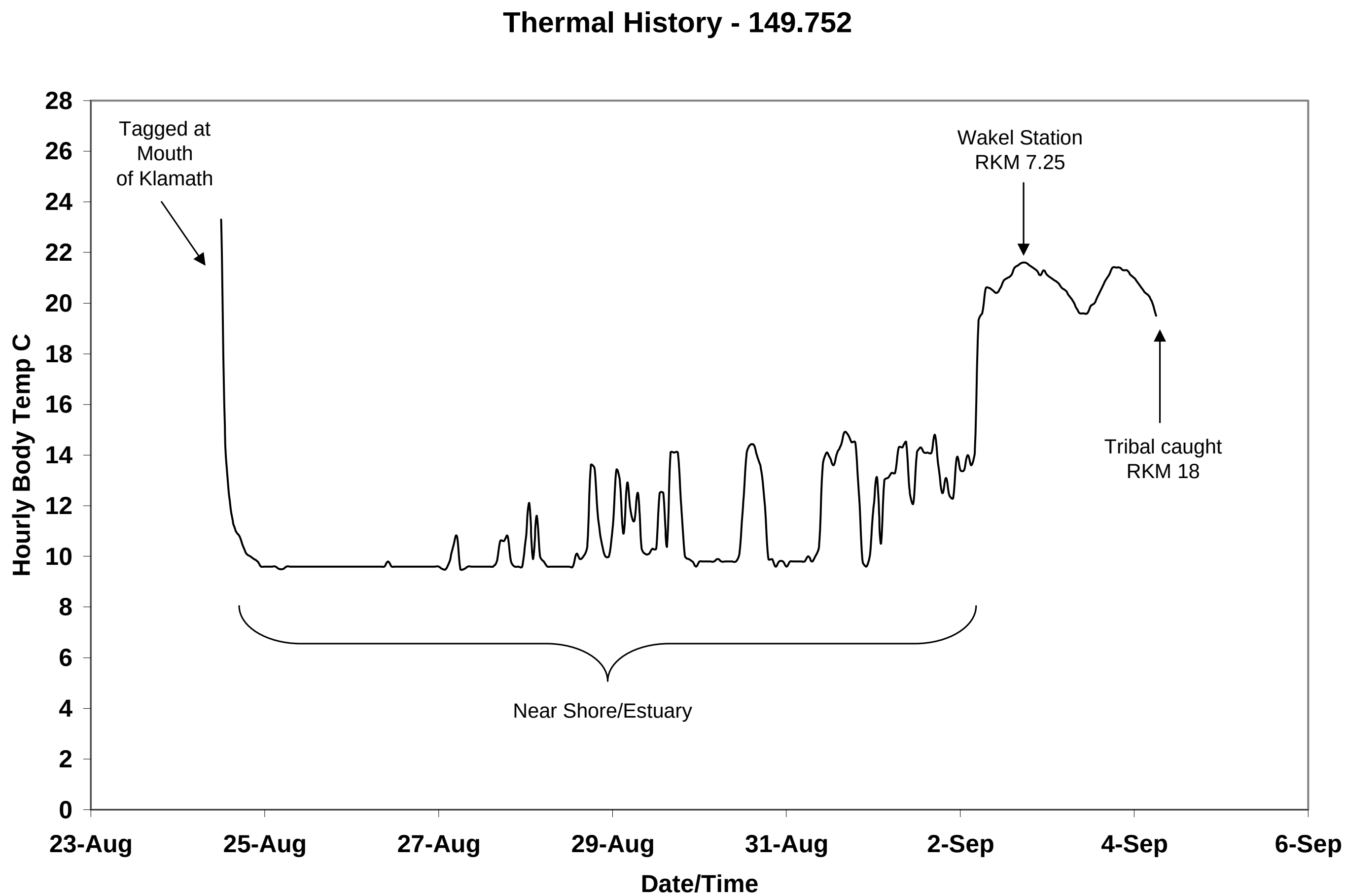


Figure 43. The thermal history (internal body temperature ^{o}C) for Chinook 149.752 during its upriver migration in the Klamath River, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

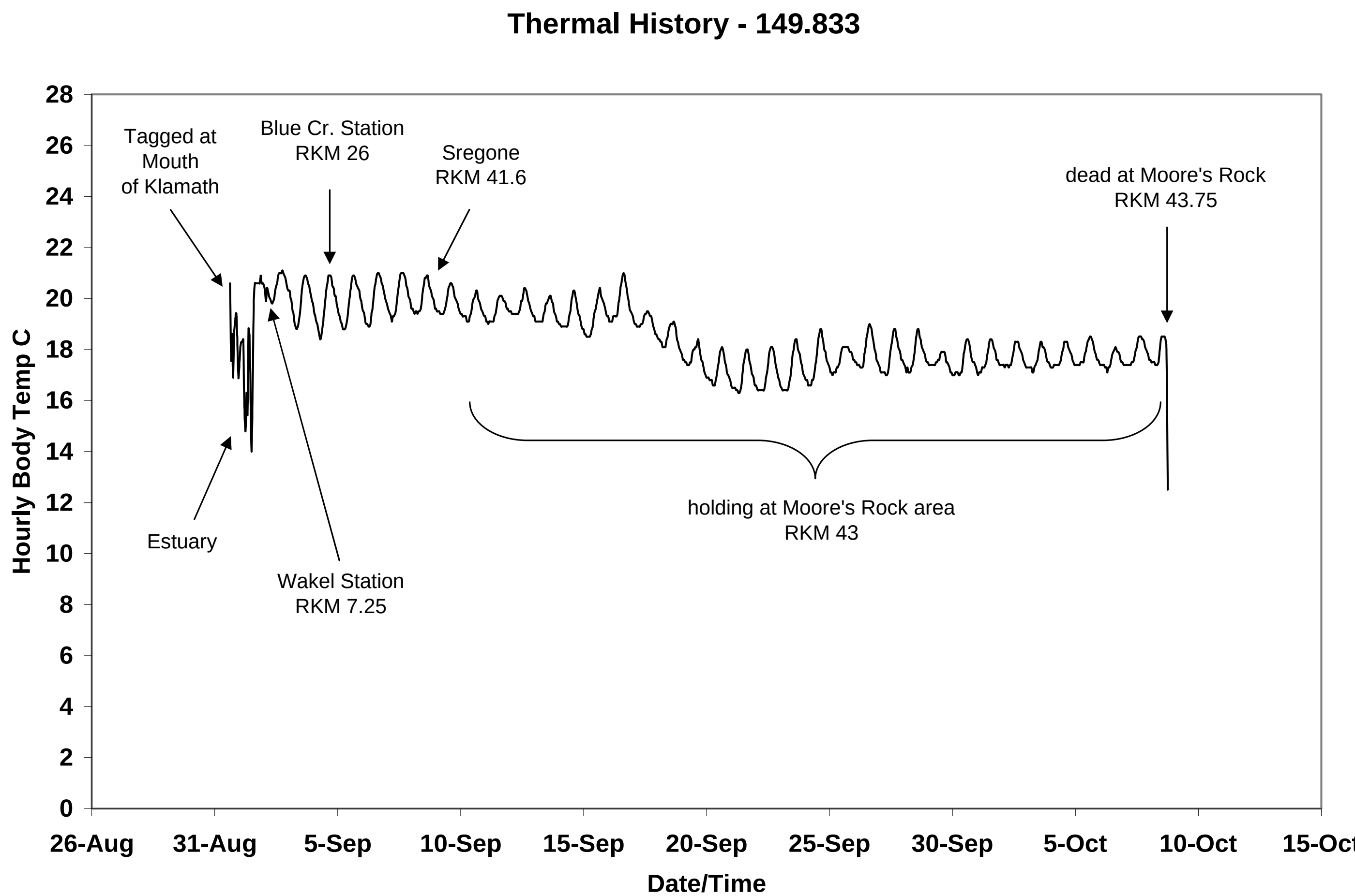


Figure 44. The thermal history (internal body temperature °C) for Chinook 149.833 during its upriver migration in the Klamath River, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

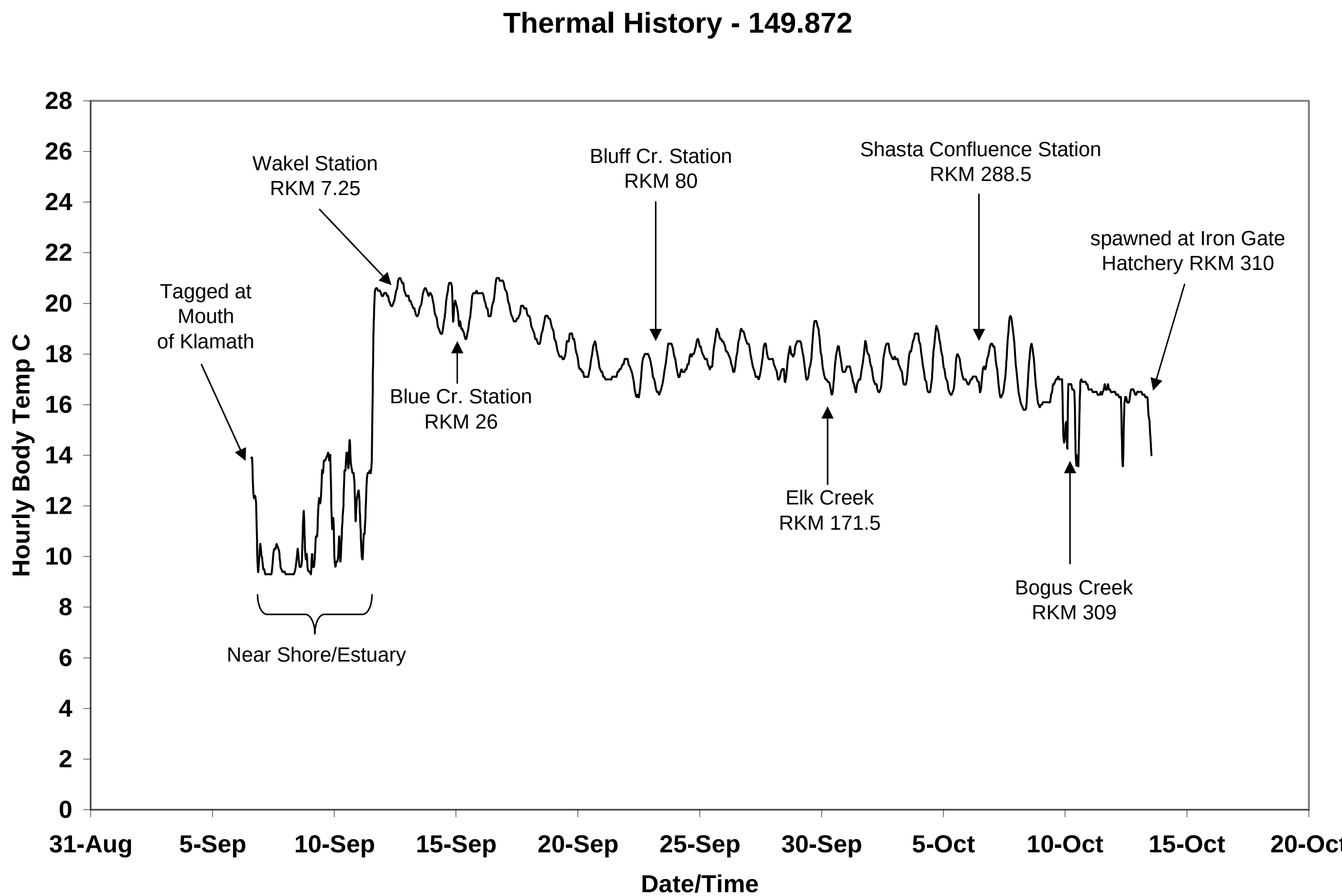


Figure 45. The thermal history (internal body temperature ^{o}C) for Chinook 149.872 during its upriver migration in the Klamath River, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

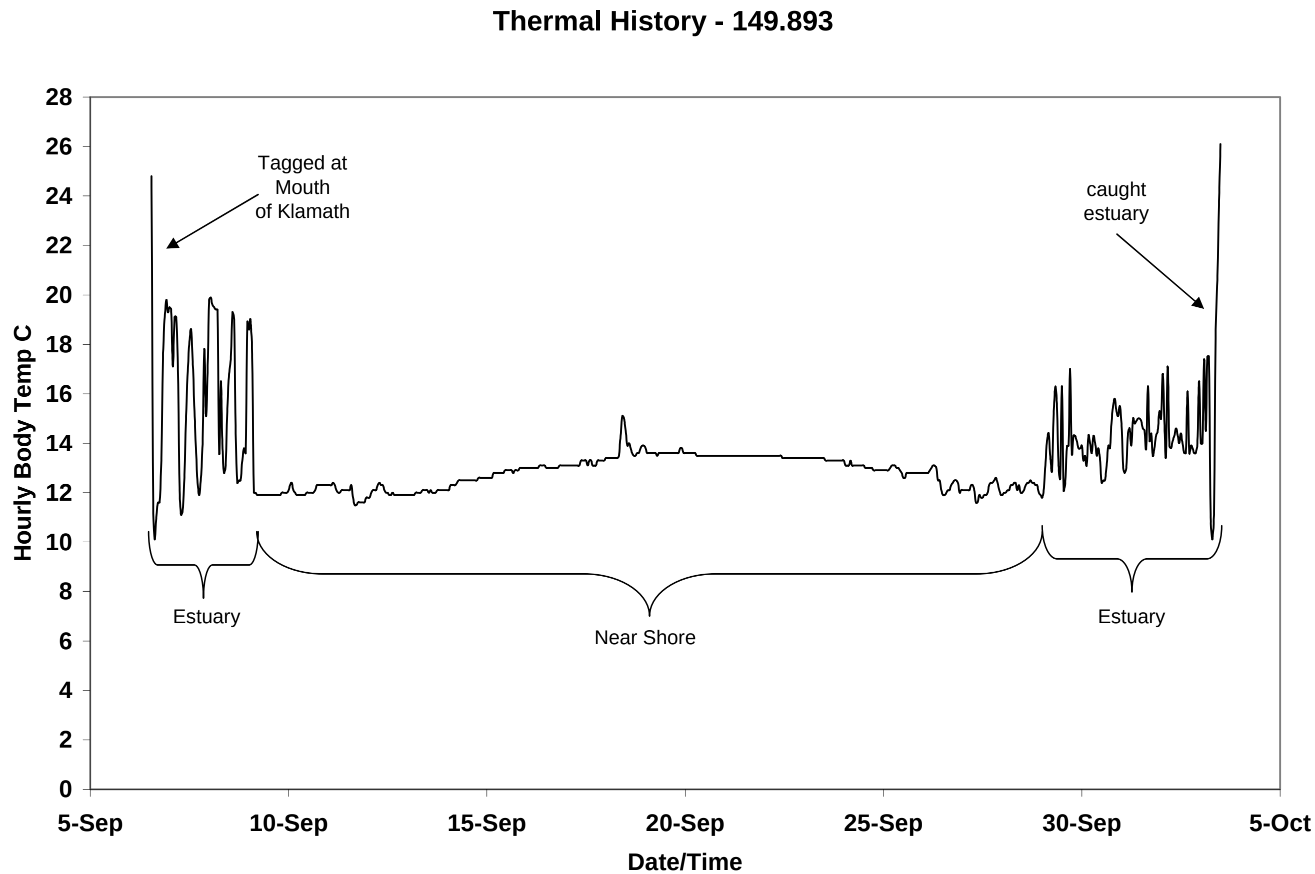


Figure 46. The thermal history (internal body temperature °C) for Chinook 149.893 during its upriver migration in the Klamath River, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

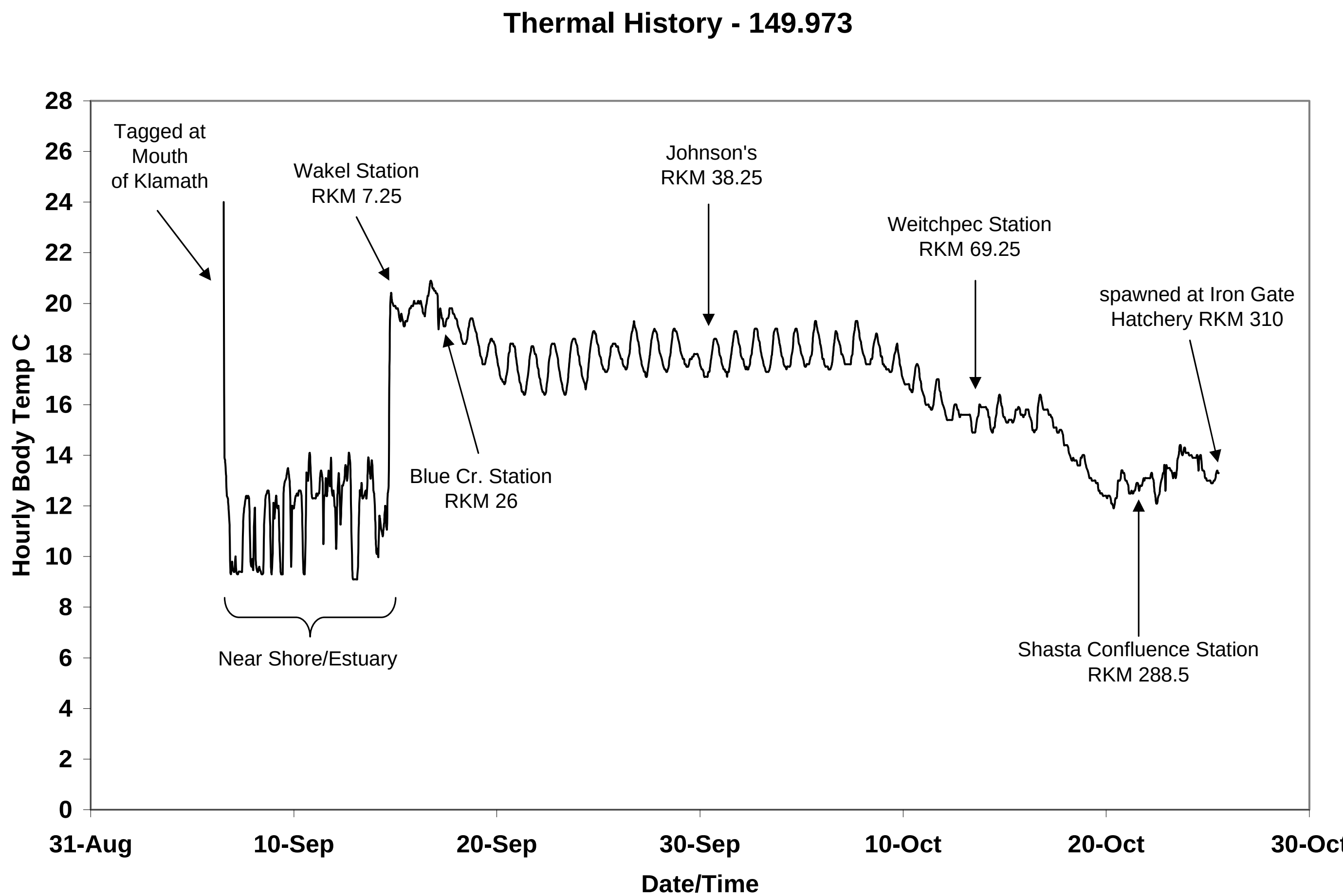


Figure 47. The thermal history (internal body temperature ^{o}C) for Chinook 149.973 during its upriver migration in the Klamath River, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

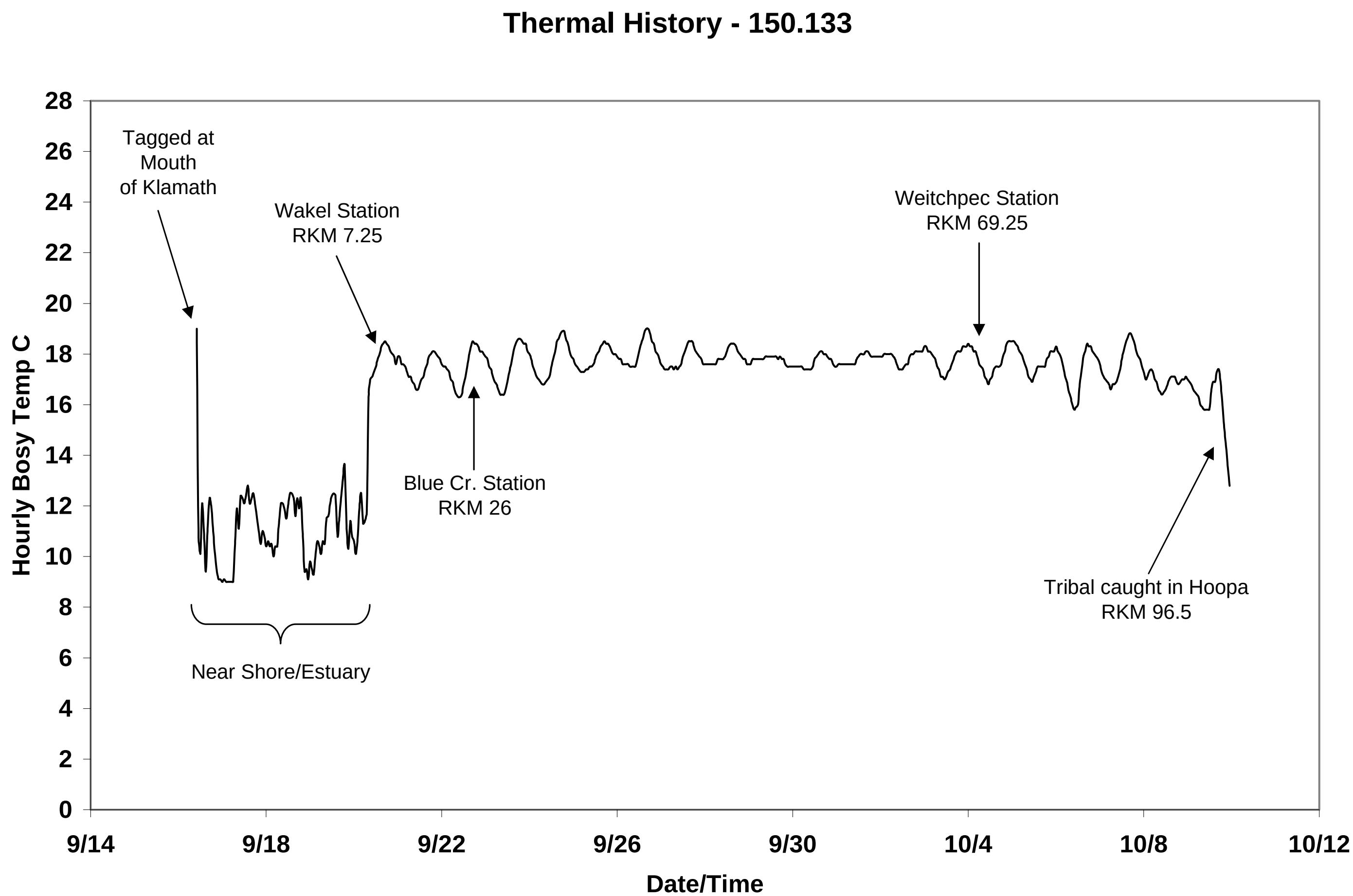


Figure 48. The thermal history (internal body temperature ^{o}C) for Chinook 150.133 during its upriver migration in the Klamath and Trinity Rivers, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

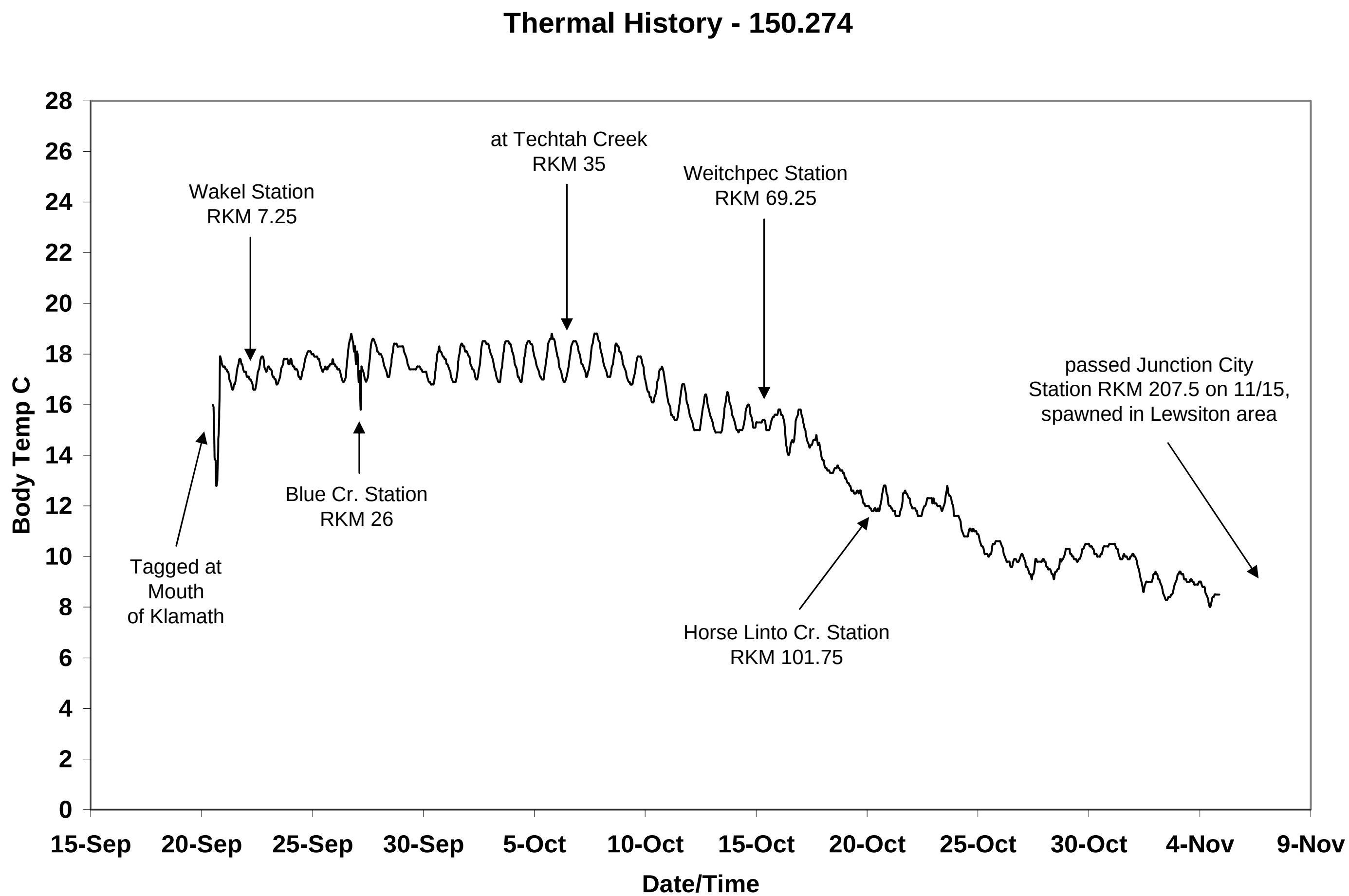


Figure 49. The thermal history (internal body temperature ^{o}C) for Chinook 150.274 during its upriver migration in the Klamath and Trinity Rivers, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

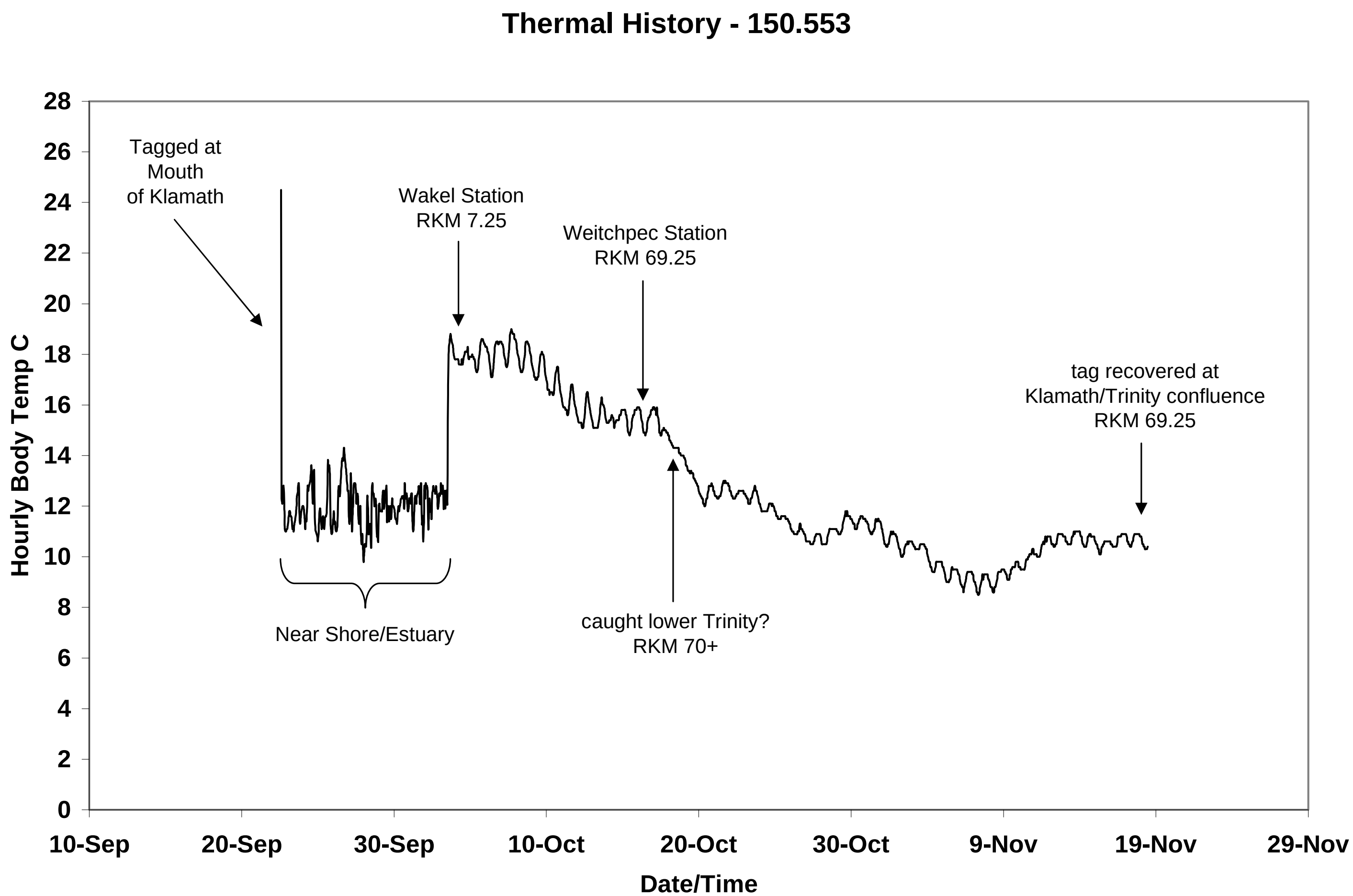


Figure 50. The thermal history (internal body temperature ^{o}C) for Chinook 150.553 during its upriver migration in the Klamath River, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

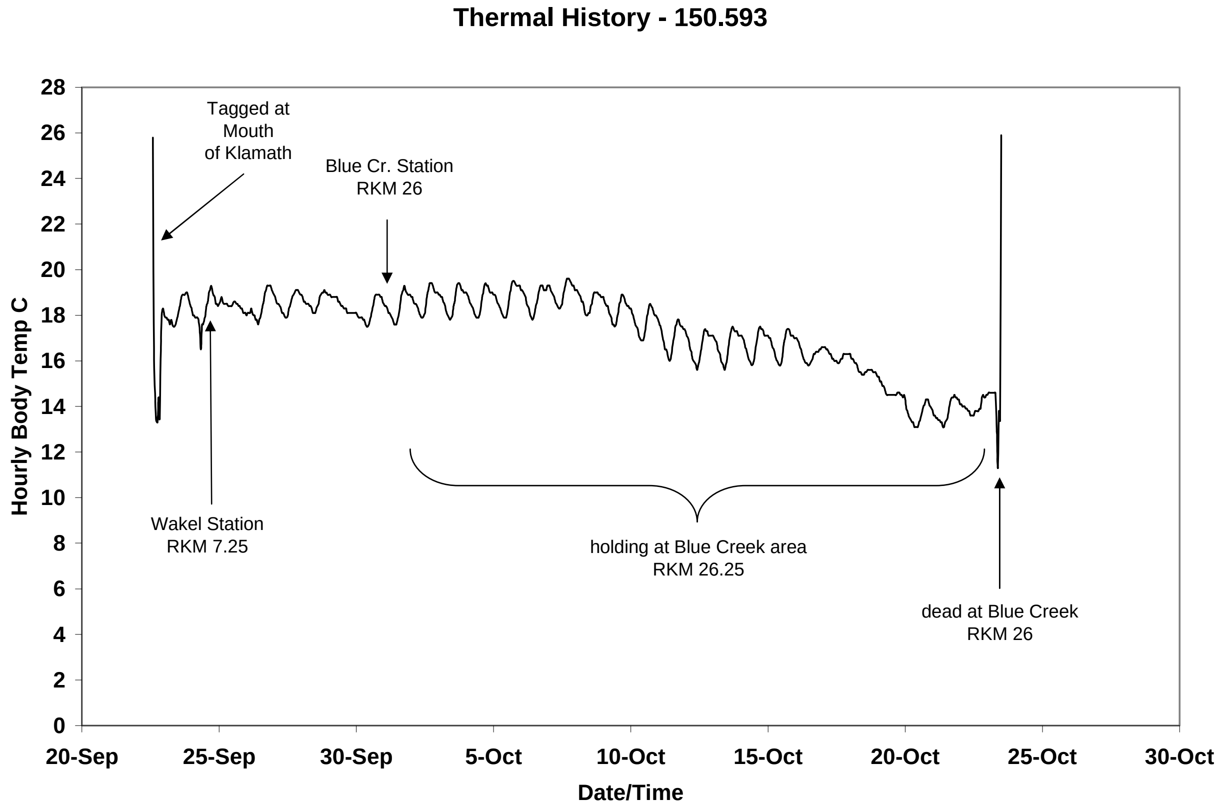


Figure 51. The thermal history (internal body temperature °C) for Chinook 150.593 during its upriver migration in the Klamath River, 2004. Important benchmarks of fish locations and events are designated by the labeled arrows or brackets which match the date/time of the body temperature recordings to the date/time of the location or event observation.

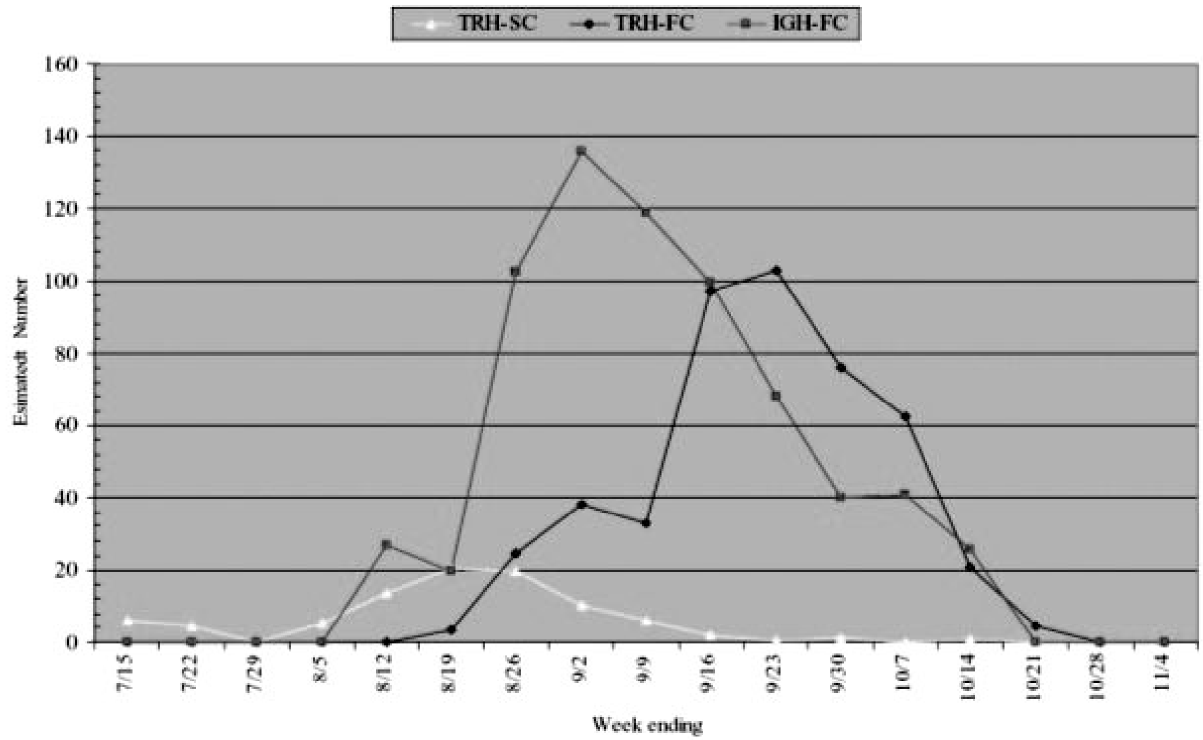


Figure 52. Average run timing by week for adult Chinook in the lower Klamath River (primarily below RKM 26) based on coded wire tag recoveries form the sport fishery. Trinity River Hatchery spring Chinook (TRH-SC) have a bimodal run timing with the larger peak in the late June. Iron Gate Hatchery fall Chinook (IGH-FC) consistently run earlier than Trinity River Hatchery fall Chinook ((TRH-FC). Source CDFG.

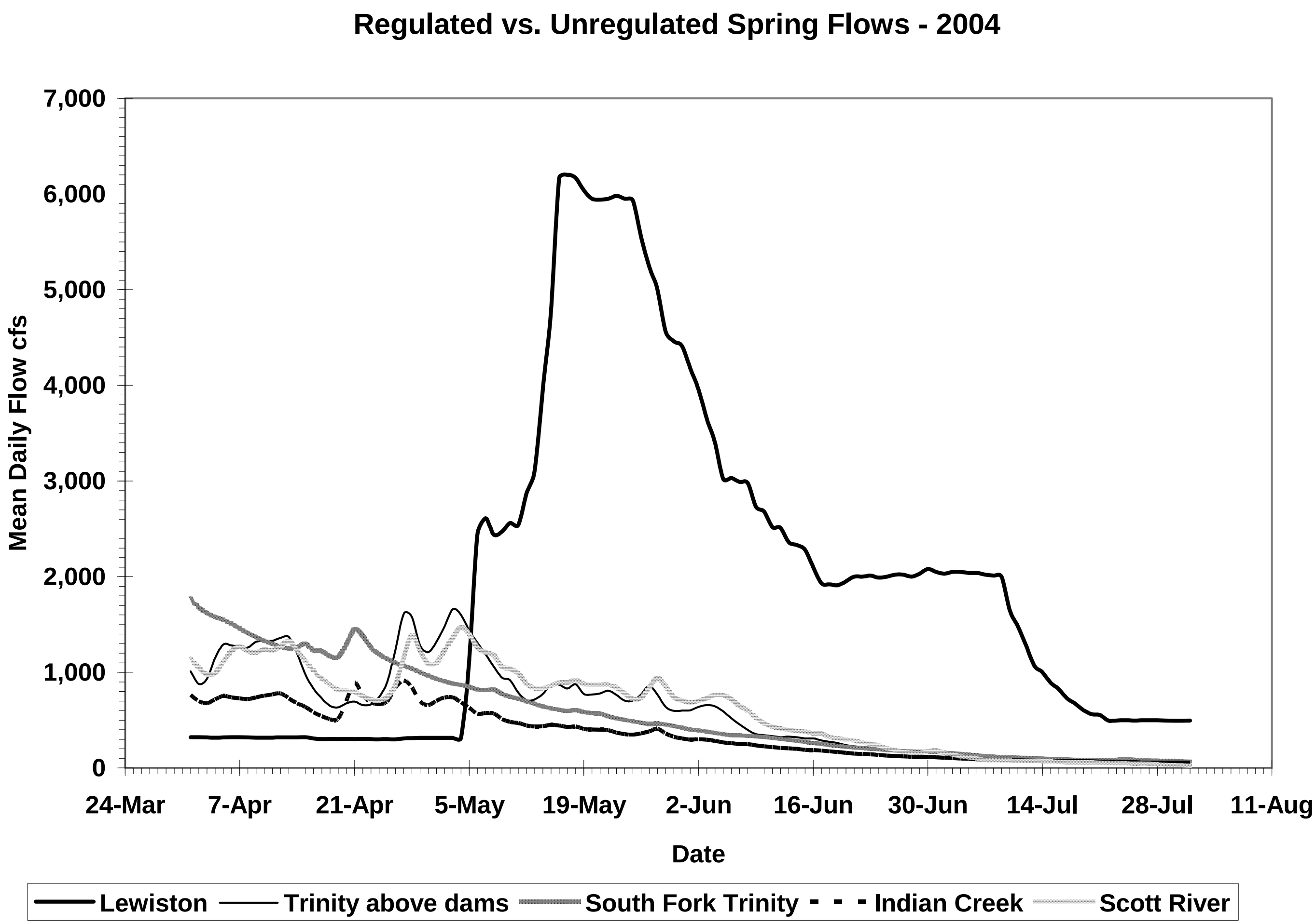


Figure 53. Comparison of the spring releases from Lewiston Dam on the mainstem Trinity River to the natural snowmelt from unregulated tributaries (Salmon River flow data not available for 2004), showing the timing discontinuity and unnaturally rapid ramp down rate at the end of the Trinity spring bench flow.

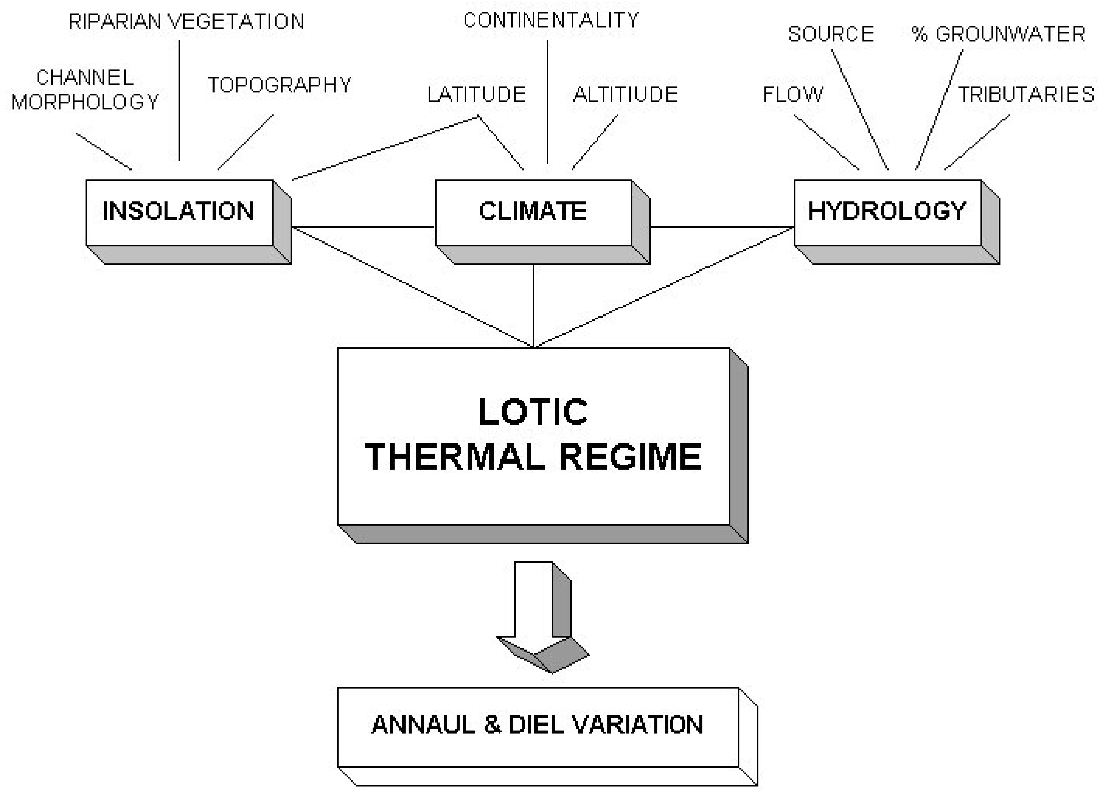


Figure 54. Factors determining the thermal regime in lotic systems (streams and rivers) (adapted from Ward 1985).

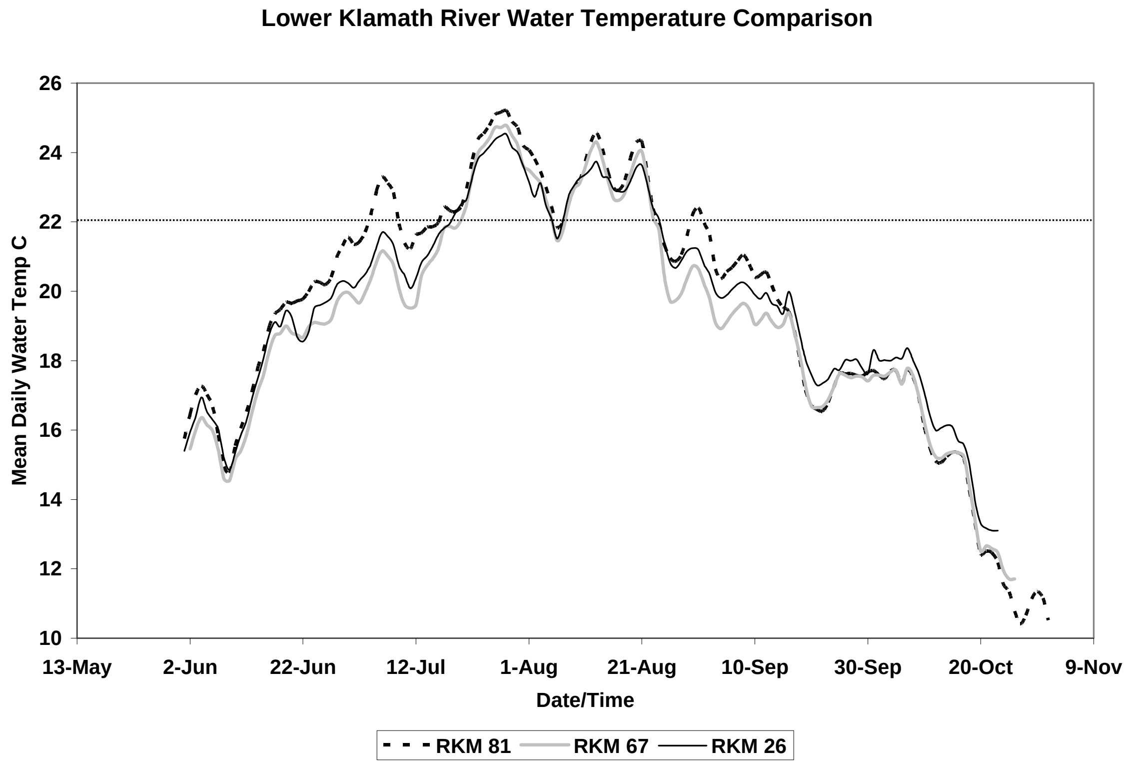


Figure 55. Mean daily water temperatures for the mainstem Klamath River at three locations. In the June temperatures are equivalent due to snowmelt throughout the KRB. By July snowmelt had ended on the mainstem Klamath River above Weitchpec but continued due to the extended spring bench release from Lewiston Dam, thus cooling temperatures at RKM 67 that subsequently continued to warm as the water traveled downriver to RKM 26. The extended spring bench release delayed the onset of mean daily temperatures ≥22°C by approximately two weeks in the lower Klamath River below Weitchpec. From the end of the Trinity spring bench release to beginning of the Trinity fall pulse flow, river temperatures were again roughly equivalent with a moderate downriver cooling trend due to the cooling from the coastal affect. This is the typical summer pattern. Starting with the arrival of cool weather and the Trinity fall pulse flow, water temperatures dropped precipitously below Weitchpec and demonstrated a pattern of downriver warming similar to what occurred in July. After the cessation of the pulse flow, temperatures reverted to a typical fall pattern with downriver warming due to the moderation of low air temperatures by the coastal affect.

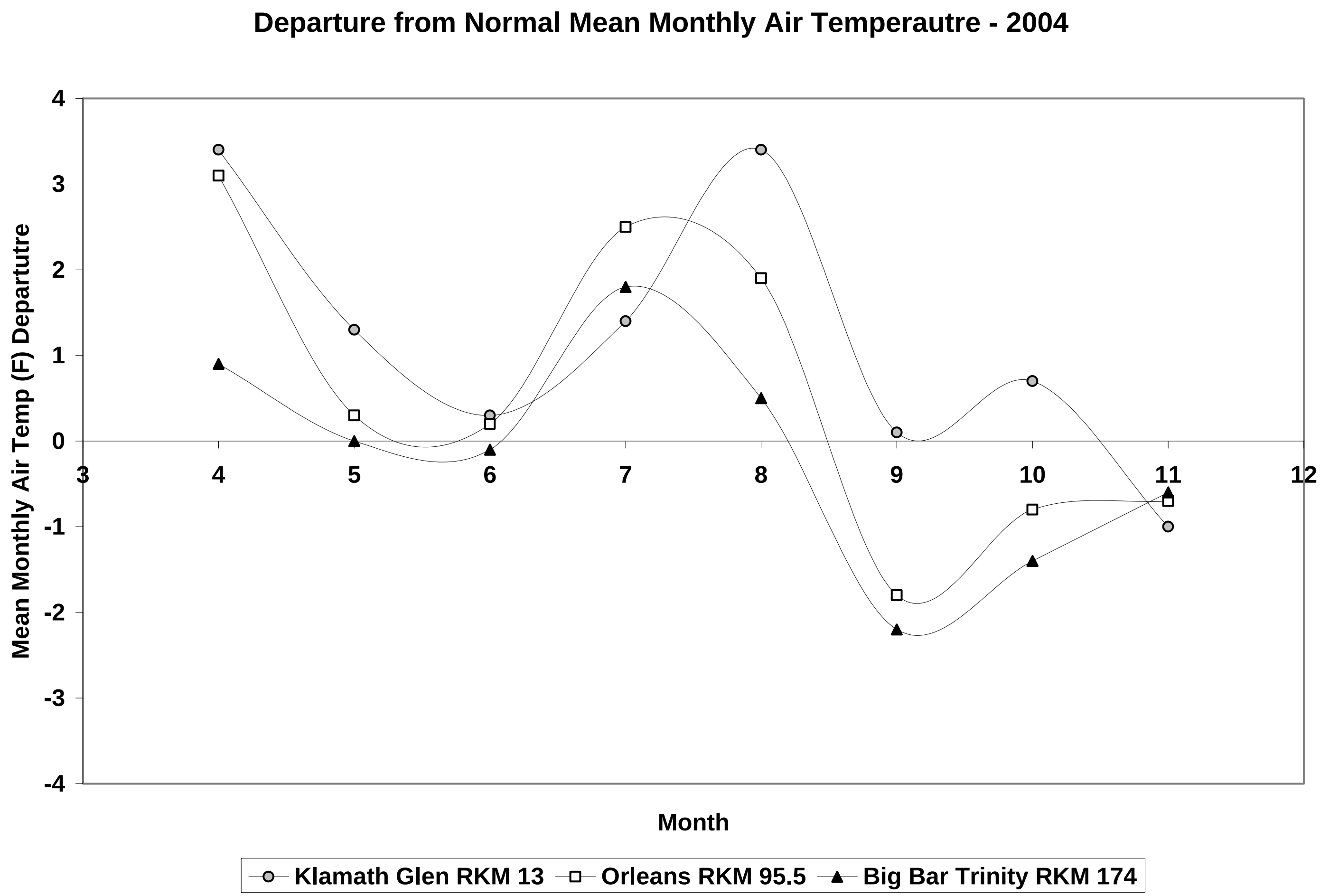


Figure 56. Mean monthly air temperature (^{o}F) departure from the normal for three locations in the KRB. Normal is defined as the mean for the last 50 years.

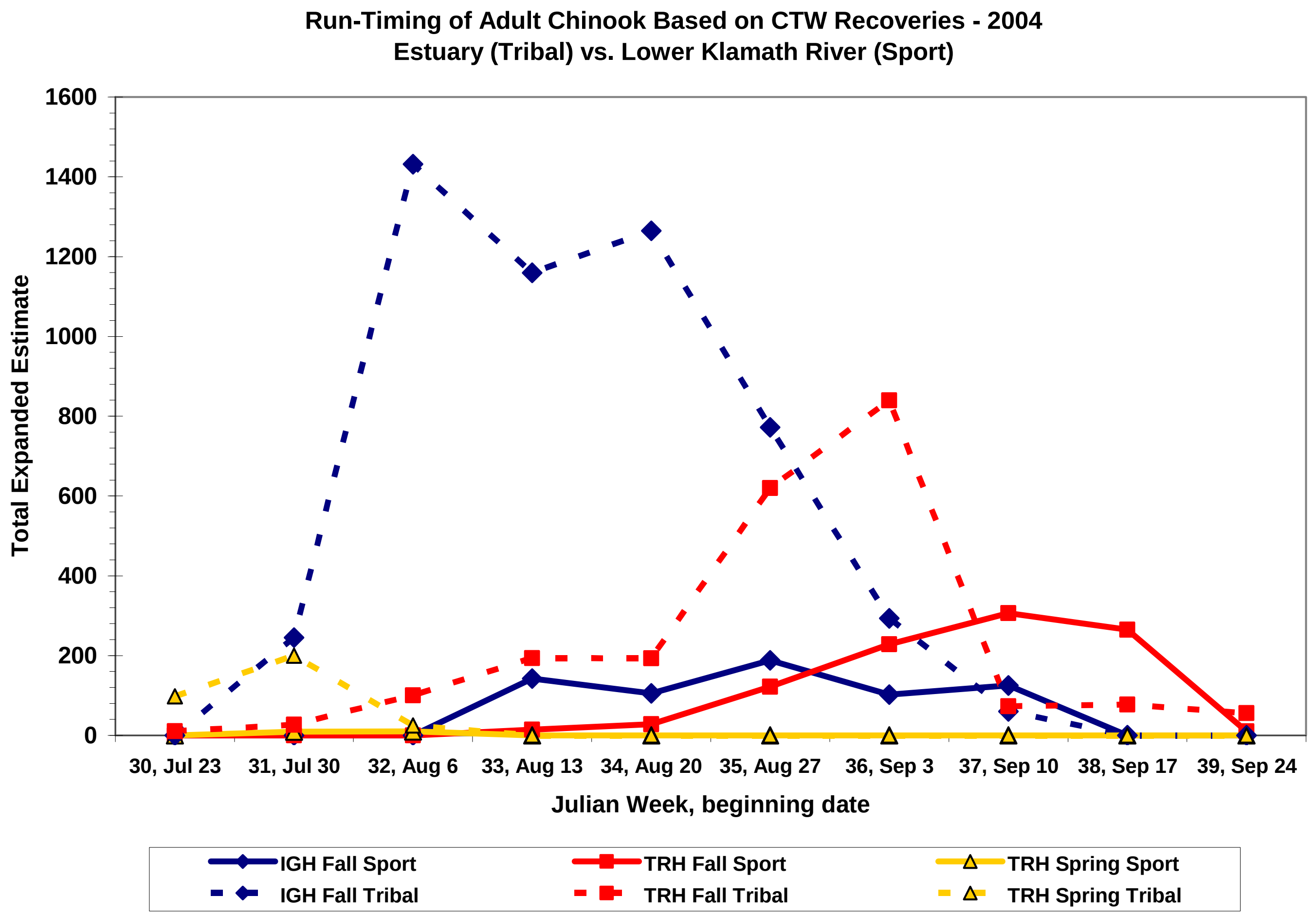


Figure 57. Approximate run-timing of Klamath and Trinity summer/'spring' and fall Chinook in 2004 based on coded wire tag recoveries from harvest in the estuary (Tribal only) and lower Klamath River (sport only) for Iron Gate and Trinity River Hatchery Chinook. The number of coded wire tags recovered is governed by the total number of hatchery fish present but is also influence by fish regulations and effort.

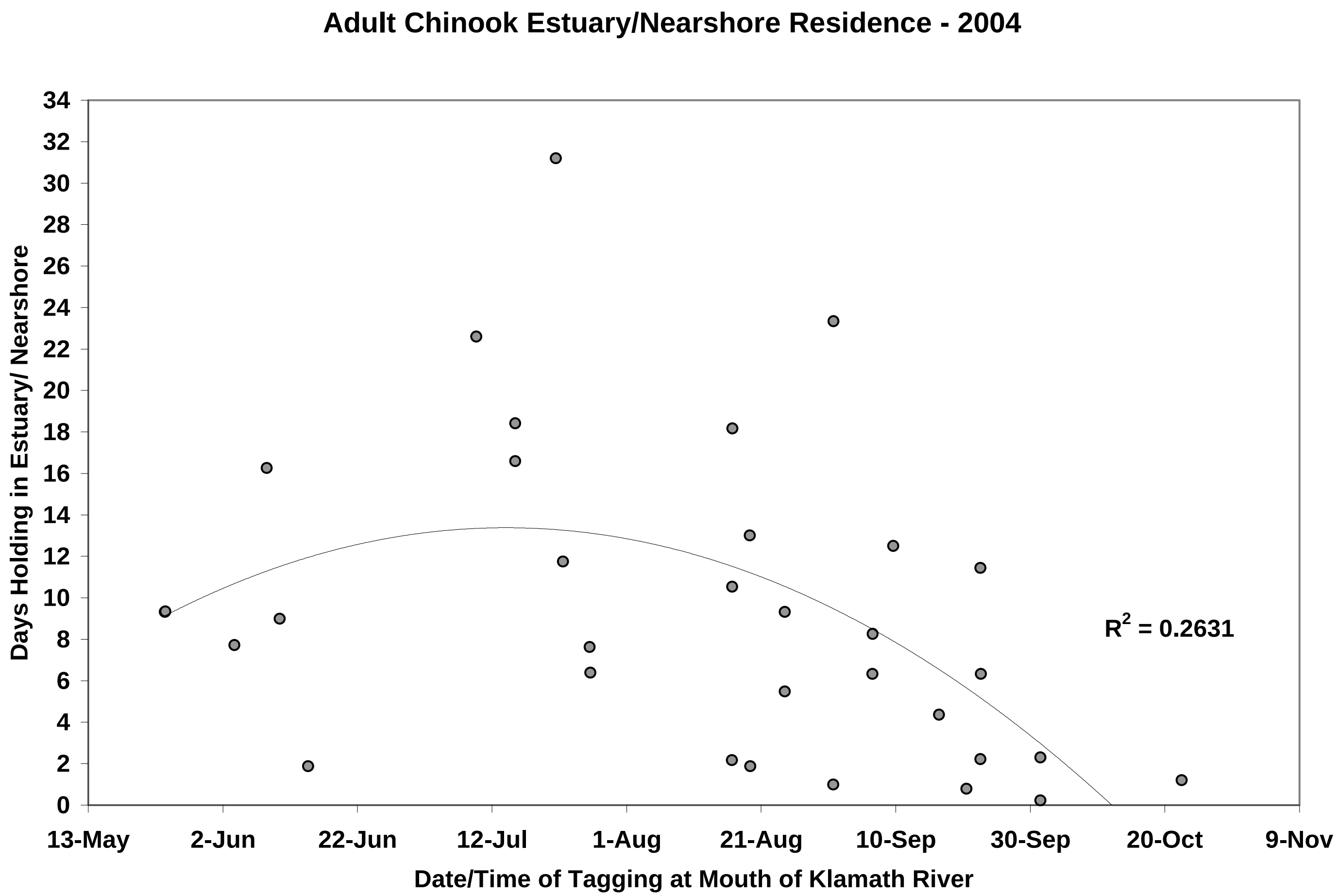


Figure 58. Residence times (days) for all tagged Chinook that emerged from the estuary and commenced upriver migration in 2004. These values are minimums since fish may have already been in and out of the estuary by the time they were caught and tagged at the mouth of the Klamath River.

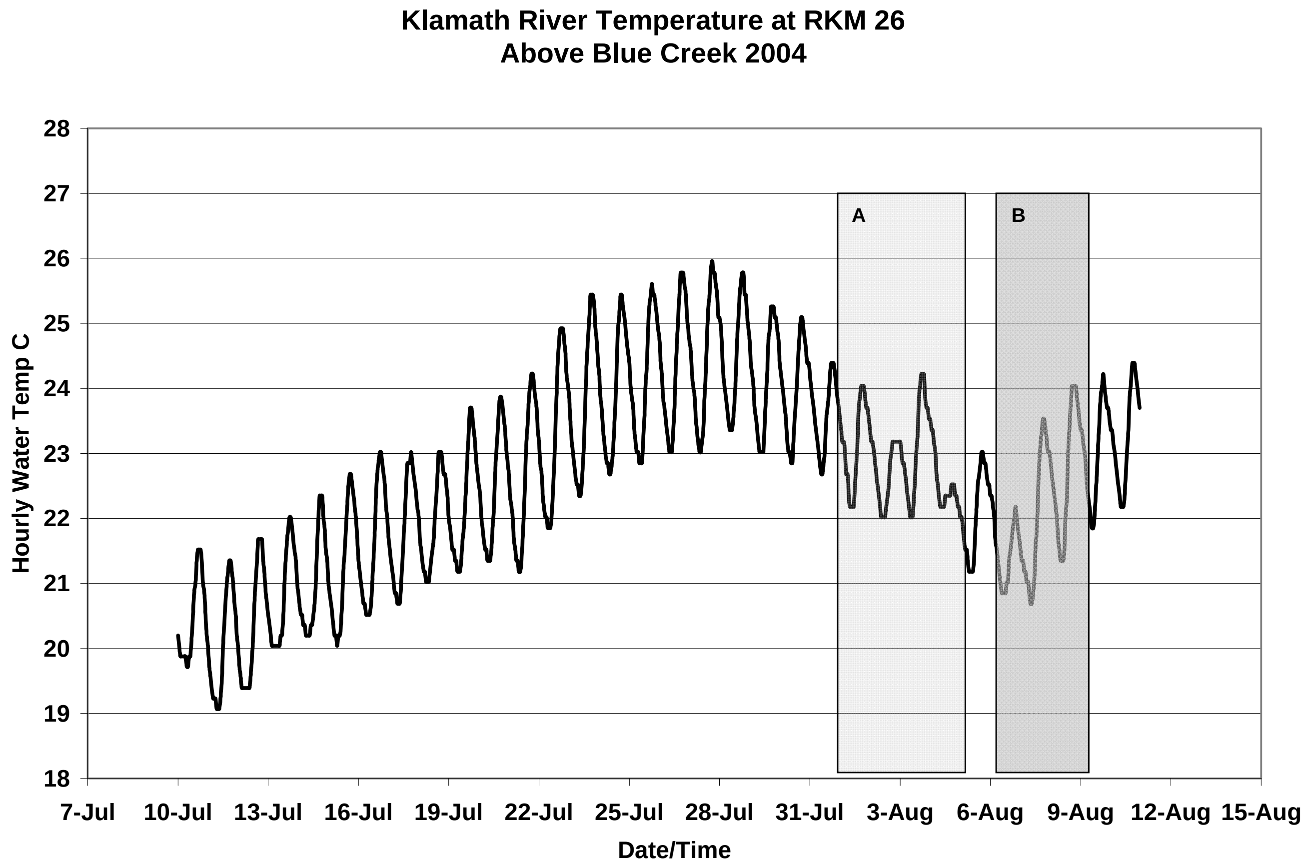


Figure 59. Close up of hourly water temperatures in the lower Klamath River (RKM 26) before and after the early August weather induced cooling event. The first shaded box (A) corresponds to the exact range in timing of commencement of upriver migration by tagged Chinook (*n*=6) from the estuary, while the second shaded box (B) shows the exact timing of upriver migration and the subsequent return of Chinook 149.114 to the estuary. This relationship captured by this data demonstrates the upper and lower thermal thresholds for migration inhibition.

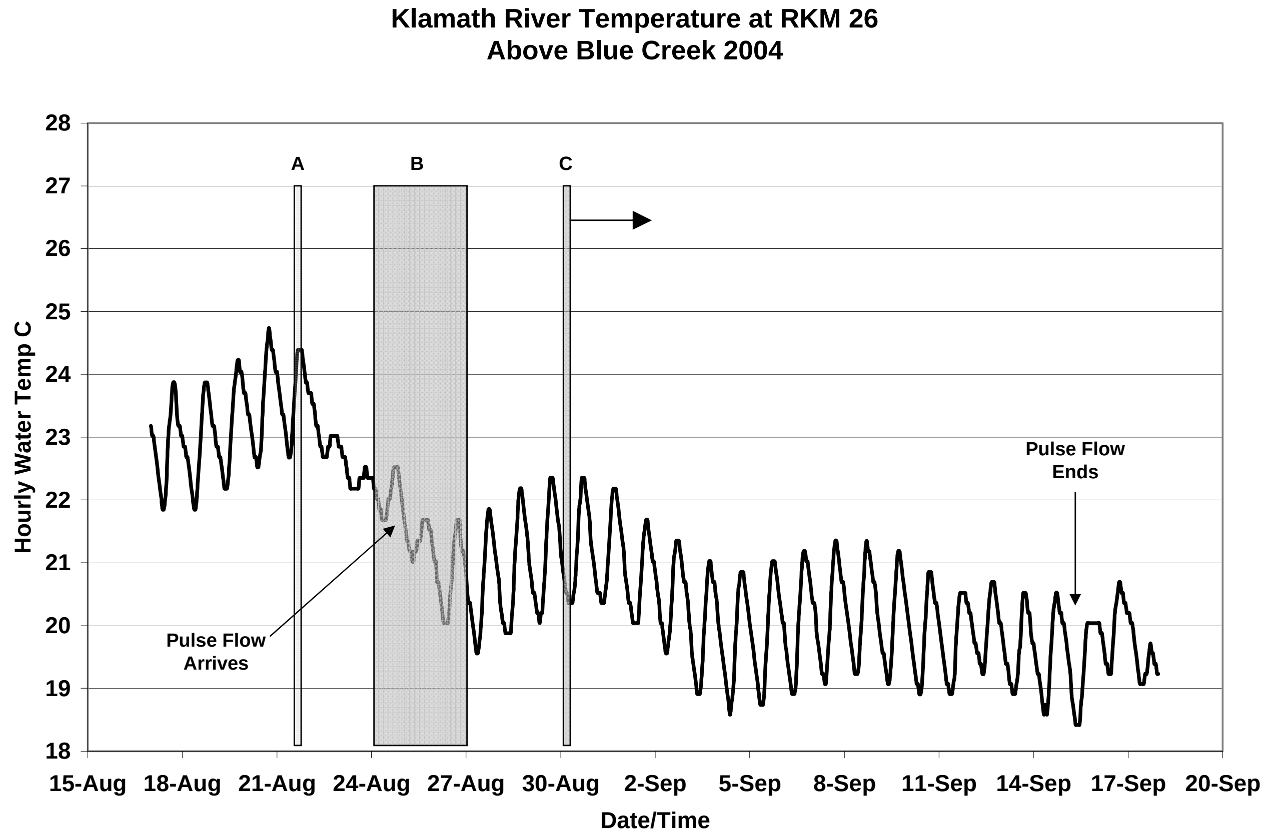


Figure 60. Close up of hourly water temperatures in the lower Klamath River (RKM 26) before and after the late August weather induced cooling event and the Trinity River fall pulse flow. The first shaded box (A) corresponds to the exact range in timing of commencement of upriver migration by two tagged Chinook from the estuary, while the second shaded box (B) shows the exact timing of upriver migration of the two Chinook migrant tagged at the Blue Creek thermal refuge and one tagged Chinook that was holding in the estuary. The third shaded box (C) shows the exact timing of resumption of emigration from the estuary by tagged Chinook. This relationship captured by this data also demonstrates the upper and lower thermal thresholds for migration inhibition.

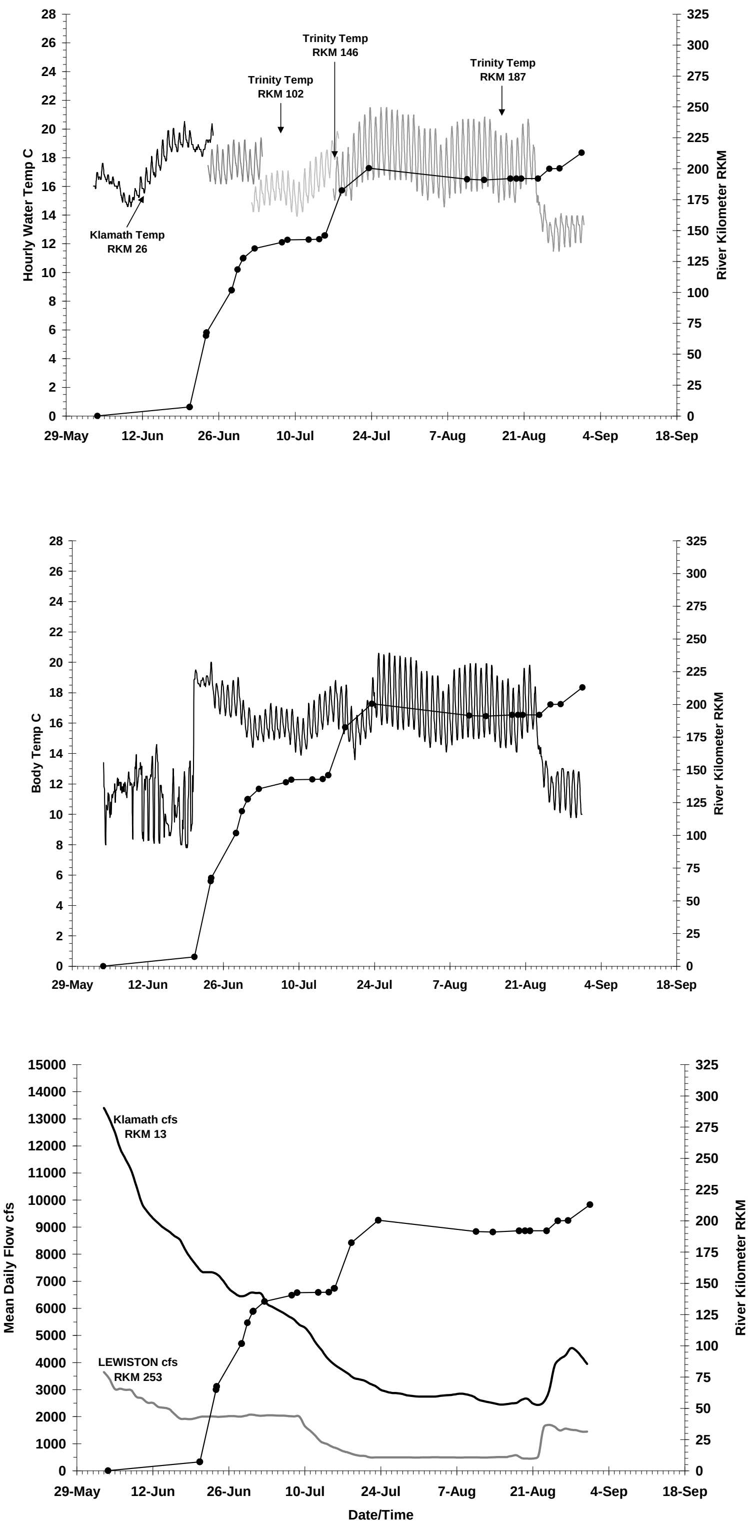


Figure 61. The thermal history (internal body temperature) for spring Chinook migrant 149.204 (tagged 6/3/04) during its upriver migration in the Klamath and Trinity Rivers 2004, in the context of its migration behavior (location versus date) and river conditions (water temperature and flow).

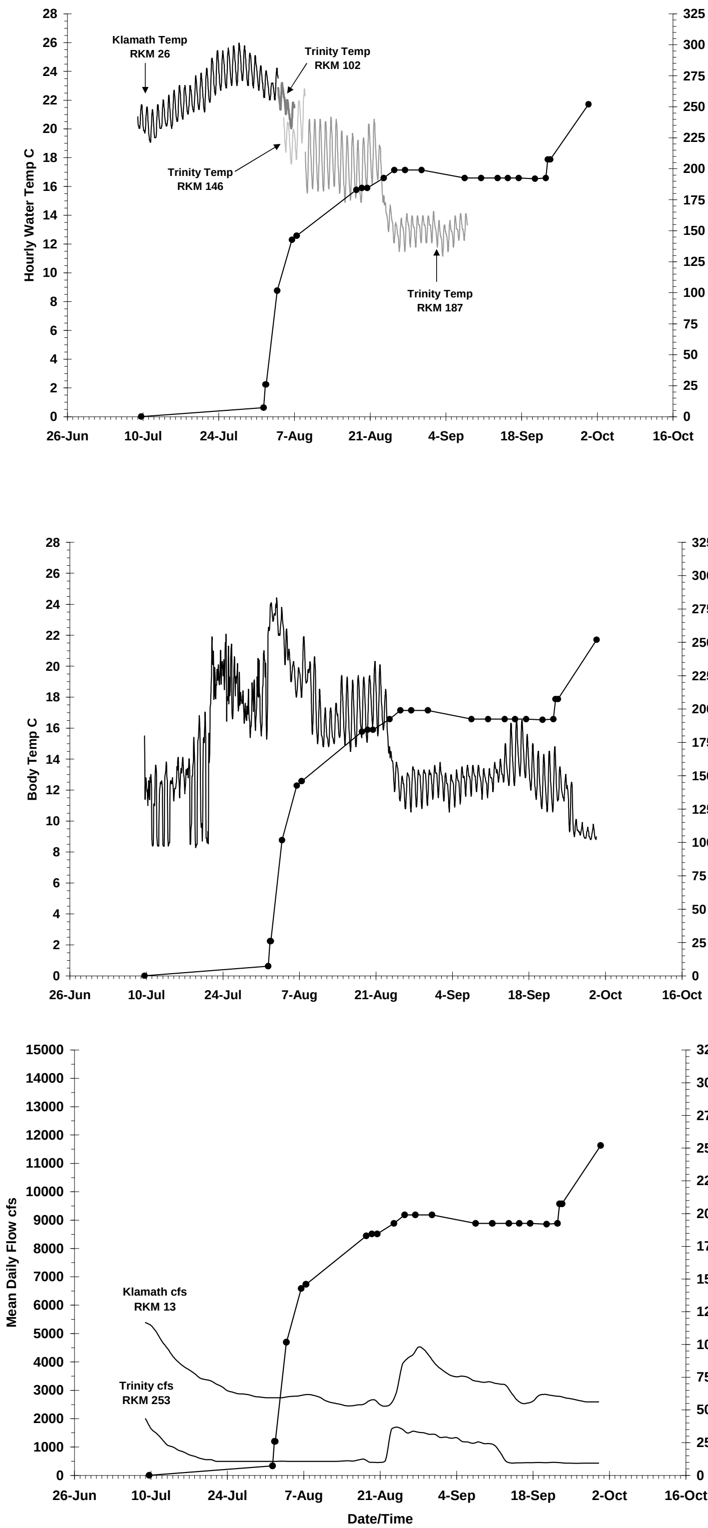


Figure 62. The thermal history (internal body temperature) for summer Chinook migrant 149.413 (tagged 7/9/04) during its upriver migration in the Klamath and Trinity Rivers 2004, in the context of its migration behavior (location versus date) and river conditions (water temperature and flow).

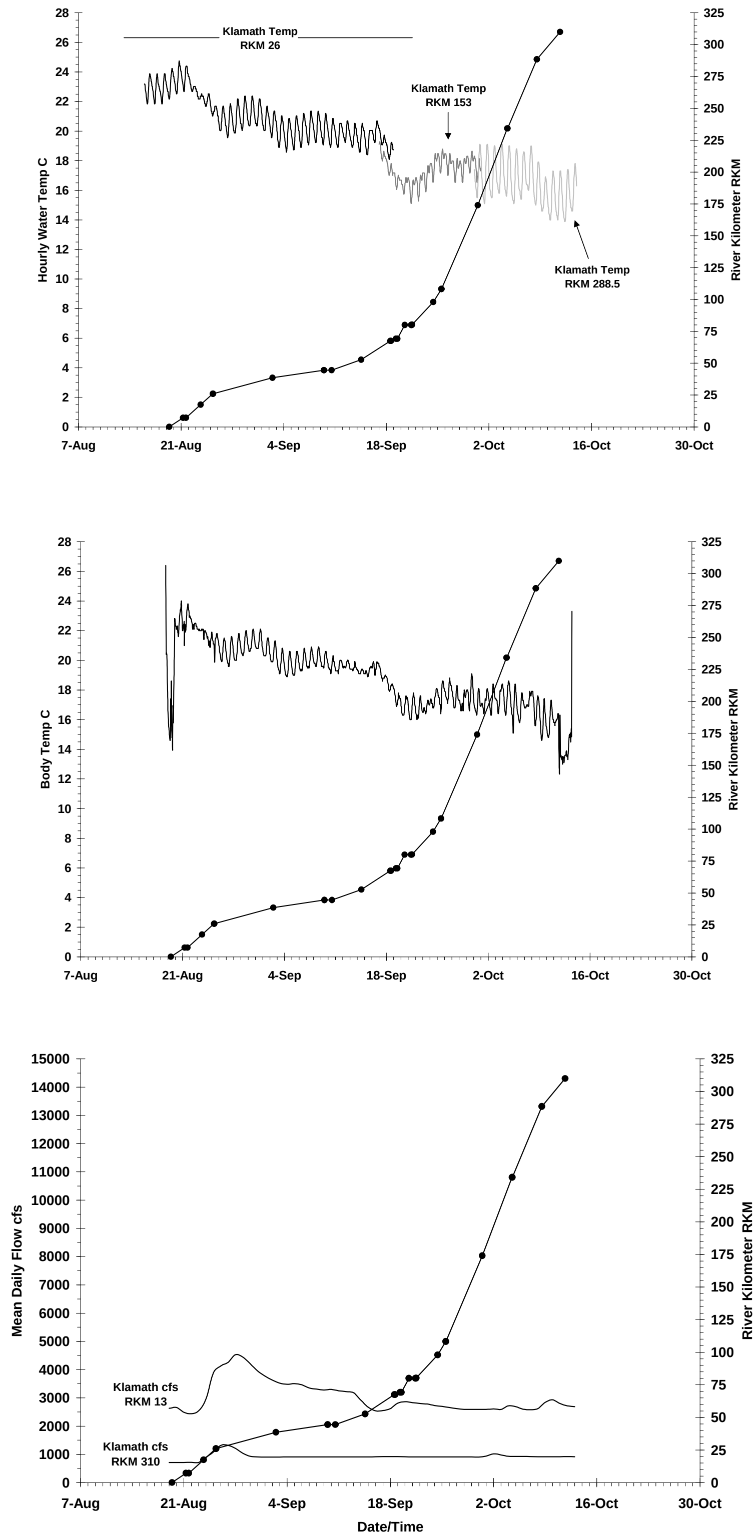


Figure 63. The thermal history (internal body temperature) for Klamath fall Chinook migrant 149.714 (tagged 8/19/04) during its upriver migration in the Klamath River 2004, in the context of its migration behavior (location versus date) and river conditions (water temperature and flow).

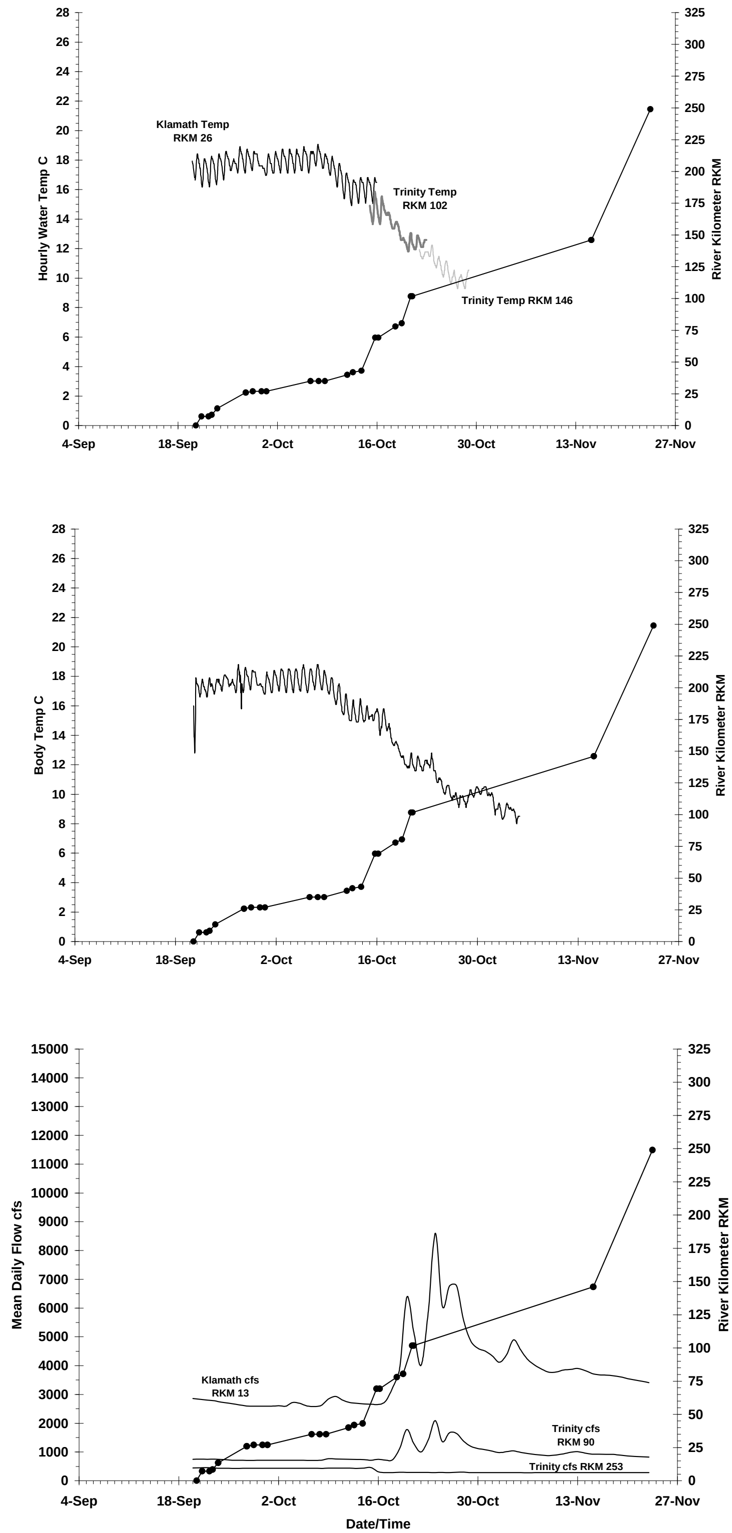


Figure 64. The thermal history (internal body temperature) for Trinity fall Chinook migrant 150.274 (tagged 9/20/04) during its upriver migration in the Klamath and Trinity Rivers 2004, in the context of its migration behavior (locations versus date) and river conditions (water temperature and flow).

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7.0 APPENDICIES

Appendix 1. Tagging data and fates or last observation of all 95 adult Chinook tagged during the 2004 season. Bold font designates fish for which there is telemetry data as reported in the telemetry summary in Appendix 2.

Tag Frequency	Tagging Date	Max River Temp C Tagging Day	Fork Length (cm)	Tagging Location	Sex	Fate/Last Observation	River/ Reach	Archival Data Recovery
149.032	21-May-04	14.0	70	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.044	**24-May-04**	**14.6**	**71**	**Mouth of Klamath**	**?**	**up to Blue Creek RKM 26 on 6/2, back to ocean on 6/18**	**Lower K**	**no**
149.053	**24-May-04**	**14.6**	**70**	**Mouth of Klamath**	**?**	**MIA near Roaches Cr. RKM 50 on 6/3**	**Lower K**	**no**
149.193	24-May-04	14.6	76.5	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.233	27-May-04	15.7	76	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.313	27-May-04	15.7	71	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.323	1-Jun-04	16.0	79	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.204	**3-Jun-04**	**17.0**	**74.5**	**Mouth of Klamath**	**?**	**sport caught in Browns Canyon RKM 213 on 8/31**	**Trinity**	**yes**
149.353	8-Jun-04	15.5	61.5	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.424	**8-Jun-04**	**15.5**	**80**	**Mouth of Klamath**	**?**	**sport caught at Bucktail RKM 241.5 on 7/27**	**Trinity**	**yes**
149.434	**10-Jun-04**	**15.9**	**76**	**Mouth of Klamath**	**?**	**Tribal caught at McCovey's RKM 16.5 on 6/19**	**Lower K**	**yes**
149.093	**14-Jun-04**	**18.6**	**81**	**Mouth of Klamath**	**?**	**died below Grays Falls RKM 140 by 7/24**	**Trinity**	**yes**
149.106	**16-Jun-04**	**19.9**	**60**	**Mouth of Klamath**	**?**	**MIA estuary/ocean**	**NA**	**no**
149.133	18-Jun-04	19.7	66	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.222B	1-Jul-04	20.5	91	Mouth of Klamath	?	Tribal caught at mouth of Klamath on 7/1	estuary	no
149.222	2-Jul-04	21.2	83	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.243	6-Jul-04	23.0	83	Mouth of Klamath	?	caught estuary on 7/21, tag found south spit	estuary	yes
149.403	9-Jul-04	21.7	82	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.413	**9-Jul-04**	**21.7**	**83**	**Mouth of Klamath**	**?**	**spawned at Lewiston Hatchery RKM 252 on 9/30**	**Trinity**	**yes**
149.546	12-Jul-04	21.7	81	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.555	12-Jul-04	21.7	68	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.644	13-Jul-04	22.0	68	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.684	13-Jul-04	22.0	76	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.722	**15-Jul-04**	**22.7**	**65**	**Mouth of Klamath**	**?**	**spawned at Lewiston Hatchery on 10/4, entered ~9/30**	**Trinity**	**no**

149.743	**15-Jul-04**	**22.7**	**74**	**Mouth of Klamath**	**?**	**Tribal caught Hoopa RKM ~90 on 8/6**	**Trinity**	**yes**
149.014	21-Jul-04	24.2	86	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.074	21-Jul-04	24.2	83	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.114	**21-Jul-04**	**24.2**	**84**	**Mouth of Klamath**	**?**	**MIA above Weitchpec RKM 69.25 on 8/28**	**K/T**	**no**
149.254	22-Jul-04	24.9	83	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.392	**22-Jul-04**	**24.9**	**72**	**Mouth of Klamath**	**?**	**caught Hoopa RKM 86 on 8/7**	**Trinity**	**yes**
149.494	**26-Jul-04**	**25.8**	**85**	**Mouth of Klamath**	**?**	**spawned out in Junction City RKM 207 by 10/22**	**Trinity**	**yes**
149.515	**26-Jul-04**	**25.8**	**75**	**Mouth of Klamath**	**?**	**tag found near Steelbridge RKM 231 on 11/3**	**Trinity**	**yes**
149.983	28-Jul-04	25.8	80	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.173	**16-Aug-04**	**23.9**	**83**	**Mouth of Klamath**	**male**	**spawned out in lower Bogus Cr RKM 309 by 10/29**	**Klamath**	**yes**
149.475	**16-Aug-04**	**23.9**	**82**	**Mouth of Klamath**	**?**	**Tribal caught at lower Blakes RKM 12 on 8/23**	**Lower K**	**yes**
149.564	**16-Aug-04**	**23.9**	**81**	**Mouth of Klamath**	**?**	**tag found at mouth of Walker Creek RKM 219 on 11/22**	**Klamath**	**yes**
149.583	16-Aug-04	23.9	96	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.594	16-Aug-04	23.9	91	Mouth of Klamath	?	Tribal caught estuary on 8/17	estuary	yes
149.673	16-Aug-04	23.9	81	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.063	**18-Aug-04**	**23.9/18.5**	**79**	**Blue Cr. Refuge**	**?**	**spawned out lower Junction City RKM 192 by 10/26**	**Trinity**	**yes**
149.270	**18-Aug-04**	**23.9/18.5**	**95**	**Blue Cr. Refuge**	**?**	**MIA above Shasta River RKM 288.5 on 10/7**	**Klamath**	**no**
149.333	18-Aug-04	23.9/18.5	69	Blue Creek Refuge	?	dead at Lambs RKM 21 by 9/9	Lower K	NA
149.375	19-Aug-04	24.2	97	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.622	**19-Aug-04**	**24.2**	**75**	**Mouth of Klamath**	**?**	**MIA Iron Gate Dam RKM 310 on 10/5 - hatchery?**	**Klamath**	**no**
149.633	19-Aug-04	24.2	76	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.704	**19-Aug-04**	**24.2**	**73**	**Mouth of Klamath**	**?**	**Tribal caught estuary on 8/27**	**estuary**	**yes**
149.714	**19-Aug-04**	**24.2**	**78**	**Mouth of Klamath**	**male**	**spawned at Iron Gate Hatchery RKM 310 on 10/11**	**Klamath**	**yes**
149.732	**24-Aug-04**	**22.5**	**91**	**Mouth of Klamath**	**male**	**spawned out below R Ranch RKM 302 on 10/29**	**Klamath**	**yes**
149.752	**24-Aug-04**	**22.5**	**66**	**Mouth of Klamath**	**?**	**Tribal caught near Coopers RKM 18 on 9/4**	**Lower K**	**yes**
149.772	24-Aug-04	22.5	76	Mouth of Klamath	?	Tribal caught estuary	estuary	no
149.782	24-Aug-04	22.5	76	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.795	27-Aug-04	21.9	66	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.812	27-Aug-04	21.9	67	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.782B	27-Aug-04	21.9	76	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.833	**31-Aug-04**	**22.2**	**66**	**Mouth of Klamath**	**?**	**dead at Moores Rock RKM 44 by 10/8**	**Lower K**	**yes**
149.843	**31-Aug-04**	**22.2**	**91**	**Mouth of Klamath**	**?**	**spawned below Iron Gate Dam RKM 307 by 11/22**	**Klamath**	**no**

149.853	31-Aug-04	22.2	67	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.872	**6-Sep-04**	**21.2**	**67**	**Mouth of Klamath**	**?**	**spawned at Iron Gate Hatchery RKM 310 on 10/13**	**Klamath**	**yes**
149.893	**6-Sep-04**	**21.2**	**91**	**Mouth of Klamath**	**?**	**caught estuary on 10/3**	**estuary**	**yes**
149.905	6-Sep-04	21.2	97	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.913	6-Sep-04	21.2	84	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.943	6-Sep-04	21.2	75	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.973	**6-Sep-04**	**21.2**	**93**	**Mouth of Klamath**	**male**	**spawned at Iron Gate Hatchery RKM 310 on 10/25**	**Klamath**	**yes**
150.014	**9-Sep-04**	**21.2**	**68**	**Mouth of Klamath**	**?**	**MIA above Weitchpec RKM 69.25 on 10/9**	**K/T**	**no**
150.023	9-Sep-04	21.2	70	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.033	9-Sep-04	21.2	74	Mouth of Klamath	?	Tribal caught estuary on 9/10	estuary	yes
150.054	13-Sep-04	20.5	77	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.064	13-Sep-04	20.5	67	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.074	13-Sep-04	20.5	67	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.114	14-Sep-04	20.5	75	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.146	14-Sep-04	20.5	76	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.172	14-Sep-04	20.5	66	Mouth of Klamath	?	MIA estuary/ocean, ad clip	NA	no
150.133	**16-Sep-04**	**20.7**	**65**	**Mouth of Klamath**	**?**	**Tribal caught in Hoopa RKM 96.5 on 9/9**	**Trinity**	**yes**
150.191	16-Sep-04	20.7	80	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.243	20-Sep-04	18.4	68	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.274	**20-Sep-04**	**18.4**	**69**	**Mouth of Klamath**	**female**	**ad clip 1162uu, spawned out Lewiston R1 RKM 249 by 11/23**	**Trinity**	**yes**
150.313	21-Sep-04	18.1	70	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.413	22-Sep-04	18.3	100	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.454	22-Sep-04	18.3	65	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.473	22-Sep-04	18.3	71	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.512	22-Sep-04	18.3	76	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.553	**22-Sep-04**	**18.3**	**78**	**Mouth of Klamath**	**?**	**Weitchpec RKM 69.3 on 10/19, likely caught here**	**Lower K**	**yes**
150.572	22-Sep-04	18.3	68	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.583	22-Sep-04	18.3	69	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.593	**22-Sep-04**	**18.3**	**90**	**Mouth of Klamath**	**?**	**died just above Blue Creek RKM 26.25 by 10/23**	**Lower K**	**yes**
150.613	22-Sep-04	18.3	72	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.634	22-Sep-04	18.3	73	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.654	**22-Sep-04**	**18.3**	**76**	**Mouth of Klamath**	**?**	**MIA above Junction City Weir RKM 207.5 on 10/26**	**Trinity**	**no**

150.793	**1-Oct-04**	**18.6**	**66**	**Mouth of Klamath**	**?**	**above JC RKM 207.5 11/9; returned 11/24, dead RKM 179 12/14**	**Trinity**	**no**
150.853	1-Oct-04	18.6	66	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.873	1-Oct-04	18.6	66	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.923	**1-Oct-04**	**18.6**	**72**	**Mouth of Klamath**	**?**	**spawned near Blue Heron RKM 235 in early Dec**	**Klamath**	**no**
150.963	1-Oct-04	18.6	67	Mouth of Klamath	?	MIA estuary/ocean	NA	no
150.984	1-Oct-04	18.6	92	Mouth of Klamath	?	MIA estuary/ocean	NA	no
149.453	**22-Oct-04**	**13.4**	**66**	**Mouth of Klamath**	**?**	**last observed in Burnt Ranch Gorge on 12/8**	**Trinity**	**no**

Appendix 2. Summary of all telemetry observations for relevant tagged Chinook during 2004. Telemetry observations were recorded for a total of 38 tagged Chinook, which included 36 fish that migrated and ended up above the estuary and 2 fish that eventually disappeared in the estuary or nearshore ocean. An asterisk next to the tag frequency indicates internal body temperature data was successfully recovered from the archival tag. All river kilometers (RKMs) are measured from the mouth of the Klamath River and travel rates (km/day) represent the average rate of travel to one observation location from the one proceeding. All river temperatures were recorded at the time and location where the fish was observed or at the closest available temperature probe and are accurate to within approximately 0.5^{o}C. Temperature sensitive radio transmitters allowed for a determination of real-time fish body temperature, which should be viewed as approximate due to multiple sources of potential error.

Chinook Radio Tag 149.044

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
5/24/2004	10:42	Klamath	0.1	tagged at mouth of Klamath River		14.6	
6/2/2004	18:50	Klamath	26	Blue Creek Station	17.3	16.5	2.78
6/18/2004	13:00	Klamath	19	Matt's Camp below Coopers	19.3	18.1	-0.45
6/18/2004	18:48	Klamath	7.25	Wakel Station – back to ocean	19.7	19.7	-48.62

Chinook Radio Tag 149.053

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
5/24/2004	8:57	Klamath	0.1	tagged at mouth of Klamath River		14.6	
6/2/2004	16:44	Klamath	48	Notchko	16.8	15.9	5.15

6/3/2004	11:50	Klamath	50.25	Roaches Creek area	16.1	15.8	2.83

Chinook Radio Tag 149.204*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
6/3/2004	17:40	Klamath	0.1	tagged at mouth of Klamath River		17	
6/20/2004	15:12	Klamath	7.25	Wakel Station	20.2	19.9	0.79
6/23/2004	15:30	Klamath	65	between Pine Cr and Martins Ferry	20.5	19.5	19.32
6/23/2004	17:56	Klamath	67.5	Lower Weitchpec Station	21.1	19.9	24.66
6/28/2004	8:19	Trinity	101.75	Horse Linto Creek Station	17.4	16.5	7.45
6/29/2004	10:30	Trinity	118.5	2km below SF Trinity confluence	17.7	16.8	15.60
6/30/2004	10:45	Trinity	127.5	Twin Bridges below Tunnel Flat	16.0	16.3	8.91
6/30/2004	12:27	Trinity	127.75	below 2nd twin bridge below Tunnel Flat	16.3	15.5	3.53
7/2/2004	14:01	Trinity	135.5	just upriver of Hawkins Bar	16.9	15.5	3.75
7/7/2004	14:10	Trinity	140.5	Grays Falls area up	15.6	16.2	1.00
7/8/2004	14:00	Trinity	142.5	3rd Burnt Ranch Falls	15.8	15.5	2.01
7/12/2004	11:39	Trinity	142.7	Burnt Ranch Falls	16.5	15.1	0.05

7/14/2004	10:00	Trinity	143	above Burnt Ranch Falls		16	0.16
7/15/2004	9:49	Trinity	146	China Slide Station	16.9	16.3	3.02
7/18/2004	13:50	Trinity	182.5	Pigeon Point Run above upper Tidy Bowl	17.6	16.8	11.78
7/23/2004	12:30	Trinity	200.5	300 m above Dutch Cr Bridge	18.2	15.1	3.64
8/10/2004	12:45	Trinity	191.5	25mph curve below Junction City (JC)	17.4	18	-0.50
8/13/2004	15:30	Trinity	191	lower Junction City 25 mph curve		20.3	-0.16
8/18/2004	11:13	Trinity	192	lower JC at 25 mph curve	16.2	16.7	0.21
8/19/2004	13:45	Trinity	192	lower JC 25 mph curve	15.9	17.2	0.00
8/20/2004	11:22	Trinity	192	lower JC 25 mph curve access	16.3	16.6	0.00
8/23/2004	13:00	Trinity	192	lower JC lower 25 mph curve	17.1	16.6	0.00
8/25/2004	14:40	Trinity	200	Dutch Cr Rd bridge in JC	12.8	12.2	3.87
8/27/2004	11:50	Trinity	200.25	just above Dutch Cr Rd Bridge in JC	12.0	12.2	0.13
8/31/2004	13:00	Trinity	213	sport caught Browns Canyon		10	3.15

Chinook Radio Tag 149.424*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day

6/8/2004	12:30	Klamath	0.1	tagged at mouth of Klamath River		15.5	
6/24/2004	18:39	Klamath	7.25	Wakel Station	21.0	20.2	0.45
6/25/2004	16:20	Klamath	23	Cleveland, 2 pools above Lambs	20.8	20	17.99
6/26/2004	5:09	Klamath	26	Blue Creek Station	19.6	19.2	5.62
6/30/2004	14:38	Trinity	83	Jimmy Jackson's in Hoopa	19.1	18.3	13.00
7/2/2004	15:05	Trinity	100.5	Sugar Bowl Falls	19.0	18.3	8.67
7/2/2004	16:44	Trinity	101.75	Horse Linto Creek Station	19.8	18.9	18.18
7/6/2004	10:30	Trinity	139.5	Grays Falls	16.1	15.2	10.27
7/8/2004	13:10	Trinity	139.25	one riffle below Grays Falls	16.5	15.5	-0.12
7/12/2004	11:06	Trinity	141.5	above New River confluence	15.6	15.1	0.57
7/14/2004	13:33	Trinity	145.5	just below Box in Burnt Ranch Gorge	17.6	16.8	1.90
7/14/2004	17:27	Trinity	146	China Slide Station	19.1	18.1	3.08
7/15/2004	10:15	Trinity	149.7	1/2 km above Cedar Flat	16.9	15.5	5.66
7/15/2004	15:24	Trinity	157	2.4 miles below Hayden Flat	18.3	16.5	34.02
7/21/2004	15:38	Trinity	216	Steiner Flat near Douglas City	15.1	15.5	9.82

7/23/2004	15:00	Trinity	241.3	Bucktail River access	14.0	13.8	12.82
7/26/2004	14:30	Trinity	241.3	Bucktail River access	13.0	14.4	0.00
7/27/2004	7:00	Trinity	241.5	sport caught Bucktail		10	0.29

Chinook Radio Tag 149.434*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
6/10/2004	11:08	Klamath	0.1	tagged at mouth of Klamath River		15.9	
6/19/2004	10:55	Klamath	7.25	Wakel Station	19.8	19.1	0.81
6/19/2004	18:00	Klamath	16.25	Tribal caught at McCovey's	20.5	20.4	31.69

Chinook Radio Tag 149.093*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
6/14/2004	16:00	Klamath	0.1	tagged at mouth of Klamath River		18.6	
6/16/2004	13:03	Klamath	18.75	below Coopers	19.6	18.5	9.99
6/17/2004	12:50	Klamath	29	just downriver from Bear Creek	21.3	18.6	10.34
6/17/2004	13:09	Klamath	29.75	at Bear Creek	20.2	18.6	56.84
6/18/2004	11:30	Klamath	47.5	Ryerson Ranch below Notchko	19.5	18.4	19.06

6/18/2004	18:20	Klamath	52	at Morek Creek below Keppel	20.5	19	15.80
6/23/2004	13:21	Trinity	101.75	Horse Linto Creek Station	18.4	17.7	10.38
6/24/2004	15:34	Trinity	106.25	above Trinity River Farms (O'Gormans)	19.4	18.05	4.16
6/30/2004	12:50	Trinity	128.5	1/2 upriver from Tunnel Flat rest area	15.7	15.5	3.78
7/1/2004	16:55	Trinity	133.5	Hawkins Bar Trinity Village	17.4	17	4.27
7/2/2004	13:24	Trinity	134.7	Hawkins Bar	15.9	15.5	1.41
7/15/2004	15:02	Trinity	139.25	first riffle below Grays Falls	18.1	16.5	0.35
7/24/2004	12:00	Trinity	139.25	died below Grays Falls		22	0.00

Chinook Radio Tag 149.106

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
6/16/2004	17:04	Klamath	0.1	tagged at mouth of Klamath River		19.9	
6/25/2004	9:40	Klamath	0.25	mouth of Klamath at lips		18.2	0.03

Chinook Radio Tag 149.413*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
7/9/2004	16:00	Klamath	0.1	tagged at mouth of Klamath River		21.7	
8/1/2004	6:23	Klamath	7.25	Wakel Station	23.5	22.5	0.32

8/1/2004	15:00	Klamath	26	Blue Creek Station	24.4	23.7	56.96
8/3/2004	19:17	Trinity	101.75	Horse Linto Creek Station	24.6	23.7	37.25
8/6/2004	12:30	Trinity	142.7	Burnt Ranch Falls	19.1	18.3	15.17
8/7/2004	9:15	Trinity	146	China Slide Station	18.9	17.9	3.82
8/18/2004	10:46	Trinity	183	3 miles upriver from Big Flat	16.5	17.2	3.36
8/19/2004	11:15	Trinity	184.5	2 miles below Pigeon Point MM 34.18	16.4	15.5	1.47
8/20/2004	11:02	Trinity	184.5	2 miles below Pigeon Point	16.7	16.6	0.00
8/23/2004	12:01	Trinity	192.5	lower Junction City above 25 mph curve	18.5	16.6	2.63
8/25/2004	11:30	Trinity	199	near BLM campground in Junction City (JC)	11.7	12.2	3.29
8/27/2004	10:45	Trinity	199	BLM campground in JC	10.1	11.6	0.00
8/30/2004	11:53	Trinity	199	BLM campground in JC	11.3	11.6	0.00
9/7/2004	11:30	Trinity	192.5	lower JC just above 25 mph curve	11.8	12.2	-0.81
9/10/2004	12:45	Trinity	192.5	just above 25 mph curve in lower JC	13.2	13.3	0.00
9/13/2004	13:45	Trinity	192.5	lower JC above 25 mph curve	14.9	14.5	0.00
9/15/2004	11:00	Trinity	192.5	lower JC just above 25 mph curve	14.0	14.7	0.00

9/17/2004	11:30	Trinity	192.5	lower JC above 25 mph curve	14.6	16	0.00
9/20/2004	11:40	Trinity	192	just below 25 mph curve in lower JC	13.6	14.5	-0.17
9/22/2004	11:30	Trinity	192.5	lower JC above 25 mph curve	12.6	12.5	0.25
9/22/2004	20:40	Trinity	207.5	Junction City Weir Station	13.3	12.4	39.27
9/30/2004	9:00	Trinity	252	spawned Lewiston Hatchery		9	6.29

Chinook Radio Tag 149.743*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
7/15/2004	10:35	Klamath	0.1	tagged at mouth of Klamath River		22.7	
8/2/2004	20:36	Klamath	7.25	Wakel Station	22.3	23.2	0.39
8/3/2004	7:47	Klamath	26	Blue Creek Station	23.4	22.1	42.93
8/3/2004	11:50	Klamath	32.25	Surpur	24.2	22	40.00
8/4/2004	16:40	Klamath	67.5	Lower Weitchpec Station	24.1	22.7	29.34
8/6/2004	10:04	Trinity	88.7	first riffle above Hoopa Bridge Hwy 96	18.0	20.1	12.31
8/6/2004	11:00	Trinity	90	Tribal caught Hoopa		20	33.43

Chinook Radio Tag 149.722

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
7/15/2004	10:45	Klamath	0.1	tagged at mouth of Klamath River		22.7	
8/1/2004	0:45	Klamath	7.25	Wakel Station	23.5	22.8	0.44
8/1/2004	20:54	Klamath	26	Blue Creek Station	23.4	23.7	22.44
8/2/2004	19:00	Klamath	67.5	Lower Weitchpec Station	25.2	23.9	46.40
8/3/2004	19:53	Trinity	101.75	Horse Linto Creek Station	24.4	23.5	33.10
8/6/2004	10:32	Trinity	146	China Slide Station	18.5	17.6	16.99
8/6/2004	13:07	Trinity	148.8	1/2 km below Cedar Flat	18.7	18.3	51.04
8/13/2004	15:00	Trinity	250.5	New Lewiston Bridge pool		12	14.37
8/19/2004	15:00	Trinity	249	Old Lewiston Bridge	10.8	11.1	-0.25
8/20/2004	14:50	Trinity	249	Old Lewiston Bridge	12.1	12.2	0.00
8/23/2004	15:56	Trinity	252	base of Lewiston Dam	5.9	14.4	0.98
8/25/2004	16:30	Trinity	251.75	base of Lewiston Dam	9.8	9.5	-0.12
8/27/2004	16:00	Trinity	252	Lewiston Dam below spillway	14.7	10.1	0.13
8/30/2004	15:00	Trinity	252	Lewiston Dam	10.4	8.5	0.00

9/3/2004	15:45	Trinity	252	Lewiston Dam	10.5	9	0.00
9/7/2004	15:55	Trinity	252	Lewiston Dam	10.5	9.5	0.00
9/8/2004	8:18	Trinity	252	Lewiston Dam			0.00
9/13/2004	15:45	Trinity	252	Lewiston Dam	10.4	10.5	0.00
9/15/2004	15:55	Trinity	252	Lewiston Dam	10.7	12.1	0.00
9/17/2004	15:45	Trinity	252	Lewiston Dam	11.2	12	0.00
9/22/2004	16:05	Trinity	252.1	Trinity River Hatchery fish ladder	10.1	11	0.02
10/4/2004	9:00	Trinity	252	spawned Lewiston Hatchery		-0.01	

Chinook Radio Tag 149.114

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
7/21/2004	12:00	Klamath	0.1	tagged at mouth of Klamath River		24.2	
8/6/2004	0:00	Klamath	7.25	Wakel Station	21.8	21.5	0.47
8/9/2004	9:03	Klamath	7.25	Wakel Station	23.3	21.8	0.00
8/21/2004	17:21	Klamath	7.25	Wakel Station	24.8	24.4	0.00
8/25/2004	15:15	Klamath	18.75	above Brooks below Coopers	22.2	21	2.95

8/26/2004	6:51	Klamath	26	Blue Creek Station	21.0	20	11.15
8/27/2004	16:55	Klamath	67.5	Lower Weitchpec Station	21.9	20.5	29.39
8/27/2004	18:44	Klamath	69.25	Klamath Trinity Confluence Station	21.8	20.5	23.55
8/28/2004	6:24	Klamath	69.25	Klamath Trinity Confluence Station - MIA	20.7	19.3	0.00

Chinook Radio Tag 149.392*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
7/22/2004	13:30	Klamath	0.1	tagged at mouth of Klamath River		24.9	
8/3/2004	7:24	Klamath	7.25	Wakel Station	22.7	22.1	0.62
8/3/2004	10:55	Klamath	11	Riffles RV Park at Klamath Glen	22.8	21.3	29.19
8/4/2004	20:33	Klamath	26	Blue Creek Station	23.5	22.4	10.70
8/6/2004	2:36	Klamath	67.5	Lower Weitchpec Station	23.1	21.8	36.96
8/7/2004	10:00	Trinity	86	caught Hoopa		20.5	14.48

Chinook Radio Tag 149.494*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
7/26/2004	12:00	Klamath	0.1	tagged at mouth of Klamath River		25.8	

8/3/2004	2:49	Klamath	7.25	Wakel Station	22.2	22.8	0.95
8/3/2004	22:31	Klamath	7.25	Wakel Station	23.8	23.6	0.00
8/5/2004	8:32	Klamath	7.25	Wakel Station	22.0	22	0.00
8/5/2004	9:01	Klamath	7.25	Wakel Station	22.1	22	0.00
8/6/2004	11:44	Klamath	26	Blue Creek Station	21.7	20.8	16.84
8/8/2004	2:32	Klamath	67.5	Lower Weitchpec Station	23.8	22.6	25.94
8/10/2004	8:54	Trinity	101.75	Horse Linto Creek Station	22.9	22	15.30
8/10/2004	11:00	Trinity	105	Whitson’s Bar below Willow Creek	23.0	22.2	40.34
8/17/2004	8:49	Trinity	146	China Slide Station	19.1	18.2	5.93
8/18/2004	10:16	Trinity	151	just above Cedar Flat MM 15.87	19.3	18.3	4.89
8/19/2004	10:44	Trinity	159.5	just downriver of Hayden Flat MM 20.42	20.6	20.1	8.34
8/20/2004	10:30	Trinity	174	Big Bar Grover’s Gulch RV Park	18.5	18.5	14.64
8/23/2004	17:00	Trinity	199	BLM campground in Junction City MM 42.00	15.9	16.6	7.64
8/25/2004	12:45	Trinity	199.5	1/2 km above JC BLM campground	12.0	12.7	0.27
8/27/2004	11:30	Trinity	199.5	1/2 km above BLM campground in JC	11.2	12.2	0.00

8/30/2004	12:00	Trinity	199.5	near BLM campground in JC	11.7	11.6	0.00
9/3/2004	13:00	Trinity	199.5	near JC BLM campground MM 42.45	11.4	12.2	0.00
9/7/2004	12:00	Trinity	199	BLM campground in JC MM 42.45	12.2	12.2	-0.13
9/8/2004	8:33	Trinity	198.5	Junction City below Canyon Creek			-0.58
9/10/2004	13:45	Trinity	198.75	just below JC BLM campground	12.1	12.2	0.11
9/15/2004	12:55	Trinity	204.5	JC 2 miles up Skyranch Rd	14.4	15.1	1.16
9/17/2004	13:00	Trinity	204	2.5 miles up Dutch Cr Rd in JC	14.5	16	-0.25
9/20/2004	12:10	Trinity	203.75	up Dutch Cr Rd in JC	12.5	14	-0.08
9/22/2004	12:15	Trinity	204	2.5 miles up Dutch Cr Rd in JC	11.4	13.1	0.12
9/27/2004	13:00	Trinity	204.5	2 miles up Skyranch Rd in JC	12.6	14.5	0.10
10/1/2004	12:20	Trinity	204.6	2 miles up Skyranch Rd in JC	13.8	15	0.03
10/4/2004	12:10	Trinity	204.5	2 miles up Skyranch Rd in JC	13.3	14	-0.03
10/12/2004	13:00	Trinity	207.5	at JC Weir station	11.4	11.3	0.37
10/15/2004	11:30	Trinity	202.5	1mile above Skyranch Rd access		11.1	-1.70
10/18/2004	14:00	Trinity	207	just below 2004 JC Weir location		11	1.45

10/22/2004	12:00	Trinity	207	spawned out near JC weir		10.1	0.00

Chinook Radio Tag 149.515*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
7/26/2004	15:00	Klamath	0.1	tagged at mouth of Klamath River		25.8	
8/2/2004	0:08	Klamath	7.25	Wakel Station	23.1	22	1.14
8/3/2004	3:47	Klamath	26	Blue Creek Station	23.7	22.7	16.41
8/4/2004	1:53	Klamath	67.5	Lower Weitchpec Station	24.6	23.2	45.65
8/4/2004	17:10	Trinity	92	Blue Slide/Fish On in Hoopa		23	39.11
8/5/2004	1:08	Trinity	101.75	Horse Linto Creek Station	23.1	22.2	29.37
8/6/2004	8:05	Trinity	139.5	Grays Falls Station	19.7	17.3	29.51
8/6/2004	12:21	Trinity	140.7	New River and Trinity confluence	20.1	19.4	8.11
8/8/2004	13:32	Trinity	146	China Slide Station	21.5	20.5	2.59
8/10/2004	12:15	Trinity	177.25	pool below Big Flat rest area at Big Bar Creek	18.0	18	16.63
8/18/2004	12:28	Trinity	202	Skyranch Rd access in JC	16.4	16.7	3.09
8/19/2004	12:31	Trinity	202.25	upriver end of Skyranch Rd access	16.3	16.6	0.25

8/20/2004	11:52	Trinity	202	Skyranch Rd access in JC	17.2	17.2	-0.26
8/23/2004	14:00	Trinity	201	lower Skyranch Rd access in JC	13.6	16.6	-0.32
8/25/2004	14:00	Trinity	201	lower Skyranch Rd access in JC	11.1	11.6	0.00
8/27/2004	13:00	Trinity	202	Skyranch Rd access in JC	12.3	11.6	0.51
9/8/2004	8:25	Trinity	212	Brown's Canyon near Brown's Creek			0.85
9/22/2004	13:45	Trinity	241.5	Bucktail Bridge lower Lewiston	12.4	13	2.07
9/27/2004	15:10	Trinity	244.5	just below Salt Flat Rd in Lewiston	13.2	13	0.59
10/1/2004	15:00	Trinity	244	just below Salt Flat Rd Bridge	12.1	12	-0.13
10/18/2004	15:20	Trinity	231.5	just above Steelbridge access	10.4	10	-0.73
11/3/2004	10:00	Trinity	231	tag found near Steelbridge		9	-0.03

Chinook Radio Tag 149.173*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
8/16/2004	17:00	Klamath	0.1	tagged at mouth of Klamath River		23.9	
8/27/2004	5:44	Klamath	7.25	Wakel Station	21.1	19.9	0.69
9/4/2004	6:36	Klamath	26	Blue Creek Station	19.4	19	2.34

9/10/2004	18:18	Klamath	36.25	lower Johnson's	20.8	19.8	1.58
9/14/2004	13:15	Klamath	48.75	downriver from Notchko Creek	19.8	19.1	3.30
9/16/2004	13:38	Klamath	67.5	Lower Weitchpec Station	19.8	19.1	9.30
9/16/2004	16:53	Klamath	69.25	Klamath Trinity Confluence Station	20.2	19.7	14.32
9/18/2004	17:58	Klamath	80	Bluff Creek Station	19.0	17.8	5.29
9/19/2004	17:38	Klamath	108.25	Ishi Pishi Station	17.9	17	29.27
9/21/2004	11:00	Klamath	120	2 km below Irving Creek	16.3	16.6	6.85
9/23/2004	13:35	Klamath	162.5	just below Wingate Bar	17.4	17.2	20.16
9/23/2004	15:38	Klamath	164	Buzzard Cr above Oak Flat Cr	17.4		17.56
9/24/2004	13:00	Klamath	182.5	Muck Muck Mine at China Point	18.2	18	20.78
9/27/2004	14:49	Klamath	234.25	Blue Heron Station	18.3	18.4	16.83
9/28/2004	17:12	Klamath	238	at Everill Cr downriver from Horse Cr	18.7	18	51.00
9/29/2004	13:49	Klamath	276	below Cayuse access	17.3	17.2	44.24
9/30/2004	8:52	Klamath	288.5	Shasta Confluence Station	15.9	15.5	15.75
10/13/2004	9:00	Klamath	309.2	just below mouth of Bogus Creek	15.8	16.2	1.59

10/21/2004	14:27	Klamath	309.5	mouth of Bogus Creek	8.5	14	0.04
10/29/2004	13:12	Klamath	309	spawned out below Bogus Creek	9.8	12.6	-0.06

Chinook Radio Tag 149.564*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
8/16/2004	17:30	Klamath	0.1	tagged at mouth of Klamath River		23.9	
9/3/2004	21:32	Klamath	7.25	Wakel Station	21.3	20.6	0.40
9/5/2004	6:17	Klamath	26	Blue Creek Station	20.0	19.1	18.65
9/13/2004	15:12	Klamath	69	first bend below Weitchpec confluence	20.3	19.5	5.14
10/2/2004	17:12	Klamath	69.25	Klamath Trinity Confluence Station	18.9	17.8	0.01
10/3/2004	18:17	Klamath	80	Bluff Creek Station	19.3	17.4	12.54
10/7/2004	14:00	Klamath	106.7	Salmon River confluence	19.1	18	7.64
10/8/2004	12:44	Klamath	106.7	Salmon River confluence	16.5	17.3	0.00
10/9/2004	15:00	Klamath	108.25	Ishi Pishi Station	17.3	17.1	1.42
10/13/2004	17:00	Klamath	158	at Douglas Creek downriver from Clear Cr	15.5	15.2	12.20
10/14/2004	13:17	Klamath	169.2	upriver from Rattlesnake Rapid	15.9	15	13.25

10/21/2004	16:03	Klamath	217	Walker Creek area	13.5	13	6.72
10/29/2004	16:51	Klamath	217	mouth of Walker Creek, tag found here 11/22	12.9	12.5	0.00

Chinook Radio Tag 149.475*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
8/16/2004	16:00	Klamath	0.1	tagged at mouth of Klamath River		23.9	
8/18/2004	20:01	Klamath	7.25	Wakel Station	24.5	23.7	3.35
8/23/2004	8:00	Klamath	12	Tribal caught lower Blake's		22	1.06

Chinook Radio Tag 149.063*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
8/18/2004	15:00	Klamath	26	tagged at mouth of Blue Creek		18.5	
8/18/2004	18:22	Klamath	26	Blue Creek Station	22.5	23.9	0.00
8/23/2004	16:44	Klamath	25	1st pool below Blue Creek	21.8	22	-0.26
8/24/2004	17:59	Klamath	25	1st pool below Blue Creek	22.6	22.5	0.00
8/26/2004	8:28	Klamath	26	Blue Creek Station	20.3	20	0.62
8/28/2004	15:43	Klamath	67.5	Lower Weitchpec Station	21.0	20.5	18.10

8/28/2004	17:25	Klamath	69.25	Klamath Trinity Confluence Station	21.1	20.7	25.20
8/31/2004	4:49	Trinity	101.75	Horse Linto Creek Station	17.5	17.1	13.36
9/3/2004	15:10	Trinity	139.5	Grays Falls Station	14.6	14.1	11.05
9/8/2004	14:12	Trinity	144.5	Tight Squeeze in Burnt Ranch Gorge	14.6	15.2	1.02
9/10/2004	11:30	Trinity	145	Burnt Ranch Gorge MM 11.82	11.5	13.8	0.26
9/13/2004	12:00	Trinity	172.5	Big Bar below Grover's Gulch RV Park	13.0	15.1	9.10
9/14/2004	13:22	Trinity	179	pool below Fish Tail Rapid	12.9	14.5	6.15
9/15/2004	10:00	Trinity	178.5	just below Big Flat campground	12.9	14.1	-0.58
9/17/2004	11:00	Trinity	187.5	pool below Pigeon Point campground	14.5	16	4.41
9/20/2004	11:30	Trinity	188	pool below NF Trinity confluence	11.4	15	0.17
9/22/2004	11:00	Trinity	188	near North Fork Trinity Bridge	12.1	14	0.00
9/27/2004	11:30	Trinity	188	first pool below NF Trinity	12.9	14.5	0.00
10/1/2004	11:20	Trinity	188	1st pool below NF Trinity confluence pool	13.2	15	0.00
10/4/2004	11:30	Trinity	188	1st pool below NF Trinity confluence pool	11.2	14	0.00
10/5/2004	12:56	Trinity	188	1st pool below NF Trinity confluence pool	12.4	13.8	0.00

10/12/2004	13:42	Trinity	192.5	Coopers Bar lower Junction City (JC)	12.2	12	0.64
10/15/2004	10:30	Trinity	192	lower JC at 25 mph curve	11.1	10.5	-0.17
10/15/2004	13:28	Trinity	192.5	Coopers Bar in lower Junction City	11.9	13	4.04
10/18/2004	12:00	Trinity	192	25 mph curve in lower JC MM 39.0	11.2	11.5	-0.17
10/26/2004	19:00	Trinity	192	spawned out lower JC near 25 mph curve		9	0.00

Chinook Radio Tag 149.270

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
8/18/2004	15:00	Klamath	26	tagged at mouth of Blue Creek		18.5	0.00
8/23/2004	12:00	Klamath	26	Blue Creek confluence pool	22.6	22.3	0.00
8/25/2004	14:28	Klamath	29	just below Bear Creek	22.0	21	0.43
8/27/2004	8:54	Klamath	67.5	Lower Weitchpec Station	19.6	18.9	21.78
8/27/2004	10:57	Klamath	69.25	Klamath Trinity Confluence Station	19.6	18.9	31.11
8/27/2004	16:45	Klamath	71.8	run below Saints Rest Creek	23.1	22.2	22.12
9/7/2004	16:55	Klamath	105	just below Little Ike’s Falls	21.4	22.5	3.02
9/10/2004	10:56	Klamath	106.75	mouth of the Salmon River in Salmon R water	19.4	20	0.64

9/10/2004	16:04	Klamath	108.25	Ishi Pishi Station	21.7	21	7.01
9/23/2004	13:56	Klamath	170.5	lower Happy Camp at bend at 1st house	17.7	18.1	4.83
9/24/2004	11:50	Klamath	178	Happy Camp station	17.4	17.9	8.22
10/1/2004	19:11	Klamath	216	Seiad Valley Bridge	17.7	19.1	5.20
10/3/2004	11:36	Klamath	234.25	Blue Heron Station	16.8	16.2	10.84
10/7/2004	12:23	Klamath	288.5	Shasta Confluence Station - MIA	16.4	16.8	13.49

Chinook Radio Tag 149.622

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
8/19/2004	7:30	Klamath	0.1	tagged at mouth of Klamath River		24.2	
9/1/2004	7:36	Klamath	7.25	Wakel Station	21.3	20	0.56
9/4/2004	6:04	Klamath	26	Blue Creek Station	19.4	19.1	6.39
9/10/2004	14:25	Klamath	40	below Pecwan Creek		20.5	2.21
9/14/2004	13:30	Klamath	50.5	at Roaches Creek	20.3	19.1	2.76
9/15/2004	18:35	Klamath	67.5	Lower Weitchpec Station	20.2	19.5	14.03
9/16/2004	6:55	Klamath	69.25	Klamath Trinity Confluence Station	19.8	19.1	3.46

9/16/2004	14:23	Klamath	77	big pool below Bluff Cr resort - greasy spoon	16.7	20	25.83
9/16/2004	17:30	Klamath	80	Bluff Creek Station	20.9	19.5	23.10
9/18/2004	16:33	Klamath	108.25	Ishi Pishi Station	17.8	17.5	14.54
9/22/2004	13:08	Klamath	177.5	Happy Camp Station	17.7		11.94
9/23/2004	15:05	Klamath	180	2 km above Happy Camp Station Woods Bar		18.1	2.32
9/24/2004	14:02	Klamath	197.5	below Seattle Creek access	18.4	18.9	18.30
9/26/2004	11:52	Klamath	234.25	Blue Heron Station	16.7	16.5	19.24
9/28/2004	16:12	Klamath	264	Beaver Creek Lodge MM 88.88	17.6	17.9	13.73
9/29/2004	9:39	Klamath	288.5	Shasta Confluence Station	16.1	15.9	33.70
10/1/2004	16:30	Klamath	305	5 km below Iron Gate	18.3	18.8	7.26
10/5/2004	14:00	Klamath	310	foot of Iron Gate Dam at fish ladder		18	1.28

Chinook Radio Tag 149.704*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
8/19/2004	8:00	Klamath	0.1	tagged at mouth of Klamath River		24.2	
8/27/2004	8:30	Klamath	1.5	Tribal caught in Klamath estuary	14.5	19.6	0.00

Chinook Radio Tag 149.714*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
8/19/2004	9:30	Klamath	0.1	tagged at mouth of Klamath River		24.2	
8/21/2004	6:34	Klamath	7.25	Wakel Station	22.9	23.1	3.86
8/21/2004	16:15	Klamath	7.25	Wakel Station	24.2	24.4	0.00
8/23/2004	16:16	Klamath	17.5	first riffle above McCovey's	22.4	22	5.12
8/25/2004	7:48	Klamath	26	Blue Creek Station	21.5	21	5.16
9/2/2004	11:30	Klamath	38.6	Johnson's Bar	20.2	19.5	1.55
9/9/2004	11:38	Klamath	44.5	between Moore's Rock and Metah Cr at sand dunes	20.3	19.5	0.84
9/9/2004	12:18	Klamath	44.5	between Metah Cr and Moore's Rock	21.2	20.5	0.00
9/10/2004	13:02	Klamath	44.5	between Moore's Rock and Metah Cr		20.5	0.00
9/14/2004	13:45	Klamath	52.75	downriver Keppel Cr near bedrock	20.3	19.2	2.05
9/18/2004	13:12	Klamath	67.5	Lower Weitchpec Station	18.5	17.8	3.71
9/19/2004	7:30	Klamath	69.25	Klamath Trinity Confluence Station	17.4	17.1	2.64

9/20/2004	12:31	Klamath	80	Bluff Creek Station	17.0	17.1	10.62
9/21/2004	9:30	Klamath	80	Bluff Cr confluence pool	15.9	16.1	0.00
9/21/2004	12:19	Klamath	80.2	upriver of Bluff Creek	18.7	17.2	5.24
9/24/2004	10:00	Klamath	98	upper Dolan's Bar	17.5	17.2	6.13
9/25/2004	12:09	Klamath	108.25	Ishi Pishi Station	17.8	16.9	9.41
9/30/2004	11:15	Klamath	174	just above Happy Camp bridge	16.7	15.5	13.30
10/4/2004	12:20	Klamath	234.25	Blue Heron Station	17.6	16.6	14.89
10/8/2004	13:01	Klamath	288.5	Shasta Confluence Station	16.2	16.3	13.56
10/11/2004	17:00	Klamath	310	spawned Iron Gate Hatchery		16	6.81

Chinook Radio Tag 149.732*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
8/24/2004	12:30	Klamath	0.1	tagged at mouth of Klamath River		22.5	
8/30/2004	0:07	Klamath	7.25	Wakel Station	22.9	21.2	1.32
9/2/2004	11:12	Klamath	24	between Cleveland's and Blue Creek Bob's	20.7	19.2	5.29
9/2/2004	13:18	Klamath	26	Blue Creek Station	21.8	20.5	22.86

9/9/2004	11:44	Klamath	43	Moore's Rock	20.5	20.1	2.45
9/13/2004	15:50	Klamath	62	just above Tully Creek	20.9	19.5	4.56
9/14/2004	10:40	Klamath	69	super riffle at Weitchpec confluence	18.9	18.5	8.92
9/14/2004	14:24	Klamath	69.25	Klamath Trinity Confluence Station	20.2	18.9	1.61
9/15/2004	9:18	Klamath	77	near first riffle below Bluff Cr campground	20.4	19.8	10.27
9/15/2004	16:25	Klamath	80	Bluff Creek Station	21.5	19.9	10.12
9/18/2004	6:38	Klamath	108.25	Ishi Pishi Station	17.6	17.4	10.96
9/21/2004	14:01	Klamath	177.5	Happy Camp Station	18.0		21.00
9/24/2004	15:50	Klamath	216.1	just above Seiad Valley bridge	19.7	18.9	12.58
9/25/2004	16:40	Klamath	234.25	Blue Heron Station	19.5	19.4	17.54
9/28/2004	8:30	Klamath	261	1km below Quigley's MM 86.25			10.13
9/28/2004	15:30	Klamath	270	Gottville	18.0	17.9	30.86
9/29/2004	7:01	Klamath	288.5	Shasta Confluence Station	17.1	16.1	28.61
9/29/2004	15:30	Klamath	299	above Hornbrook above RR bridge	19.5	19	30.48
10/1/2004	16:35	Klamath	306	4 km below Iron Gate Dam	18.8	18.8	3.42

10/5/2004	14:37	Klamath	308.8	~1 km below Iron Gate Dam	18.3	17.8	0.71
10/29/2004	12:08	Klamath	302.3	spawned out Klamath Country Estates Campground	13.8	13.9	-0.27

Chinook Radio Tag 149.752*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
8/24/2004	12:30	Klamath	0.1	tagged at mouth of Klamath River		22.5	
9/2/2004	20:02	Klamath	7.25	Wakel Station	22.1	21	0.78
9/4/2004	6:30	Klamath	18	Tribal caught below Brooks	19.4	19.1	2.23

Chinook Radio Tag 149.833*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
8/31/2004	17:30	Klamath	0.1	tagged at mouth of Klamath River		22.2	
9/1/2004	17:18	Klamath	7.25	Wakel Station	21.8	21.7	7.31
9/4/2004	18:53	Klamath	26	Blue Creek Station	22.1	20.8	6.12
9/7/2004	21:12	Klamath	37	split channel below Johnson’s	21.5	19.5	3.56
9/8/2004	14:00	Klamath	41.6	Sregon, across from road to village	20.7	20.7	6.57
9/9/2004	11:57	Klamath	42.25	Sregon below Moore’s Rock	21.3	20.5	0.71

9/9/2004	12:08	Klamath	42.25	Sregon below Moore's Rock	20.9	20.5	0.00
9/10/2004	13:45	Klamath	42.75	downstream Moore's Rock		20.4	0.47
9/13/2004	13:20	Klamath	42.75	below Moore's Rock top of Sregon Bar	19.8	19	0.00
9/14/2004	13:00	Klamath	42.9	riffle below Moore’s Rock	20.3	19.2	0.15
9/15/2004	10:44	Klamath	43	Moore’s Rock	20.4	18.9	0.11
9/15/2004	14:46	Klamath	43	Moore’s Rock	21.0	20.1	0.00
9/17/2004	12:30	Klamath	43.2	Moore’s Rock	20.6	18.9	0.10
9/21/2004	11:15	Klamath	42.95	just below Moores Rock	18.1	16.1	-0.06
9/22/2004	12:51	Klamath	42.75	downriver of Moore’s Rock		17.5	-0.19
9/23/2004	11:25	Klamath	43	Moore’s Rock	17.9	16.4	0.27
9/24/2004	12:09	Klamath	42.9	200 m downriver from Moore’s Rock	18.8	17.8	-0.10
9/28/2004	15:30	Klamath	43.9	one bend above Moore’s Rock	19.3	17.8	0.24
9/29/2004	12:30	Klamath	44.4	between Moore's Rock and Metah Cr	19.5	17.4	0.57
9/30/2004	11:20	Klamath	43.8	above Moore’s Rock	18.4	17.2	-0.63
10/1/2004	13:13	Klamath	43.5	above Moore’s, still alive		17.6	-0.28

10/8/2004	11:50	Klamath	43.75	above Moore’s Rock	18.2	17.5	0.04
10/8/2004	16:00	Klamath	43.75	dead at Moore’s Rock, unknown cause		18	0.00

Chinook Radio Tag 149.843

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
8/31/2004	17:30	Klamath	0.1	tagged at mouth of Klamath River		22.2	
9/24/2004	2:03	Klamath	26	Blue Creek Station	18.3	17.9	1.11
9/28/2004	15:09	Klamath	67.5	Lower Weitchpec Station	18.0	17.4	9.50
10/16/2004	2:17	Klamath	177.5	Happy Camp Station	15.6	15.3	6.30
10/20/2004	8:26	Klamath	234.25	Blue Heron Station	12.4	13.1	13.35
11/5/2004	12:47	Klamath	309.6	below Iron Gate Hatchery bridge	11.8	12	4.66
11/22/2004	16:44	Klamath	307	Blue Heron Campground below Iron Gate	8.4	9.1	-0.15
12/3/2004	10:00	Klamath	294	upriver of I5 rest stop	6.3	6	-1.21
12/9/2004	2:06	Klamath	260	moribund downriver of Quigley’s	6.1		-6.00
12/9/2004	13:30	Klamath	258	upper end of Klamath Golf Course	6.3		-4.21

Chinook Radio Tag 149.872*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
9/6/2004	13:00	Klamath	0.1	tagged at mouth of Klamath River		21.2	
9/12/2004	20:53	Klamath	7.25	Wakel Station	21.4	20.2	1.15
9/15/2004	1:35	Klamath	26	Blue Creek Station	20.5	19.6	10.57
9/16/2004	11:45	Klamath	28.65	just below Bear Cr	19.9	19.7	2.09
9/17/2004	12:05	Klamath	30.75	downriver from Surpur Creek	20.5	18.9	2.07
9/21/2004	11:30	Klamath	52.75	downriver of Keppel Cr	18.5	16.1	5.53
9/23/2004	8:34	Klamath	80	Bluff Creek Station	17.1	16.1	14.51
9/24/2004	16:24	Klamath	108.25	Ishi Pishi Station	19.7	18.1	21.43
9/30/2004	10:45	Klamath	171.5	mouth of Elk Creek	16.5	15.5	11.01
10/3/2004	14:51	Klamath	234.25	Blue Heron Station	19.3	18.2	19.79
10/6/2004	16:40	Klamath	288.5	Shasta Confluence Station	20.2	18.9	17.71
10/13/2004	12:00	Klamath	310	spawned Iron Gate Hatchery		14	3.16

Chinook Radio Tag 149.893*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day

9/6/2004	13:30	Klamath	0.1	tagged at mouth of Klamath River	0.0	21.2	
10/3/2004	8:30	Klamath		Tribal caught in Klamath estuary	17.4	17.2	0.00

Chinook Radio Tag 149.973

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
9/6/2004	13:30	Klamath	0.1	tagged at mouth of Klamath River		21.2	
9/14/2004	19:40	Klamath	7.25	Wakel Station	21.1	20.2	0.88
9/15/2004	2:12	Klamath	7.25	Wakel Station	20.7	19.5	0.00
9/15/2004	18:35	Klamath	14.25	lower Starwin	21.0	19.5	10.25
9/16/2004	12:05	Klamath	21.1	Lambs	21.3	19.4	9.39
9/16/2004	19:51	Klamath	26	Blue Creek Station	21.6	20.5	15.14
9/17/2004	12:00	Klamath	28.7	below Bear Creek	20.1	19.4	4.14
9/20/2004	12:15	Klamath	34.75	along bedrock ledge below Techtah Cr	18.0	16.7	2.01
9/22/2004	12:20	Klamath	34.75	pool below Techtah near bedrock	18.6	17.5	0.00
9/23/2004	11:00	Klamath	34.85	50 m below Techtah bedrock ledge	17.5	16.4	0.11
9/28/2004	13:15	Klamath	38.5	Johnson's	18.5	17.2	0.72

9/29/2004	13:17	Klamath	38.25	behind big rock at Johnson's Bar	18.5	17.5	-0.25
9/29/2004	15:01	Klamath	38.25	Johnson's	18.3	17.4	0.00
9/30/2004	12:15	Klamath	38.25	just below Johnson's Creek	18.5	17.2	0.00
10/7/2004	19:24	Klamath	43	Moore's Rock	20.0	17.9	0.65
10/13/2004	16:50	Klamath	69.25	Klamath Trinity Confluence Station	16.4	15.4	4.45
10/21/2004	21:45	Klamath	288.5	Shasta Confluence Station	12.9	14.2	26.75
10/25/2004	14:00	Klamath	310	spawned Iron Gate Hatchery		14	5.88

Chinook Radio Tag 150.014

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
9/9/2004	15:00	Klamath	0.1	tagged at mouth of Klamath River		21.2	
9/22/2004	3:01	Klamath	7.25	Wakel Station	17.8	17.3	0.58
9/23/2004	3:50	Klamath	26	Blue Creek Station	17.6	17.3	18.18
10/7/2004	19:40	Klamath	43	Moore's Rock	19.4	17.9	1.17
10/8/2004	11:59	Klamath	43.5	above Moore's Rock	18.3	17.5	0.74
10/9/2004	14:10	Klamath	67.5	Lower Weitchpec Station	17.5	16.8	22.00

10/9/2004	16:02	Klamath	69.25	Klamath Trinity Confluence Station - MIA	17.6	17.1	28.00

Chinook Radio Tag 150.133*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
9/16/2004	10:30	Klamath	0.1	tagged at mouth of Klamath River		20.7	
9/20/2004	19:15	Klamath	7.25	Wakel Station	18.6	18.3	1.66
9/22/2004	16:47	Klamath	26	Blue Creek Station	18.8	18.2	9.91
10/3/2004	8:09	Klamath	67.5	Lower Weitchpec Station	17.6	17.1	3.90
10/4/2004	5:40	Klamath	69.25	Klamath Trinity Confluence Station	18.0	17.6	2.10
10/4/2004	13:50	Trinity	69.9	1st riffle in Trinity above confluence	17.6	18	2.53
10/5/2004	10:15	Trinity	70	Pierson's run below the pool	16.8	16.8	0.12
10/6/2004	10:00	Trinity	74.8	lower end of Weitchpec Gorge	15.9	17	4.85
10/7/2004	8:40	Trinity	77	1km downstream of Weitchpec Bluffs	16.1	16.5	3.62
10/8/2004	11:30	Trinity	79.5	near Red Rock area MM 17.5		16.8	2.28
10/9/2004	17:30	Trinity	96.5	Tribal caught mouth of Tish Tang Creek	17.4	17.4	7.92

Chinook Radio Tag 150.274*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
9/20/2004	12:00	Klamath	0.1	tagged at mouth of Klamath River, ad clip		18.4	
9/21/2004	6:57	Klamath	7.25	Wakel Station	17.5	16.5	9.18
9/22/2004	7:13	Klamath	7.25	Wakel Station	17.2	16.5	0.00
9/22/2004	17:40	Klamath	8.5	Charles Camp	17.2	18	2.87
9/23/2004	12:50	Klamath	13.5	lower Starwin	18.1	17.5	6.26
9/27/2004	12:37	Klamath	26	Blue Creek Station	17.9	17.5	3.13
9/28/2004	12:35	Klamath	26.95	below Ah Pah Creek	18.5	17.2	0.98
9/29/2004	18:07	Klamath	26.95	below Ah Pah Creek	16.8	17.6	0.00
9/30/2004	10:50	Klamath	26.95	below Ah Pah Creek	17.1	16.7	0.00
10/6/2004	15:40	Klamath	35	at Techtah Creek	18.0	18.6	1.30
10/7/2004	19:00	Klamath	35	at Techtah Creek	18.7	18.7	0.00
10/8/2004	16:15	Klamath	35	at Techtah Creek	18.6	17.9	0.00
10/11/2004	19:38	Klamath	40	Pecwan	16.2	16.1	1.59

10/12/2004	14:48	Klamath	42	Sregon	15.8	15.5	2.50
10/13/2004	19:41	Klamath	43.15	Moore's Rock	15.7	15.4	0.96
10/15/2004	18:22	Klamath	69.25	Klamath Trinity Confluence Station	16.0	15.5	13.42
10/18/2004	14:34	Trinity	78	bluffs of Weitchpec Gorge	13.2	14	3.64
10/19/2004	11:58	Trinity	80.5	Red Rock in Hoopa	13.3	13	2.80
10/20/2004	18:32	Trinity	101.75	Horse Linto Creek Station	13.0	12.6	16.68
11/15/2004	4:05	Trinity	207.5	Junction City Weir Station	9.5	8.9	1.76
11/23/2004	12:00	Trinity	249	spawned out Lewiston Reach 1			12.39

Chinook Radio Tag 150.553*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
9/22/2004	14:30	Klamath	0.1	tagged at mouth of Klamath River		18.3	
10/4/2004	1:01	Klamath	7.25	Wakel Station	18.3	18.3	0.63
10/4/2004	19:18	Klamath	16.5	McCovey's riffle	18.5	17.9	17.74
10/6/2004	7:46	Klamath	26	Blue Creek Station	17.8	17.3	6.25
10/6/2004	16:25	Klamath	26.25	1st pool above Blue Creek	18.7	18.8	0.71

10/7/2004	18:32	Klamath	27.25	Ah Pah	18.6	18.9	0.92
10/8/2004	16:04	Klamath	32.5	riffle above Surpur Creek	18.7	17.9	5.85
10/16/2004	13:19	Klamath	69.25	Klamath Trinity Confluence Station	15.2	14.9	4.66
10/18/2004	15:19	Trinity	70.25	Pierson's Store Hole, likely caught here	14.5	14	0.48
10/19/2004	15:18	Klamath	69.25	Klamath Trinity confluence	12.8	13.9	-1.00
11/18/2004	14:30	Klamath	69.25	tag found at Klamath Trinity confluence	0.0	14.9	0.00

Chinook Radio Tag 150.593*

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
9/22/2004	14:30	Klamath	0.1	tagged at mouth of Klamath River		18.3	
9/24/2004	19:37	Klamath	7.25	Wakel Station	18.8	18.5	3.28
10/1/2004	4:46	Klamath	26	Blue Creek Station	17.9	17.4	2.94
10/1/2004	15:38	Klamath	26	at Blue Creek	18.4	18.3	0.00
10/4/2004	19:55	Klamath	26	at Blue Creek	19.1	18.4	0.00
10/6/2004	16:30	Klamath	26.25	below rock island in pool above Blue Cr	18.9	18.8	0.13
10/7/2004	18:25	Klamath	26.25	pool above Blue Creek with rock island	20.6	18.9	0.00

10/8/2004	15:46	Klamath	26.25	pool above Blue Creek with rock island	18.3	18.3	0.00
10/11/2004	22:02	Klamath	26.25	pool above Blue Creek with rock island	16.7	16.7	0.00
10/13/2004	18:46	Klamath	26.25	pool above Blue Creek with rock island	16.8	16.7	0.00
10/14/2004	17:12	Klamath	26.25	pool above Blue Creek with rock island	16.4	16.7	0.00
10/18/2004	18:02	Klamath	26.25	pool above Blue Creek	15.4	14.3	0.00
10/19/2004	23:32	Klamath	26	Blue Creek Station	14.0	13.5	-0.20
10/23/2004	11:11	Klamath	26	dead near Blue Creek Station			0.00

Chinook Radio Tag 150.654

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
9/22/2004	15:30	Klamath	0.1	tagged at mouth of Klamath River		18.3	
9/28/2004	23:27	Klamath	26	Blue Creek Station	18.7	18.4	4.11
10/3/2004	17:31	Klamath	67.5	Lower Weitchpec Station	18.5	17.8	8.75
10/4/2004	4:44	Klamath	69.25	Klamath Trinity Confluence Station	18.3	17.8	3.89
10/4/2004	13:46	Klamath	69.75	upper end of confluence at Weitchpec	18.0	17.4	1.33
10/4/2004	18:13	Klamath	69.25	Klamath Trinity Confluence Station	18.7	17.9	-2.70

10/5/2004	10:30	Trinity	72.5	below Bull Creek in Weitchpec Gorge	17.3	16.9	4.79
10/6/2004	11:07	Trinity	78.5	upper Weitchpec Gorge	16.3	16.3	5.85
10/10/2004	8:19	Trinity	101.75	Horse Linto Creek Station	15.3	15.1	5.99
10/12/2004	16:11	Trinity	102	above Horse Linto Creek	14.9	15.4	0.11
10/19/2004	10:20	Trinity	105.5	below Willow Creek weir area	12.6	13	0.52
10/23/2004	10:30	Trinity	146	China Slide Station	11.3	11.5	10.11
10/26/2004	20:38	Trinity	207.5	Junction City Weir Station - MIA	10.0	9.7	18.15

Chinook Radio Tag 150.793

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
10/1/2004	12:00	Klamath	0.1	tagged at mouth of Klamath River		18.6	
10/3/2004	19:08	Klamath	7.25	Wakel Station	19.1	18.6	3.16
10/4/2004	3:01	Klamath	7.25	Wakel Station	18.1	17.9	0.00
10/4/2004	19:11	Klamath	16	McCovey's hole	18.4	17.9	12.99
10/6/2004	11:34	Klamath	26	Blue Creek Station	17.7	17.3	5.94
10/6/2004	16:08	Klamath	27	Ah Pah	18.7	18.6	6.58

10/7/2004	18:45	Klamath	32	Surpur	19.0	18.9	4.51
10/8/2004	16:08	Klamath	34	riffle below Techtah Creek	18.4	17.9	2.24
10/17/2004	7:44	Klamath	69.25	Klamath Trinity Confluence Station	15.6	15.2	4.08
10/18/2004	14:25	Trinity	76.5	Weitchpec Gorge	13.5	14	5.75
10/19/2004	12:01	Trinity	80.5	near Red Rocks in Hoopa	12.8	12.9	4.44
10/19/2004	13:32	Trinity	82	below Jimmy Jackson's	13.0	12.9	23.74
10/20/2004	13:41	Trinity	101.75	Horse Linto Creek Station	12.3	12.6	19.63
11/3/2004	16:54	Trinity	146	China Slide Station	9.1		3.13
11/9/2004	23:22	Trinity	207.5	Junction City Weir Station	9.7	9.5	10.08
11/24/2004	23:02	Trinity	207.5	Junction City Weir Station	7.5	7	0.00
12/14/2004	17:05	Trinity	179	dead or moribund Fish Tail Rapid above Big Flat	6.9	9	-1.44

Chinook Radio Tag 150.923

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
10/1/2004	12:00	Klamath	0.1	tagged at mouth of Klamath River		18.6	
10/1/2004	17:27	Klamath	7.25	Wakel Station	18.9	18.6	31.93

10/4/2004	20:25	Klamath	13.25	Turup upriver from USGS Gauge	18.1	18.1	3.78
10/6/2004	15:00	Klamath	25.25	below bend downriver from Blue Creek	17.6	18.4	6.76
10/6/2004	15:26	Klamath	26	Blue Creek Station	18.8	18.4	41.54
10/7/2004	19:55	Klamath	33.75	between Surpur and Techtah	19.3	18.7	6.60
10/8/2004	12:24	Klamath	34.5	just below Techtah	17.6	17.5	1.09
10/11/2004	19:15	Klamath	35	at Techtah Creek	17.0	16.1	0.15
10/12/2004	14:25	Klamath	34.5	below Techtah Creek	15.7	15.5	-0.63
10/13/2004	20:01	Klamath	34.75	just below Techtah Creek	16.0	15.5	0.20
10/14/2004	16:43	Klamath	35	at Techtah Creek	16.6	15.7	0.29
10/18/2004	17:05	Klamath	35	Techtah	14.5	14.3	0.00
10/19/2004	18:14	Klamath	43.75	riffle above Moore's Rock	13.4	12.3	8.35
11/17/2004	10:16	Klamath	239.2	1.5 km downriver of Horse Creek; spawning?	9.3	10	6.82
12/3/2004	11:10	Klamath	235	downriver of Blue Heron Station	3.8	5	-0.26

Chinook Radio Tag 149.453

Date	Time	River	RKM	Location	Body Temp C	Water Temp C	km/day
10/22/2004	12:00	Klamath	0.1	tagged at mouth of Klamath River		13.4	
10/27/2004	15:28	Klamath	26	Blue Creek Station	11.9		5.05
11/17/2004	1:43	Trinity	101.75	Horse Linto Creek Station	11.1		3.72
11/18/2004	21:48	Trinity	132.5	Hawkins Bar Station	10.3		16.84
12/8/2004	11:08	Trinity	142.5	in the pool below 3rd BR Falls	5.6	5.0	0.52