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BODY TEMPERATURE DURING MIGRATION IN ADULT CHINOOK SALMON AND STEELHEAD THROUGH THE LOWER COLUMBIA AND SNAKE RIVERS, 2000 AND 2002

Report for study APS-00-5

by

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Abstract

Temperature is a major environmental factor affecting salmonid physiology, behavior, reproduction, and life history, yet the range of temperatures experienced by adult Pacific salmon and steelhead during their upstream migration in the Columbia and Snake rivers has not been well documented. Here, we present temperature histories for 261 spring-summer Chinook salmon, 64 fall Chinook salmon, and 302 steelhead that were tagged with radio data storage tags (RDSTs) and released near Bonneville Dam. Sixty-seven percent of all fish released with RDSTs were recaptured and 60% of the recaptured tags were recovered at Lower Granite Dam adult fish trap. The remaining 40% were tags returned from fisheries, hatcheries, and spawning ground surveys. RDSTs were programmed to record temperature at 1 minute intervals over a 40-day period. River temperatures during the two study years (2000 and 2002) were near or below the 10-year average conditions during the migration seasons.

Few (2%) spring Chinook salmon experienced temperatures considered to be stressful (≥ 20 °C) in either year. In contrast, 13% of summer Chinook salmon, 81% of fall Chinook salmon, and 75% of steelhead experienced temperatures ≥ 20 ºC (both years combined). Fall Chinook salmon experienced the highest average percentage of time at temperatures ≥ 20 ºC (45% of time), followed by steelhead (22%), and summer Chinook (20%). Steelhead experienced the longest periods with consecutive records ≥ 20 ºC during upstream migration (mean = 12.1 h), followed by summer Chinook salmon (10.5 consecutive hours), and fall Chinook salmon (9.6 consecutive hours).

In general, salmon and steelhead experienced the highest temperatures in fish ladders at dams, although they spent less time there (range of median passage times = 1.5-3.2 hours) than in tailraces (range =0.04-0.8 days) or reservoirs (range=0.6-6.3 days). On average, Chinook salmon and steelhead experienced higher temperatures in reservoirs than in tailraces.

Overall, the results demonstrate that adult salmonids migrating through the Columbia-Snake River hydrosystem frequently experience body temperatures widely considered to be physiologically stressful, even in years with moderate river temperatures. Exposure to high temperatures during migration may hinder salmon and steelhead recovery by increasing the metabolic costs of migration, increasing exposure

and susceptibility to disease, decreasing reproductive potential, and contributing to delayed effects such as upstream *en route* or prespawn mortality. Current conditions and predicted climate warming suggest water temperature will continue to be an important environmental factor in the management of summer- and fall-run salmonid stocks.

Introduction

Temperature is perhaps the most important environmental factor affecting salmonid distribution, behavior, and physiology (Groot and Margolis 1991; Brett 1995; Newell and Quinn 2005). It has played a significant role in the evolution of life history strategies for Pacific salmonids (e.g., Brannon et al. 2004) and affects their distributions, life history traits, and migration behavior (Behnke 1992; Quinn 2005). Anadromous Pacific salmonids are poikilotherm fishes with an upper thermal limit near 20°C (Groot and Margolis 1991; Richter and Kolmes 2005) and warm summer temperatures appear to have constrained the timing of some adult migrations (Quinn and Adams 1996; Hodgson and Quinn 2002). For the aggregate of interior Columbia River basin Chinook salmon *Oncorhynchus tshawytscha*, warm summer temperatures coincide with a nadir in migration (Columbia River DART 2007), with overall run size declining in summer and increasing with the onset of fall cooling. Columbia River summer steelhead (*O. mykiss*) migrations are protracted, with many fish migrating during the summer months but also experiencing extensive migration delays and seeking thermal refugia at the warmest times (Keefer et al. 2004; High et al. 2006). Understanding the thermal ecology of adults during migration is critical, especially for summer stocks, given that Snake River spring-summer Chinook salmon, Snake River Fall Chinook salmon, Snake River steelhead, and upper Columbia River steelhead are all listed as threatened evolutionary significant units (ESUs) under the U.S. Endangered Species Act (Good et al. 2005). Although these populations have migrations that at least partially overlap with the period of warmest Columbia and Snake River water temperatures, few studies have directly evaluated the temperatures experienced by actively migrating adult salmonids in this system.

Construction of hydroelectric projects on the mainstem Columbia and Snake rivers, along with changing regional climate and patterns of land and water use, have greatly altered water temperature from historical conditions (Raymond 1988; Quinn and Adams 1996; Quinn et al. 1997; Peery et al. 2003). Prior to impoundment, water temperatures in the Snake River were highest in mid- to late summer, often exceeding 20 ºC (Sylvester 1958). Currently, similar or higher maximum temperatures occur during the summer and warm water conditions begin earlier in the spring and persist longer into the fall than historically (Quinn and Adams 1996; Quinn et al. 1997). Annual air temperature trends (1948-1988) in the Northwest have increased (≥ 1 ºC; Lettenmaier et al. 1994) and climate modeling of future conditions in the Columbia River Basin predicts an additional increase in average annual temperatures of approximately 1 ºC or greater by 2040 (Hamlet and Lettenmaier 1999; Payne et al. 2004).

There is considerable evidence that warm water temperatures negatively affect migrating salmonids. Warm temperatures increase metabolic rate (Brett 1995), decrease cardiac performance (Farrell 1997), and reduce swimming performance in adult salmonids (Macdonald et al. 2000; McCullough et al. 2001; Jain and Farrell 2003). In addition to effects on physiology and swimming, exposure to stressful temperatures has a wide variety of other negative effects that may reduce individual fitness. Stressful temperatures have been related to reduced disease resistance (Groberg et. al 1978) and increased disease prevalence and intensity in several salmonid species in both laboratory and field studies (Colgrove and Wood 1966; Becker and Fujihara 1978; Servizi and Martens 1991; Weiland et. al 1999; Baldwin et. al 2000; Materna 2001). Adult salmon encountering high water temperatures during migration can have reduced egg viability (CDWR 1988; Van der Kraak and Pankhurst 1996; King et al. 2003) and high temperatures have been associated with prespawn mortality in sockeye (Gilhousen 1990; Naughton et al. 2005; Keefer et al. *in press*) and Chinook salmon (Schreck et al. 1994; Pinson 2005). These mechanisms probably interact in negative and potentially non-additive ways. In general, future climate warming in the Pacific Northwest may hinder salmon recovery efforts through habitat degradation (Battin et al. 2007), underscoring a need for detailed understanding of temperature effects on salmonids.

In a synthesis of temperature criteria for Pacific Northwest salmonids, Richter and Kolmes (2005) reported the upper optimal temperature for adult salmon migration to be 16 ºC (weekly mean temperatures). The Environmental Protection Agency (EPA) and others suggest optimal swimming performance for salmon and steelhead is 15 to 19 ºC (constant), while swimming performance is reduced when temperatures (constant) exceed 20 ºC (McCullough et al. 2001; Salinger and Anderson 2006). After reviewing numerous studies, Marine (1992) suggested an incipient upper *lethal* temperature limit for pre-spawn adult salmon to be 17 to 20 ºC. EPA guidelines state lethal exposures (1 week) occur when temperatures are a constant 21 to 22 ºC (McCullough et al. 2001). Based on these reviews, we considered temperatures above 18˚C to be physiologically *suboptimal* and temperatures above 20° C to be *stressful*. Temperatures recorded at Columbia and Snake Rivers monitoring sites (mostly at dams) frequently exceed these thresholds (Columbia River DART 2007). Our study objectives were to: 1) record continuous migration temperatures experienced by adult salmonids in the tailraces, ladders, and reservoirs of dams, 2) determine the percent of time and consecutive time salmonids spent at temperatures ≥ 20 ºC in each migration environment, 3) examine within-season and among-stock variability in temperature histories, and 4) test for an association between temperature and migration success.

Methods

Study system

Our study focused on the lower Columbia and Snake Rivers from release sites at river kilometer (rkm) 226 (approximately 9 km below Bonneville Dam) to the adult trap at Lower Granite Dam on the lower Snake River (rkm 695; Figure 1). The study reach included the four lower Columbia River dams and reservoirs (Bonneville, The Dalles, John Day, McNary), three lower Snake River dams and reservoirs (Ice Harbor, Lower Monumental, Little Goose), and the Lower Granite Dam tailrace and lower portion of the fish ladder to the adult trap, where many adults were recaptured and archived temperature data were recovered. We also monitored migrations of a limited number of adults past four upper Columbia River dams (Priest Rapids, Wanapum, Rock Island, and Rocky Reach; Figure 1). However, because sample sizes for adults recovered from the upper Columbia River reach were very small for all runs, analyses of temperature data for these fish were limited to their migrations through the lower Columbia River.

Mean summer (July through September) water temperatures during the two study years (2000, 2002) were below the 10 year average (1996-2005) but daily and monthly mean temperatures were frequently above 18°C. In the forebay of Bonneville Dam, July-September means were 19.8, 19.7, and 20.2 ºC for 2000, 2002, and the 10-year average, respectively (Columbia River DART 2007; Figure 2). Summer water temperatures in the forebay of Ice Harbor Dam were above the 10 year average (19.6 ºC) in 2000 (20.2 ºC) and in 2002 (19.9 ºC). For comparison, mean water temperatures in 2003 (one of the warmest years on record) at both locations were 20.7 °C at Bonneville Dam and 21.1 °C at Ice Harbor Dam (Figure 3). Monthly mean temperatures were at or above 20 ºC in July and/or August in the tailraces and forebays of many dams in each year, and exceeded 18 °C at most sites from July-September (Figures 4-5).

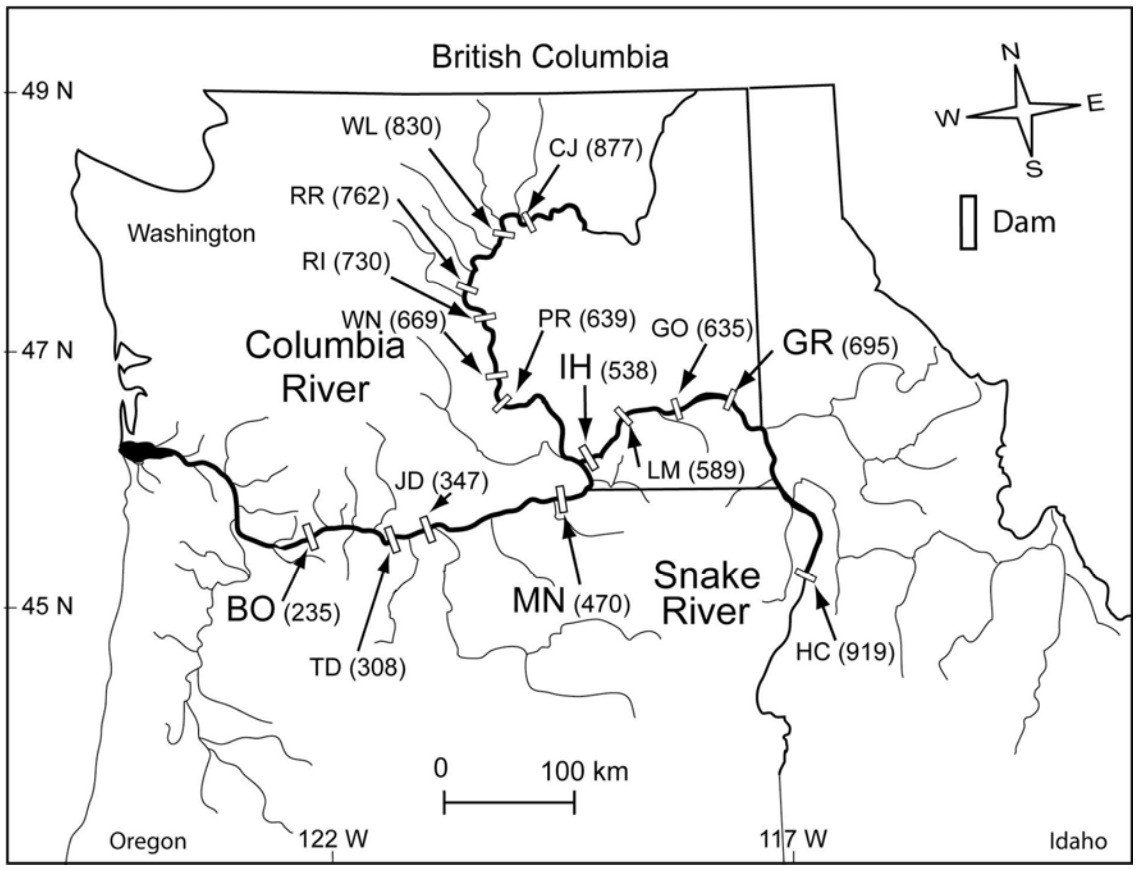


Figure 1. Map of the study region, including locations of dams. Fish were collected and tagged at Bonneville dam. Upstream migration to spawning sites was monitored as far upstream as river km (rkm) 1300 in the Snake River basin or Wells dam on the Columbia River using 150-170 fixed site antennas and mobile tracking in boats and trucks. Distances from the Columbia River mouth are given parenthetically as river kilometers (rkm). Dam abbreviations for Lower Columbia River dams: BO = Bonneville, TD = The Dalles, JD = John Day, MN = McNary; mid-Columbia River dams: PR = Priests Rapids, WN = Wanapum, RI = Rock Island, RR = Rocky Reach, WL = Wells, CJ = Chief Joseph (impassable); Snake River dams: IH = Ice Harbor, LM Lower Monumental, GO = Little Goose, GR = Lower Granite, HC = Hells Canyon (impassable).

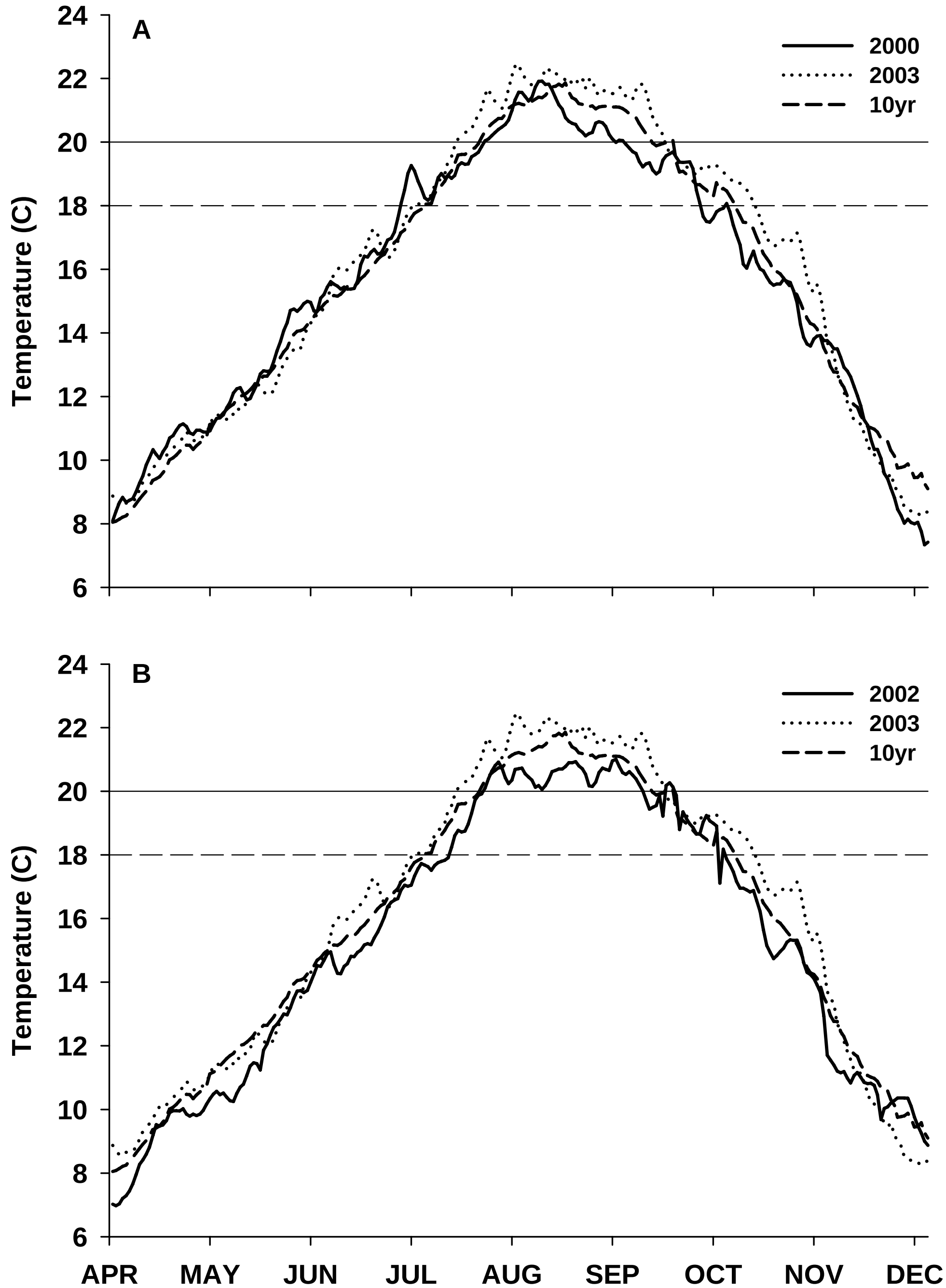


Figure 2. A) Mean daily temperatures in the forebay of Bonneville Dam in 2000 compared to the warmest year on record (2003) and the 10 year average. B) Mean daily temperatures in the forebay of Bonneville Dam in 2002 compared to 2003 and the 10 year average.

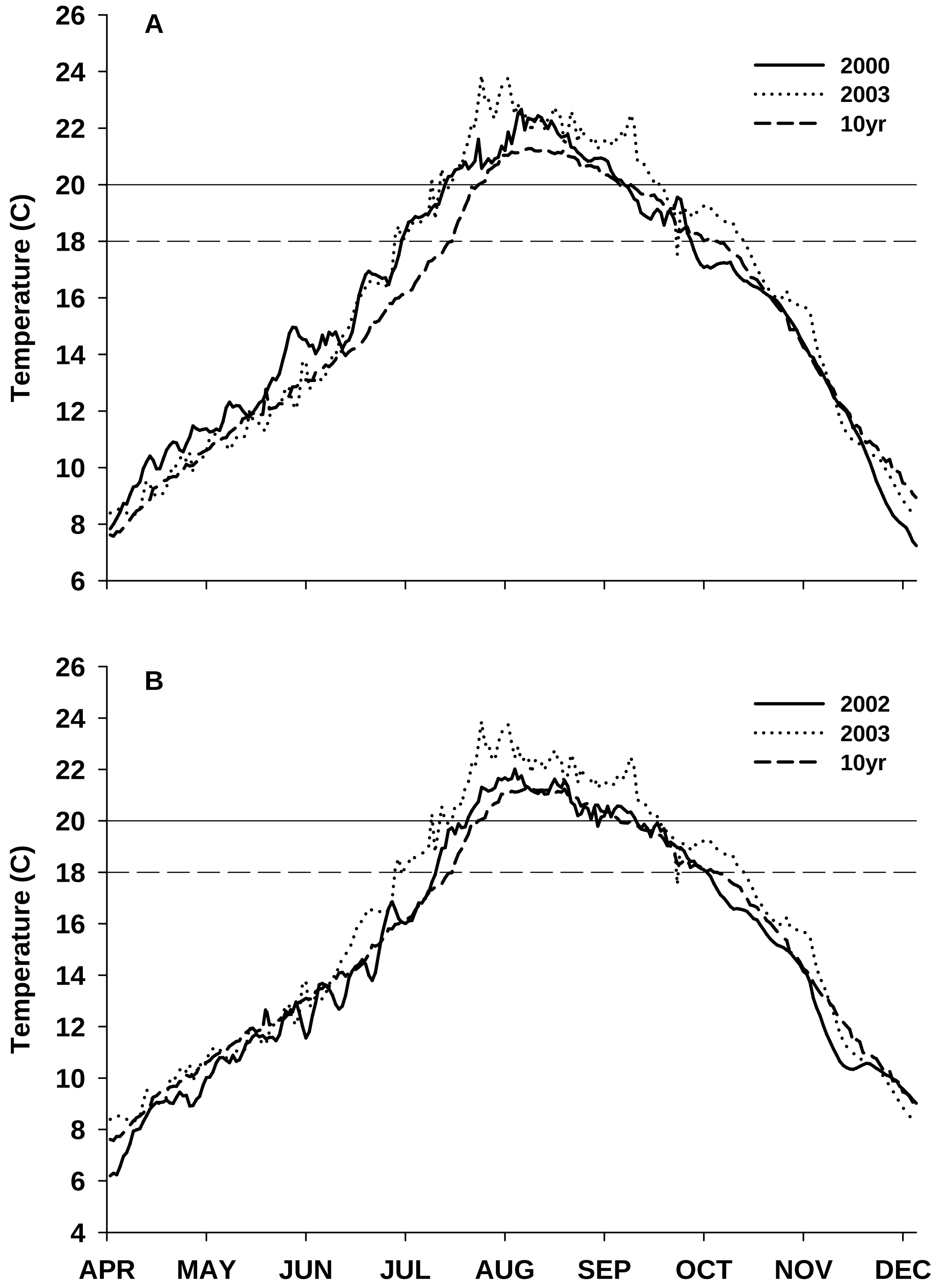


Figure 3. A) Mean daily temperatures in the forebay of Ice Harbor Dam in 2000 compared to the warmest year on record (2003) and the 10 year average. B) Mean daily temperatures in the forebay of Ice Harbor Dam in 2002 compared to 2003 and the 10 year average.

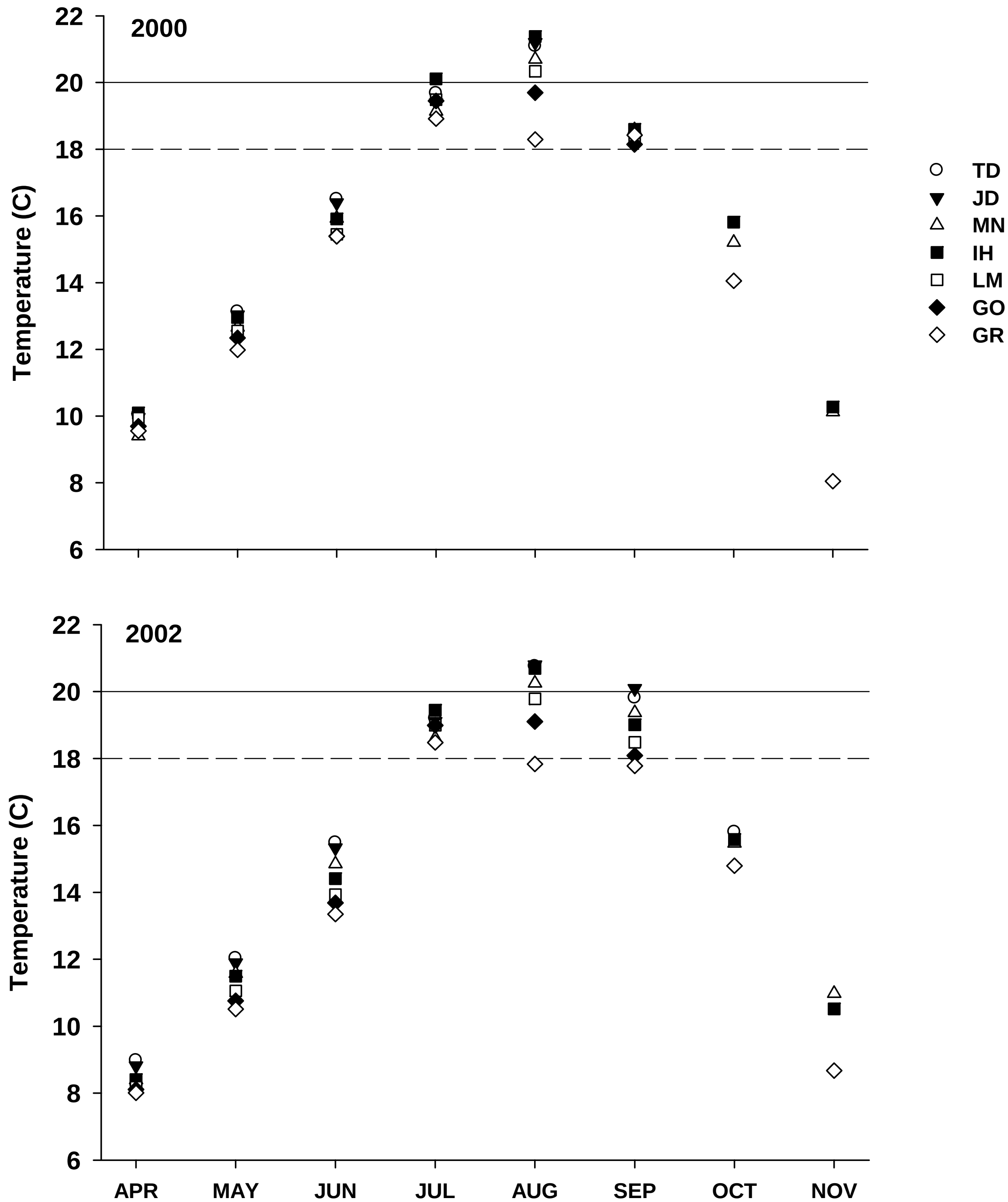


Figure 4. Mean monthly tailrace temperatures at the three Columbia and four Snake River dams in 2000 and 2002 (TD=The Dalles, JD=John Day, MN=McNary, IH=Ice Harbor, LM=Lower Monumental, GO=Little Goose, and GR=Lower Granite).

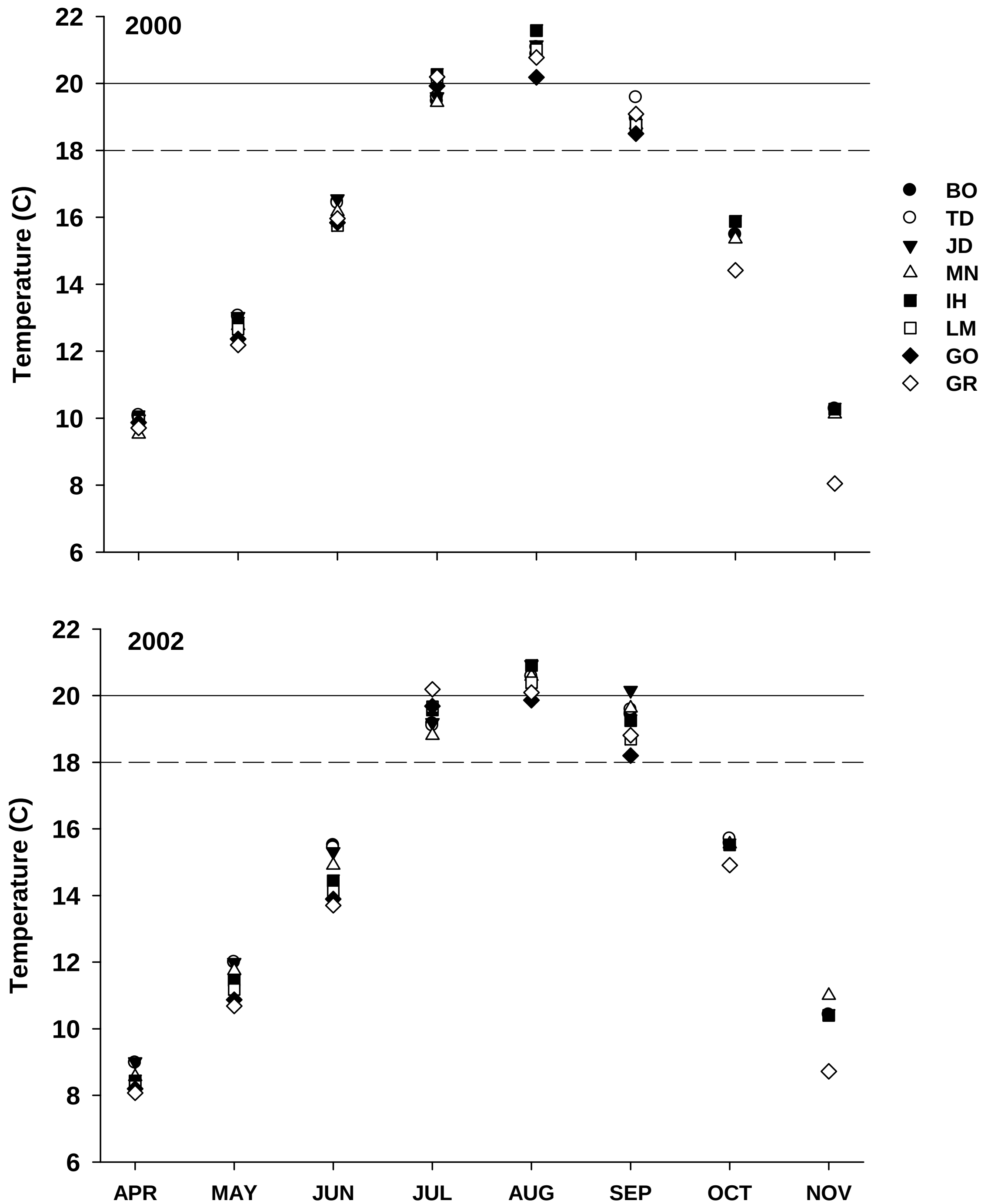


Figure 5. Mean monthly forebay temperatures at the four Columbia and Snake River dams in 2000 and 2002 (BO=Bonneville, TD=The Dalles, JD=John Day, MN=McNary, IH=Ice Harbor, LM=Lower Monumental, GO=Little Goose, and GR=Lower Granite).

Tagging and monitoring procedures

Adult Chinook salmon and steelhead were trapped and tagged at the Adult Fish Facility located adjacent to the Washington shore fishway at Bonneville Dam from 4 April through 23 October in 2000 and from 31 March through 15 October in 2002. In 2000 and 2002, respectively, totals of 228 and 184 adult spring–summer Chinook salmon, 80 and 36 fall Chinook salmon, and 181 and 229 steelhead were tagged intragastrically with a 3-volt (9 x 2 cm; 34 g in air) radio data storage transmitter (RDST; Lotek Wireless, Inc., Newmarket, Ontario). RDST's allowed for 40 d of data storage when programmed to record temperature at 1-min intervals and pressure (from which depth was inferred – see Johnson et al. [2005]) at 5-s intervals. Estimated accuracy of the temperature sensor in RDSTs was ± 0.15 ºC (water temperatures 0-20 ºC; ± 0.10 ºC water temperatures 20-35 ºC) (Lotek Wireless, Inc.). After recovery, all but 14 (1%) were released at sites ~10 km downstream from Bonneville Dam near both shorelines; the remaining 14 were released into the Bonneville forebay.

Transmitters were placed in Chinook salmon and steelhead thought to be of Snake River origin (based on passive integrated transponder [PIT] tag codes and adipose fin clips) to increase the likelihood of tags being recovered at Lower Granite Dam (Figure 1). Adults lacking a PIT tag at the time of tagging received one as a secondary tag. Fish that reached Lower Granite Dam were selectively diverted from the fish ladder into the adult fish trap based on PIT codes. Of the RDST fish recaptured at Lower Granite Dam, 99% and 83% of spring and summer Chinook salmon, 100% of fall Chinook salmon, and 76% and 48% of steelhead in 2000 and 2002, respectively, were retagged prior to being re-released with either a 3- or 7 volt (non-RDST) radio transmitter to monitor their movements and determine their final distributions upstream. More details on tagging methods at the Adult Fish Facility at Bonneville can be found in Keefer et al. (2004) and methods used at the Lower Granite adult fish trap can be found in Clabough et al. (2006).

The movements of radio-tagged salmon and steelhead past dams, through reservoirs, and into tributaries were monitored using fixed-site receivers (radio receivers connected to aerial antennas or underwater antennas) deployed at all major tributaries and dams in the Columbia and lower Snake rivers. Aerial antennas were used with sequentially scanning receivers (6 s per frequency) while underwater antennas were used in combination with SRX/DSP receivers capable of simultaneously monitoring several radio transmitter frequencies and antennas. The migration histories of individual fish were separated into three passage segments: tailraces, ladders, and dam reservoirs. Fish were considered to be in the tailrace of a dam during the interval between the first record (F1) on the tailrace receiver (0.5-3.2 km downstream of each dam) and their first fishway entry (E1). Fish were considered to be in the ladder from the time of their last record in the transition pool (LP) to their last record at a ladder top (LT). Fish were considered to be in the reservoir from the time they exited a ladder top (LT) to the first record in the tailrace (F1) of the next upstream dam. Times spent in monitored tributaries were excluded from the analyses presented in this report. Time fish spent falling back and reascending at dams was excluded from passage time analysis (i.e., only first passage times are reported). Reservoir passage times were calculated from last top-of-ladder records at the downstream dam to the first tailrace record at the upstream dam, excluding time spent in tributaries. When fish fell back and reascended the downstream dam before migrating upstream, the reservoir start time began after the last passage at the downstream dam.

Data processing

Data processing involved assigning codes to identify each fish's movement within and around dams and tributaries. A more complete explanation of telemetry data collection and processing procedures can be found in Bjornn et al. (2000). Temperature and pressure data from RDSTs were merged with radio telemetry records using a Visual Basic program (Appendix A). All data were corrected for time drift using a polynomial equation unique to each tag's calibration (provided by Lotek Wireless., Inc.). Radiotelemetry records were matched with temperature and pressure records based on date and time. All data were then loaded and stored in a Sequel server database. Information from six spring Chinook salmon, two summer Chinook salmon, five fall Chinook salmon, and 18 steelhead could not be used due to incorrect setup of tags, bad tag sensor data, or irretrievable data.

We used a combination of telemetry records, spawning ground surveys, and fishery returns to classify fish with RDSTs as successful or unsuccessful migrants. Successful migrants included salmon with final telemetry records in known spawning tributaries, fish that were caught in a spawning tributary, those found as carcasses in spawning tributary surveys, and those that returned to hatcheries. Unsuccessful migrants were typically fish with final telemetry records outside spawning tributaries, usually between dams. Returns from mainstem fisheries were excluded from fate analyses. The unsuccessful group may have included unreported fisheries harvest, but this, and other misclassification of fates, were likely to obscure differences between fate classes rather than create false differences between fate classes.

Statistical Analysis of Temperature Data

We examined three important aspects of body temperature—patterns in median, minimum, and maximum temperature in each migration environment (tailrace, ladder, reservoir) at each dam. We considered median temperature the best overall index of temperatures experienced. Maximum temperatures are also important because short-term exposure to high temperatures can have negative physiological and fitness consequences (Richter and Kolmes 2005). Minimum temperatures, in concert with thermal maxima, provided information about the variability in encountered temperatures. Additionally, for those fish that encountered water ≥ 20 °C, we estimated the longest consecutive period each fish spent above this threshold.

For most analyses, all fish within each run and year were pooled at each site and as a result sample sizes were largest at downstream dams and were progressively smaller at upstream sites as fish were harvested or entered lower river tributaries. In addition, many fish (especially steelhead) had total migration times > 40 d and therefore exceeded RDST storage capabilities prior to reaching upstream sites. Fish with long passage times tended to be those migrating at the warmest time, while those that moved rapidly through the system tended to be at relatively cooler times. This introduced some unavoidable sample bias at upstream sites and must be considered in all between-site comparisons.

A mixed-model, repeated measures ANOVA was used to test for differences in the average median temperatures of individual fish (=subjects) among tailrace, ladder or reservoir locations (fixed effect), and using compound symmetry as the covariance structure. The analyzed model was: average_fish_temperature=dam + location (dam) + year+ year*dam +year*location (dam) + error. The Kenward-Roger method estimated degrees of freedom, resulting in fractional degrees of freedom. Multiple comparisons of the median temperature for groups of individuals at each tailrace, ladder, or reservoir were performed using a Tukey-type post hoc statistic with Dunn-Sidak correction (Zar 1999).

Because of the potential bias associated with RDST storage capabilities and migration timing differences among stocks within run, we also qualitatively compared median temperatures for individual populations of successful migrants. These analyses were particularly useful for showing how temperature histories varied within season (e.g., spring and summer-run fish encountered progressively warmer temperatures as they progressed upstream) and among stocks.

Unfortunately, the RDSTs required physical recovery to obtain temperature data, potentially creating a bias in the sample if mortality systematically differed with temperature. We examined this possibility by indirectly testing for an association between temperature and fish fate for all RDST adults. Because of the steady increase in temperature during the spring and early summer and steady decline in the fall (Figures 2 and 3), we used tag date as a proxy measure of temperature, presuming that within each run late-run spring and summer Chinook salmon and early-run fall Chinook salmon experienced relatively high temperatures. We then used logistic regression analysis to test whether the probability of unsuccessful migration increased within season for spring-run stock or decreased within season for fall-run stocks. Because steelhead migrations overlapped both warming and cooling phases, analyses were qualitative for this run.

Results

A total of 412 spring and summer Chinook salmon, 116 fall Chinook salmon, and 410 steelhead were tagged with RDSTs in 2000 and 2002 (Table 1). Of those, 261 (63%) spring and summer Chinook, 64 (55%) fall Chinook and 302 (74%) steelhead were recaptured. Most recaptured fish were recovered at Lower Granite Dam adult fish trap (63% spring and summer Chinook, 44% fall Chinook, 61% steelhead; Table 1). The remaining fish were recaptured in tribal and sport fisheries, at hatcheries, on spawning ground surveys, or at weirs. We selected for Snake River fish, but the samples included fish from multiple populations, as indicated by the final recorded locations for the fish used in temperature analyses (Table 2).

Radio-tagging and the runs-at-large

We compared the frequency distributions of RDST adults to fish counts at Bonneville Dam for each year and run to assess how well the radio-tagged population represented the migration timing of the runs-at-large (Figures 6-9). We note, however, that we did not attempt to sample representatively from the entire run, as we selected for Snake River fish and for fish with existing PIT tags to increase the likelihood of RDST recovery. Generally, spring Chinook salmon were overrepresented during the late portion of the run in 2000 and somewhat so in 2002.

Summer Chinook salmon were underrepresented during the late portion of the run in both years. Fall Chinook salmon sample sizes were low in both years and generally followed the trends in counts. Steelhead sampling effort was relatively constant in 2000, resulting in undersampling during the run peak. Steelhead tagging in 2002 more closely followed the run-at-large, though the earliest portion of the run was slightly undersampled. The comparisons suggest that summer Chinook salmon and steelhead runs-at-large may have experienced warmer temperatures more frequently than reported here, while spring Chinook salmon may have experienced higher temperatures less frequently than reported.

Table 1. Number of fish tagged and recaptured with RDSTs in 2000 and 2002.

	Spring Chinook	Summer Chinook	Fall Chinook	Steelhead
2000				
Tagged	126	102	80	181
Recaptured	94	39	40	125
Recapture location				
Lower Granite	57	12	14	54
Fishery	13	8	20	60
Hatchery		9	1	2
Weir/spawning ground/found tag	3	10	5	9
2002				
Tagged	116	68	36	229
Recaptured	93	35	24	177
Recapture location				
Lower Granite	69	25	14	130
Fishery	16	7	8	39
Hatchery	2	0	1	1
Weir/spawning ground/found tag	6	3	1	7

Table 2. Final locations for RDST-tagged Chinook salmon and steelhead used in temperature analyses, 2000 and 2002. Most fish recaptured at Lower Granite Dam were retagged with non-RDST transmitters and released to determine upstream distributions.

Final	Spring Chinook		Summer Chinook		Fall Chinook		Steelhead	
Location	2000	2002	2000	2002	2000	2002	2000	2002
Lower Columbia								
Bonneville pool harvest	4	13		1	2	1	25	16
The Dalles pool harvest	1				3	1	4	6
John Day pool harvest		3			7	3	7	5
McNary pool harvest							4	
Little White Salmon					1		4	
White Salmon							2	
Hood River		1					2	
Klickitat	2				4		4	4
Deschutes	14	2			1		2	
John Day							1	
Umatilla					1			
Walla Walla							1	
Other				1	1	2	5	3
Mid-Upper Columbia								
Rocky Reach pool harvest			3					
Wells pool harvest			2	5				1
Yakima					1			
Hanford/Ringold					2	1	2	
Wanapum pool							1	
Wenatchee	3		1				1	
Entiat	2							
Methow			1					
Wells Dam/Hatchery	1		7					1
Okanogan			4	1				
Other			2					
Snake								
Lower Snake pools					5		4	1
Lower Snake harvest	1						1	1
Lyons Ferry hatchery					2			
Tucannon	1							
Lower Granite trap				9	1	1	3	60
Snake above L. Granite					3	3	9	17
Clearwater	23	17	3		3	9	18	18
Grande Ronde	1	9	2	6				5
Imnaha	4	2	1	1				2
Salmon	29	36	13	8			15	29
Oxbow Hatchery	3							
Total	**89**	**91**	**39**	**32**	**37**	**22**	**115**	**169**

We also compared the distributions of tagged fish passing Ice Harbor Dam with the distributions of fish counted there. At Ice Harbor Dam, sample sizes were smaller but more closely followed the distributions of the runs-at-large, as might be expected given our selection for Snake River fish. Two exceptions were that spring Chinook salmon were overrepresented during the late portion of the run in 2000, and summer Chinook salmon were underrepresented during the late portion of the run in both years. The early portion of the steelhead run was slightly undersampled in both years. In all cases, the sampled fish likely did not capture the full range of temperatures encountered by the runs at large but did represent general patterns at each site.

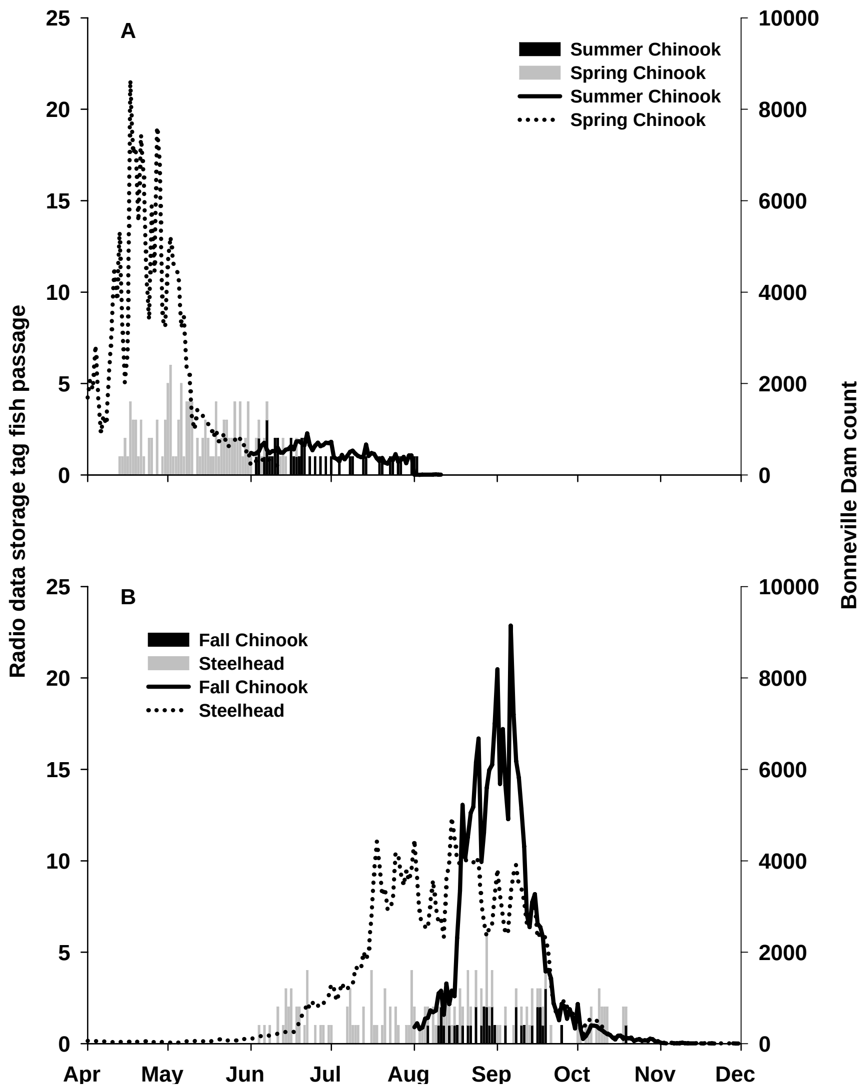


Figure 6. Number of radio tagged fish passing Bonneville Dam in 2000 versus the dam count. A) Spring and summer Chinook salmon. B) Fall Chinook salmon and steelhead.

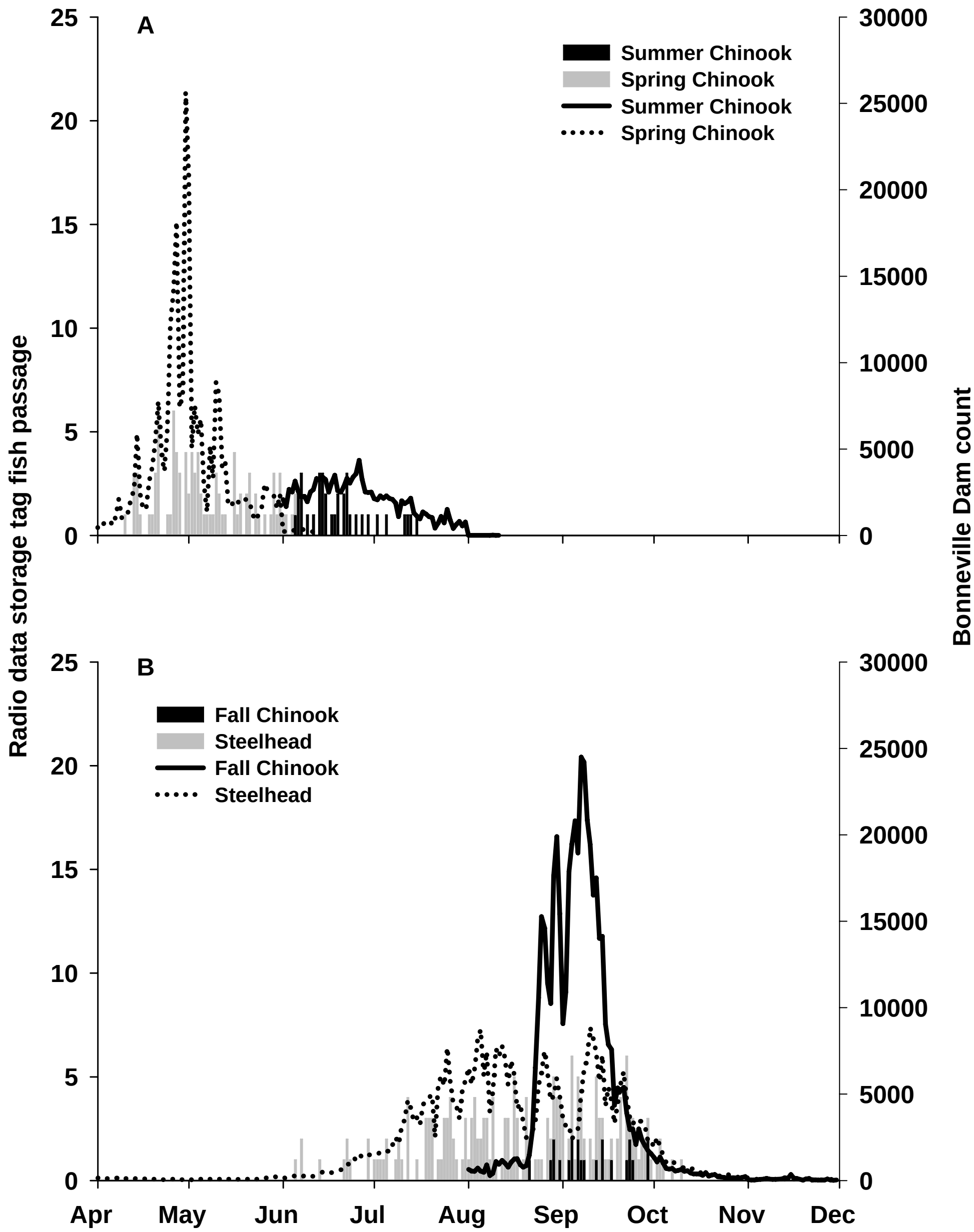


Figure 7. Number of radio tagged fish passing Bonneville Dam in 2002 versus the number counted at the dam. A) Spring and summer Chinook salmon. B) Fall Chinook salmon and steelhead.

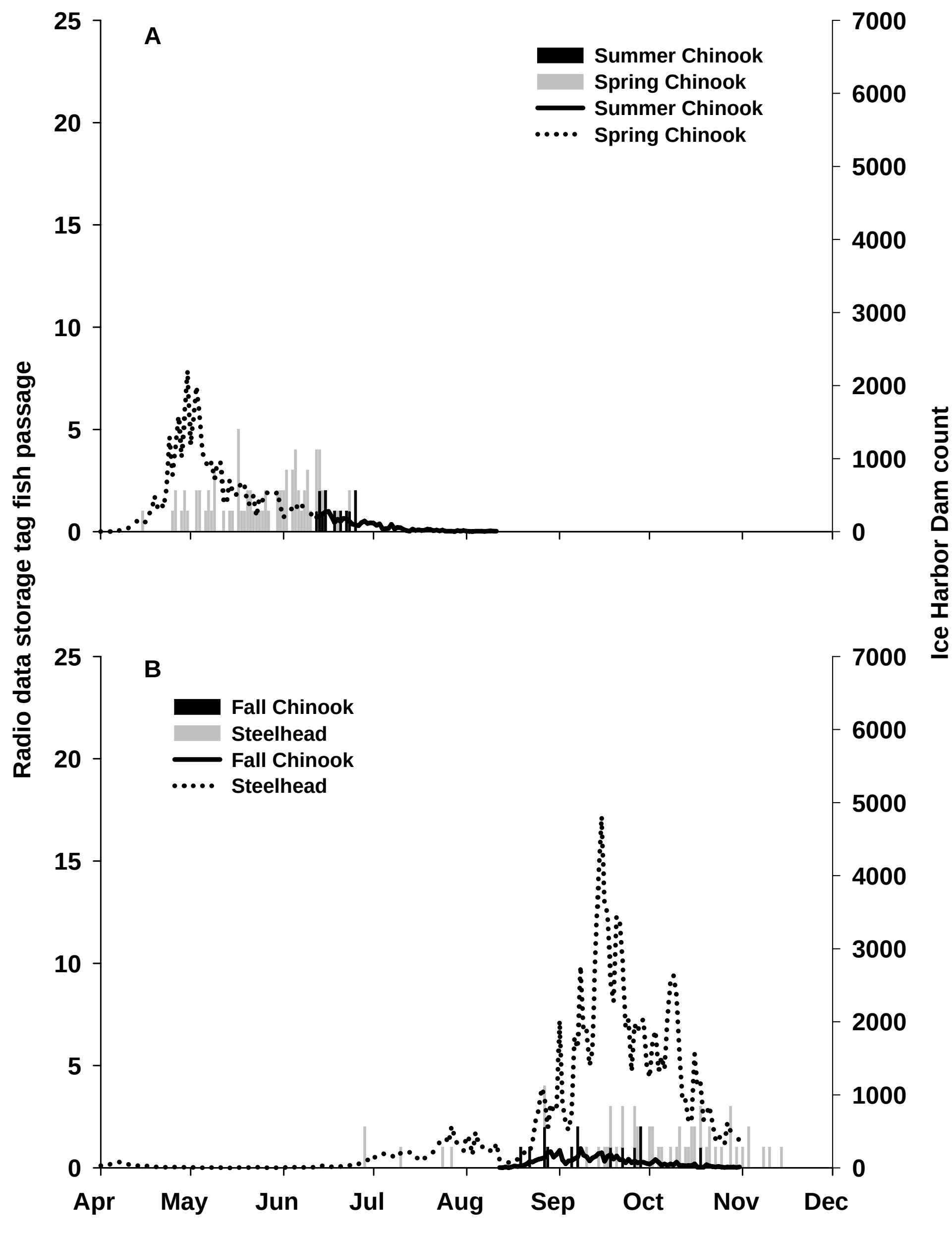


Figure 8. Number of radio tagged fish passing Ice Harbor Dam in 2000 versus the number counted at the dam. A) Spring and summer Chinook salmon. B) Fall Chinook salmon and steelhead.

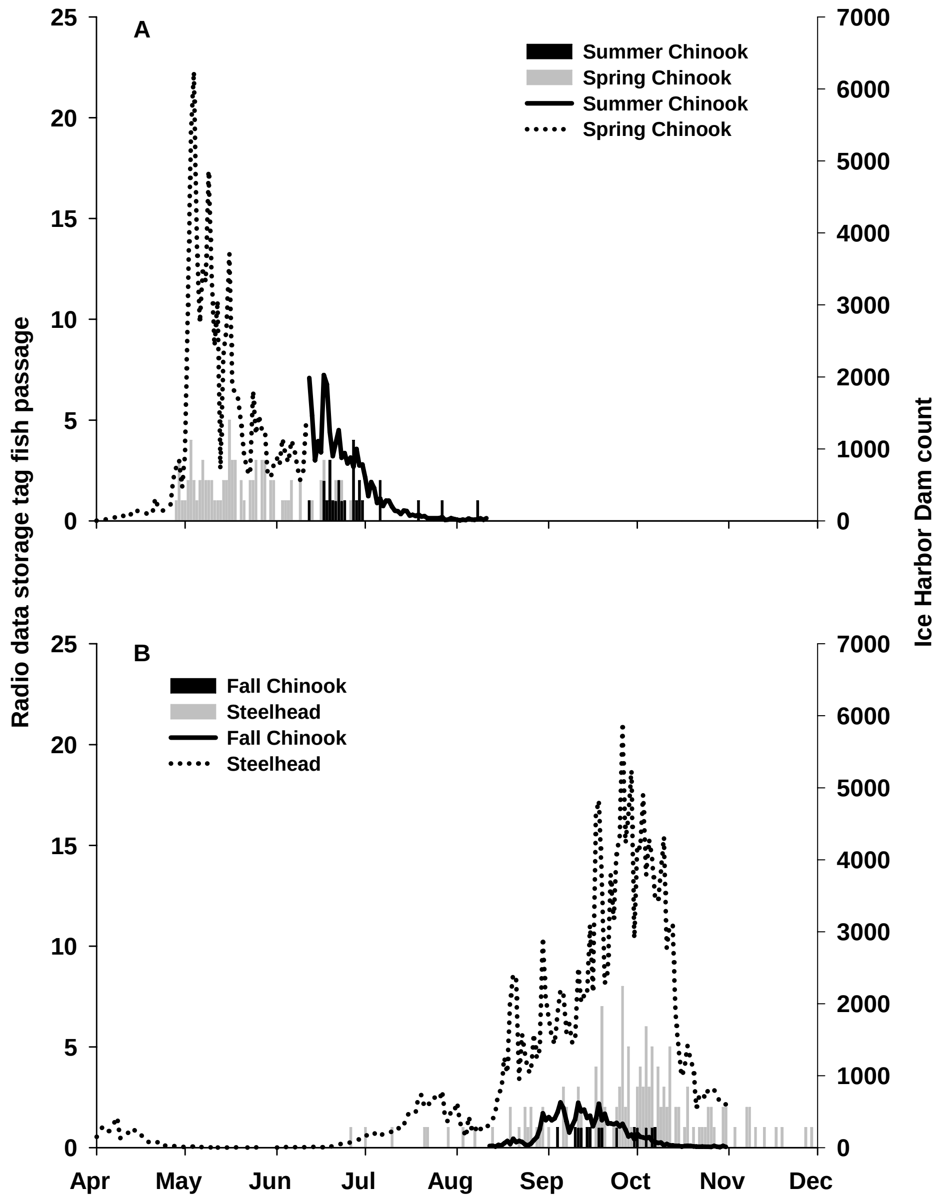


Figure 9. Number of radio tagged fish passing Ice Harbor Dam in 2002 versus the number counted at the dam. A) Spring and summer Chinook salmon. B) Fall Chinook salmon and steelhead.

Passage time

Median Chinook salmon passage times through the tailraces, ladders, and reservoirs differed among sites but were generally similar among spring-, summer-, and fall-run salmon for fish with recovered RDSTs (Tables 3-4). On median, it took all Chinook salmon 0.2 and 0.1 d in tailraces, 2.2 and 2.2 h in ladders, and 1.0 and 0.9 d in reservoirs of the Columbia and Snake river dams during 2000 and 2002, respectively. Steelhead had passage times similar to Chinook salmon except for slightly longer passage times in the reservoirs, with overall medians of 0.2 and 0.1 d in tailraces, 2.3 and 2.1 h in ladders, and 2.2 and 2.0 d in reservoirs (excluding time spent in tributaries) of the Columbia and Snake river dams, respectively (Tables 3-4). These values were broadly similar to those reported for larger radio-tagged samples (see Keefer et al. 2004, 2007, 2008 and *in review* for more complete passage time analyses).

Patterns in adult salmonid body temperature during migration

In general, we found larger differences in body temperature patterns among species/runs than among locations within species/runs. Observed differences in experienced temperature were associated primarily with run timing (Figure 10). Many adult salmon and steelhead experienced temperatures ≥ 20 °C in the mainstem Hydrosystem, including 2% of spring Chinook salmon, 13% of summer Chinook salmon, 81% of fall Chinook salmon, and 75% of steelhead (both years combined). Without adjusting for recapture location, fall Chinook salmon experienced the highest average percent of time (release to recapture) spent at temperatures ≥ 20 ºC (45%), followed by steelhead at 22%, and summer Chinook at 20%. Of those fish that encountered water temperatures ≥ 20 ºC, steelhead had the longest consecutive periods above this threshold (mean of longest consecutive period = 12.1 h; range 9.6-17.7 h). Average consecutive hours above 20 ºC were 10.5 (range 9.6-19.1 h) for summer Chinook salmon and 9.6 (range 7.9-13.3 h) for fall Chinook salmon.

Spring Chinook salmon body temperatures were typically warmer in the Snake River than in the Columbia River, which was consistent with earlier warming in the Snake River and increasing river temperatures during a migration coincident with spring warming. Body temperatures in other runs — especially summer Chinook salmon — showed an opposite pattern, though this was primarily related to differences in migration timing among stocks (e.g., Snake River summer Chinook salmon migrated much earlier than summer-run Chinook from other sites, Figure 10). Summer-fall Chinook salmon and steelhead may have experienced cooler temperatures in the Snake due to stock differences, migration delaying behaviors (many steelhead used lower Columbia thermal refugia until fall cooling), seasonal cooling, and possibly cold-water releases from Dworshak Reservoir (e.g., Clabough et al. 2006; Cook et al. 2006).

Table 3. The 25th percentile, 75th percentile, and median travel time through the tailrace, ladder and reservoir at each dam in 2000.

		Tailrace				Ladder				Reservoir			
Species	Dam	N	25th days	75th days	Median days	N	25th hours	75th hours	Median hours	N	25th days	75th days	Median days
Spring Chinook	BO	83	0.10	1.51	0.50	72	1.68	4.10	2.13	89	1.13	2.40	1.60
	TD	82	0.22	1.36	0.63	82	1.52	2.20	1.77	85	0.62	1.96	0.84
	JD	70	0.10	1.13	0.24	63	2.33	3.09	2.55	68	1.53	1.94	1.74
	MN	55	0.06	0.51	0.08	64	1.75	2.95	2.12	60	0.90	1.12	0.99
	IH	60	0.05	0.69	0.08	55	1.82	2.33	2.03	60	0.67	0.97	0.78
	LM	55	0.06	0.18	0.11	52	2.06	3.24	2.58	59	0.62	0.75	0.68
	GO	51	0.02	0.27	0.08	58	1.55	2.33	1.77	58	0.73	0.88	0.79
	GR	54	0.03	0.10	0.04								
Summer Chinook	BO	36	0.09	0.57	0.37	36	1.85	3.73	2.46	38	0.90	1.34	1.01
	TD	30	0.08	0.42	0.19	34	1.43	3.18	1.88	35	0.56	0.92	0.66
	JD	29	0.06	1.05	0.33	32	2.63	3.76	2.93	33	1.45	1.80	1.62
	MN	18	0.05	0.07	0.06	35	1.87	3.17	2.37	13	0.89	1.01	0.96
	IH	12	0.05	0.80	0.08	12	1.44	1.95	1.59	13	0.65	1.16	0.76
	LM	9	0.05	0.21	0.12	10	2.02	2.37	2.27	13	0.56	0.72	0.65
	GO	7	0.02	0.06	0.04	11	1.41	1.60	1.48	11	0.66	0.98	0.81
	GR	7	0.03	0.14	0.08								
Fall Chinook	BO	33	0.34	1.57	0.59	31	1.95	3.34	2.45	36	1.11	2.92	1.65
	TD	27	0.05	0.46	0.12	26	1.80	2.42	2.01	22	0.63	2.76	0.79
	JD	17	0.07	0.76	0.16	17	2.58	3.33	2.97	13	1.61	2.92	1.99
	MN	7	0.05	3.87	0.09	16	1.99	3.10	2.39	11	1.00	1.91	1.24
	IH	9	0.04	0.81	0.06	12	1.93	3.03	2.36	11	0.70	1.00	0.75
	LM	7	0.13	0.98	0.29	12	2.10	4.86	2.65	11	0.75	1.11	0.95
	GO	10	0.02	0.26	0.04	8	1.50	2.25	1.85	11	0.75	1.12	1.02
	GR	6	0.14	0.90	0.61								
Steelhead	BO	107	0.08	0.63	0.18	105	2.05	7.40	2.98	112	1.85	22.51	4.25
	TD	64	0.17	0.58	0.27	46	1.32	1.93	1.64	63	0.84	3.77	1.23
	JD	45	0.06	0.37	0.14	42	2.18	3.58	2.56	41	2.24	3.76	2.81
	MN	23	0.06	0.32	0.09	43	1.59	2.83	1.88	30	1.83	4.65	2.52
	IH	23	0.05	0.24	0.06	26	1.65	2.83	2.10	26	1.36	1.92	1.80
	LM	14	0.07	0.17	0.10	18	2.30	6.13	2.73	26	1.28	2.95	1.69
	GO	9	0.07	0.47	0.13	22	1.77	2.77	2.14	24	1.30	2.94	1.98
	GR	13	0.07	0.58	0.20								

Table 4. The 25th percentile, 75th percentile, and median travel time through the tailrace, ladder and reservoir at each dam in 2002.

		Tailrace				Ladder				Reservoir			
Species	Dam	N	25th days	75th days	Median days	N	25th hours	75th hours	Median hours	N	25th days	75th days	Median days
Spring Chinook	BO	77	0.31	2.30	0.75	83	2.08	4.99	2.88	90	1.03	1.83	1.35
	TD	52	0.10	0.61	0.19	69	1.53	2.12	1.82	78	0.55	0.93	0.69
	JD	65	0.05	0.43	0.13	69	2.25	3.14	2.67	74	1.52	1.82	1.67
	MN	51	0.05	0.19	0.09	63	2.09	2.80	2.40	71	0.87	1.08	0.93
	IH	67	0.03	0.11	0.05	66	1.68	2.33	1.98	70	0.66	0.92	0.77
	LM	70	0.05	0.11	0.06	51	2.06	2.66	2.48	70	0.61	0.82	0.71
	GO	54	0.06	0.38	0.13	64	1.58	1.94	1.75	69	0.76	0.95	0.83
	GR	46	0.03	0.20	0.10								
Summer Chinook	BO	31	0.08	0.50	0.32	29	1.76	3.25	2.28	32	0.88	1.15	1.01
	TD	21	0.10	0.21	0.12	28	1.43	2.61	1.95	31	0.46	0.74	0.65
	JD	26	0.06	0.45	0.18	29	2.04	3.39	2.78	29	1.43	1.79	1.63
	MN	16	0.05	0.18	0.08	26	2.10	2.95	2.48	29	0.84	1.04	0.90
	IH	23	0.03	0.14	0.04	23	1.48	2.11	1.72	23	0.55	0.72	0.67
	LM	22	0.04	0.07	0.04	18	1.93	2.98	2.16	23	0.53	0.72	0.63
	GO	16	0.03	0.57	0.17	18	1.33	2.10	1.73	22	0.63	0.79	0.70
	GR	20	0.03	0.12	0.07								
Fall Chinook	BO	18	0.05	0.83	0.37	15	2.37	3.76	3.18	20	0.97	1.23	1.03
	TD	6	0.13	0.54	0.39	15	1.69	1.95	1.82	17	0.54	0.87	0.73
	JD	13	0.06	0.24	0.10	13	2.66	3.31	3.13	14	1.39	1.85	1.76
	MN	5	0.07	0.50	0.09	13	2.34	2.62	2.50	14	0.82	1.31	0.93
	IH	9	0.02	0.15	0.04	13	1.68	2.20	1.92	13	0.65	0.89	0.75
	LM	10	0.05	0.32	0.12	5	2.33	3.78	3.17	13	0.61	1.00	0.74
	GO	8	0.03	0.31	0.14	7	1.63	2.32	1.92	13	0.79	1.08	0.87
	GR	4	0.07	1.31	0.15								
Steelhead	BO	147	0.08	1.75	0.48	136	2.04	5.61	2.72	167	1.86	26.66	6.25
	TD	71	0.11	0.28	0.17	99	1.43	2.06	1.72	118	1.01	7.61	1.87
	JD	81	0.05	0.47	0.16	74	2.13	3.10	2.41	89	2.01	2.92	2.46
	MN	37	0.07	0.41	0.09	69	1.78	3.07	2.12	75	1.53	2.89	1.98
	IH	60	0.03	0.10	0.05	60	1.59	2.41	1.85	62	1.03	2.02	1.37
	LM	47	0.05	0.14	0.07	38	2.07	3.52	2.55	59	0.95	1.57	1.10
	GO	30	0.04	0.24	0.11	41	1.55	1.94	1.70	54	1.25	2.21	1.61
	GR	27	0.10	0.68	0.37								

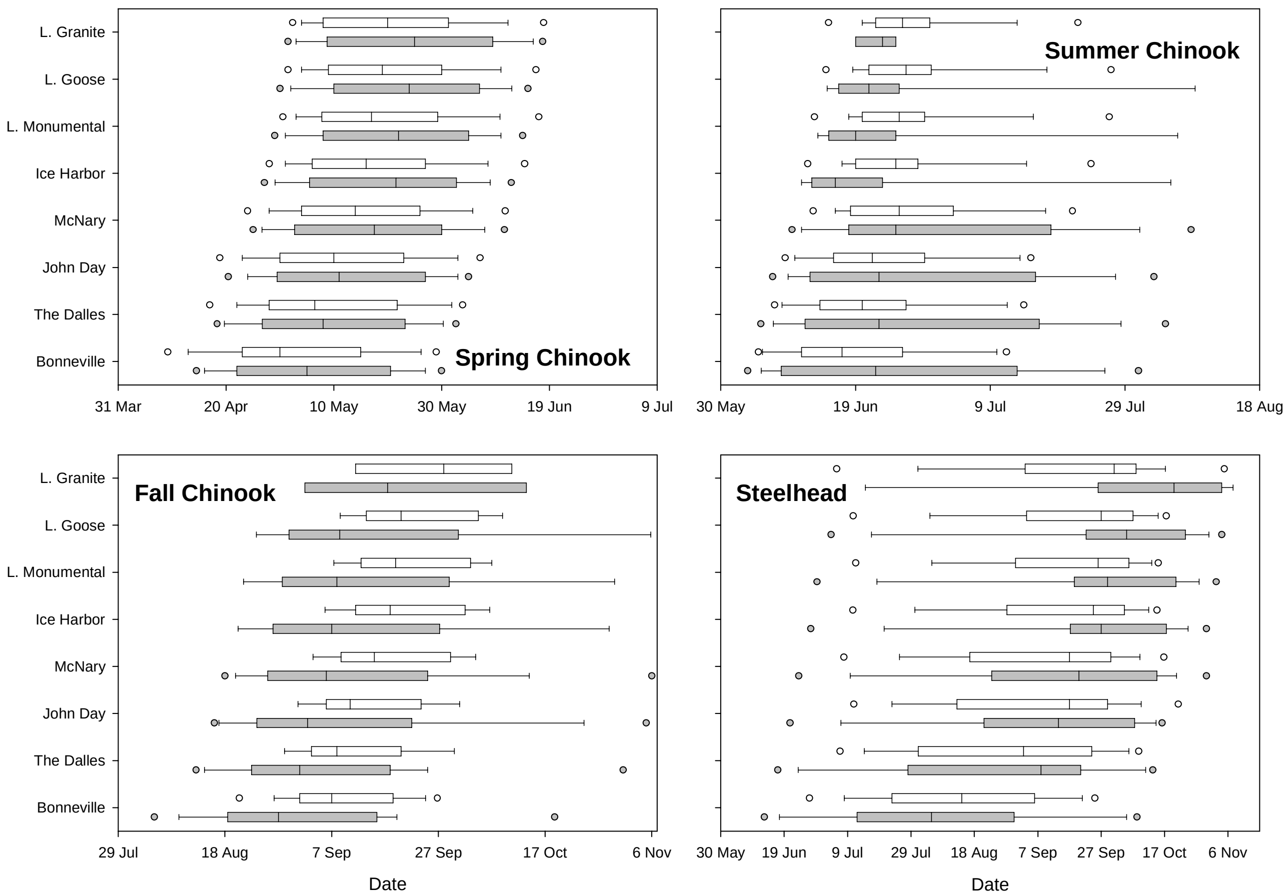


Figure 10. Migration timing distributions at study dams, for the RDST-tagged Chinook salmon and steelhead used in temperature analyses in 2000 (gray bars) and 2002 (white bars). Distributions at upstream dams do not include fish that passed after their RDST data storage capacity was exhausted (most common for steelhead). Note different x-axis scales.

Within each run, we found significant ($P<0.0001$) differences in average median temperatures fish encountered among dams (Tables 5,7,9,11), though this at least partly reflected migration timing and stock composition differences among sites (Figure 10). We also found significant differences ($P<0.05$) among locations (tailraces, ladders, and reservoirs) at individual projects. Among-location comparisons at individual projects generally indicated that temperatures adults encountered were higher in ladders than in either tailrace or reservoir environments, though differences were generally < 1 ºC (Tables 6,8,10,12). There are several caveats to these comparisons: first, adults were more likely to pass through ladders during daylight, when temperatures are typically higher; second, sample sizes differed among environments for some comparisons, reflecting differences in monitoring efficiencies (lower at tailrace sites); and third, relatively lower temperatures in the Bonneville and The Dalles reservoirs almost certainly reflected the influence of fish using cool discharge from tributary sites. Although we excluded in-tributary temperature data when telemetry information clearly indicated fish were inside tributaries, some fish used tributary plumes downstream from telemetry sites and use of these areas lowered fish body temperatures in reservoir segments.

In the ANOVA models, year was significantly associated with temperature for spring Chinook salmon only, with cooler temperatures in 2002 (Table 5). Temperatures were cooler, but not significantly so, for summer Chinook salmon in 2002. The dam×year term was significant for both spring and summer Chinook salmon (Tables 5 and 7), while the location×year term was significant for fall Chinook salmon (Table 9). Interaction terms, where significant, indicated that the observed temperature differences were not consistent in magnitude among locations between the two study years. Below we present patterns in body temperature within tailraces, in ladders, and through reservoirs for each species in detail. Among-dam comparisons from the ANOVA models are provided in Appendix B Tables 3-10, 13-20, and 24-30.

Table 5. Proc mixed repeated measures ANOVA for spring Chinook salmon in 2000 and 2002.

Effect	Numerator df	Denominator df	*F*	*P*
Dam	7	937	58.67	<0.0001
Loc(Dam)	14	1745	13.28	<0.0001
Year	1	178	60.16	<0.0001
Dam*Year	7	937	13.37	<0.0001
Loc*Year(Dam)	14	1745	0.72	0.7515

Table 6. Means of median temperatures (ºC) recorded for spring Chinook salmon in tailrace, ladder and reservoirs at lower Columbia and Snake River dams, 2000-2002. Temperatures with the same letter within year and at the same dam/reservoir differed significantly ($P < 0.05$) in pairwise tests.

	Mean of median temperatures (*n*)					
	2000			2002		
Dam	Tailrace	Ladder	Reservoir	Tailrace	Ladder	Reservoir
BO	12.53 (83)	12.82 (72)	12.74 (89)	11.21 (77)	11.36 (83)	11.35 (90)
TD	12.81 (82)	13.10 (82)	13.02 (85)	11.80 (52)	11.69 (69)	11.58 (78)
JD	12.90 (70)	13.53 (63)	13.23 (68)	11.54 (65)	12.10 (69)	11.56 (74)
MN	[ac]12.95 (55)	[a]13.39 (64)	[c]13.61 (60)	11.52 (51)	11.91 (63)	11.91 (71)
IH	13.76 (60)	13.92 (55)	13.72 (60)	11.96 (67)	[b]12.32 (66)	[b]11.87 (70)
LM	13.54 (53)	13.81 (52)	13.70 (59)	11.66 (70)	11.75 (51)	11.69 (70)
GO	13.76 (51)	14.14 (58)	13.69 (58)	[a]11.53 (54)	[ab]12.12 (64)	[b]11.66 (69)
GR	13.48 (58)	--	--		--	--

Table 7. Proc mixed repeated measures ANOVA for summer Chinook salmon in 2000 and 2002.

Effect	Numerator df	Denominator df	*F*	*P*
Dam	7	318	23.10	<0.0001
Loc(Dam)	14	569	8.42	<0.0001
Year	1	68	19.98	0.1612
Dam*Year	7	318	3.13	0.0033
Loc*Year(Dam)	14	569	1.06	0.3927

Table 8. Means of median temperatures (ºC) recorded for summer Chinook salmon in tailrace, ladder and reservoirs at lower Columbia and Snake River dams, 2000-2002. Temperatures with the same letter within year and at the same dam/reservoir differed significantly ($P < 0.05$) in pairwise tests.

	Mean of median temperatures (*n*)					
	2000			2002		
Dam	Tailrace	Ladder	Reservoir	Tailrace	Ladder	Reservoir
BO	17.89 (36)	17.96 (36)	17.72 (38)	16.10 (31)	16.26 (29)	16.19 (32)
TD	17.83 (30)	18.13 (34)	17.90 (35)	16.05 (21)	16.31 (28)	16.25 (31)
JD	18.06 (29)	18.64 (32)	18.33 (33)	[a]16.22 (26)	[a]17.11 (29)	16.70 (29)
MN	17.37 (18)	[b]18.44 (35)	[b]16.43 (13)	16.32 (16)	16.94 (26)	15.51 (29)
IH	16.18 (12)	17.05 (12)	16.92 (13)	16.07 (23)	16.34 (23)	16.20 (23)
LM	16.95 (9)	17.19 (10)	16.83 (13)	16.09 (22)	16.42 (18)	16.37 923)
GO	16.35 (7)	17.50 (11)	16.62 (11)	16.48 (16)	17.11 (18)	16.13 (22)
GR	17.29 (7)	--	--	15.74 (20)	--	--

Table 9. Proc mixed repeated measures ANOVA for fall Chinook salmon in 2000 and 2002.

Effect	Numerator df	Denominator df	*F*	*P*
Dam	7	196	67.95	<0.0001
Loc(Dam)	14	317	5.19	<0.0001
Year	1	57	2.01	0.1612
Dam*Year	7	196	1.14	0.3398
Loc*Year(Dam)	14	317	2.23	0.0069

Table 10. Means of median temperatures (ºC) recorded for fall Chinook salmon in tailrace, ladder and reservoirs at lower Columbia and Snake River dams, 2000-2002. Temperatures with the same letter within year and at the same dam/reservoir differed significantly ($P < 0.05$) in pairwise tests.

	Mean of median temperatures (*n*)					
	2000			2002		
Dam	Tailrace	Ladder	Reservoir	Tailrace	Ladder	Reservoir
BO	[c]19.89 (33)	[b]19.83 (31)	[bc]18.77 (36)	20.09 (18)	20.05 (15)	20.09 (20)
TD	19.53 (27)	20.11 (26)	19.10 (22)	20.18 (6)	20.41 (15)	19.80 (17)
JD	19.28 (17)	20.07 (17)	18.71 (13)	19.82 (15)	20.51 (13)	19.81 (14)
MN	17.78 (7)	19.01 (16)	18.21 (11)	18.72 (5)	19.39 (13)	18.96 (14)
IH	18.25 (9)	19.54 (12)	18.23 (11)	18.56 (9)	19.01 (13)	18.53 (13)
LM	18.67 (7)	18.80 (12)	16.95 (11)	18.09 (11)	18.14 (5)	18.12 (13)
GO	17.37 (10)	17.22 (8)	17.15 (11)	18.00 (8)	18.35 (7)	17.91 (13)
GR	16.40 96)	--	--	17.13 (4)	--	--

Table 11. Proc mixed repeated measures ANOVA for steelhead in 2000 and 2002.

Effect	Numerator df	Denominator df	*F*	*P*
Dam	7	747	36.18	<0.0001
Loc(Dam)	14	1490	75.17	<0.0001
Year	1	282	3.24	0.0730
Dam*Year	7	747	1.21	0.2970
Loc*Year(Dam)	14	1490	1.27	0.2195

Table 12. Means of median temperatures (ºC) recorded for steelhead in tailrace, ladder and reservoirs at lower Columbia and Snake River dams, 2000-2002. Temperatures with the same letter within year and at the same dam/reservoir differed significantly ($P < 0.05$) in pairwise tests.

	Mean of median temperatures (*n*)					
	2000			2002		
Dam	Tailrace	Ladder	Reservoir	Tailrace	Ladder	Reservoir
BO	[c]19.04 (107)	[b]19.27 (105)	[bc]16.12 (112)	[ac]19.47 (147)	[ab]19.88 (136)	[bc]16.00 (167)
TD	[a]18.49 (64)	[ab]19.84 (46)	[b]18.13 (63)	[ac]19.35 (71)	[ab]19.91 (99)	[bc]18.23 (118)
JD	18.82 (45)	18.81 (42)	18.20 (41)	19.39 (81)	[b]19.75 (74)	[b]18.88 (89)
MN	17.75 (23)	18.28 (43)	17.76 (30)	18.56 (37)	18.84 (69)	75 (18.24)
IH	17.82 (23)	17.94 (26)	17.48 (26)	18.36 (60)	18.72 (60)	18.15 (62)
LM	17.71 (14)	17.51 (18)	16.43 (26)	17.88 (47)	18.01 (38)	17.59 (59)
GO	15.98 (9)	17.24 (22)	16.13 (24)	17.35 (30)	17.76 (41)	17.45 (54)
GR	14.93 (13)	--	--	16.85 (27)	--	--

Tailraces

Spring Chinook salmon

Spring Chinook salmon rarely experienced temperatures ≥ 18 °C at any location. With both years combined, the average median fish temperature for spring Chinook salmon was 12.1 ºC (*range* 7.8-17.8 ºC) for fish migrating through lower Columbia River dam tailraces and was 12.6 ºC (*range* 9.5-20.3 ºC) in the lower Snake River dam tailraces (Appendix B Tables 1-2). Only one fish of 51 (2%) encountered tailrace water temperatures ≥ 20 ºC in 2000 (Figure 11; Table 13). We found significant (P<0.0001) differences in fish temperatures in tailraces among dams in both 2000 and 2002, reflecting seasonal differences as fish progressed upstream (Appendix B Tables 3-4).

Summer Chinook salmon

The average median summer Chinook salmon temperatures in 2000 and 2002 were 17.0 ºC (range 13.0-22.5 ºC) in lower Columbia River tailraces and 16.4 ºC (range 13.4-21.6 ºC) in lower Snake River dam tailraces (Appendix B Tables 1-2). In 2000, 17-30% of summer Chinook salmon encountered temperatures ≥ 20 ºC in the four lower Columbia River dam tailraces and these fish spent the majority of their time in the tailrace above this threshold; no fish encountered 20 ºC water in the lower Snake River tailraces (Figure 13; Table 13; Appendix B Table 5). In the cooler 2002, 1-2 (4-9%) summer Chinook salmon encountered 20 ºC water in all tailraces except Bonneville and The Dalles (Figure 14; Appendix B Table 6). In both years, fish exposed to the 20 ºC threshold spent < 1 d at these temperatures on average at each dam (Tables 13-14).

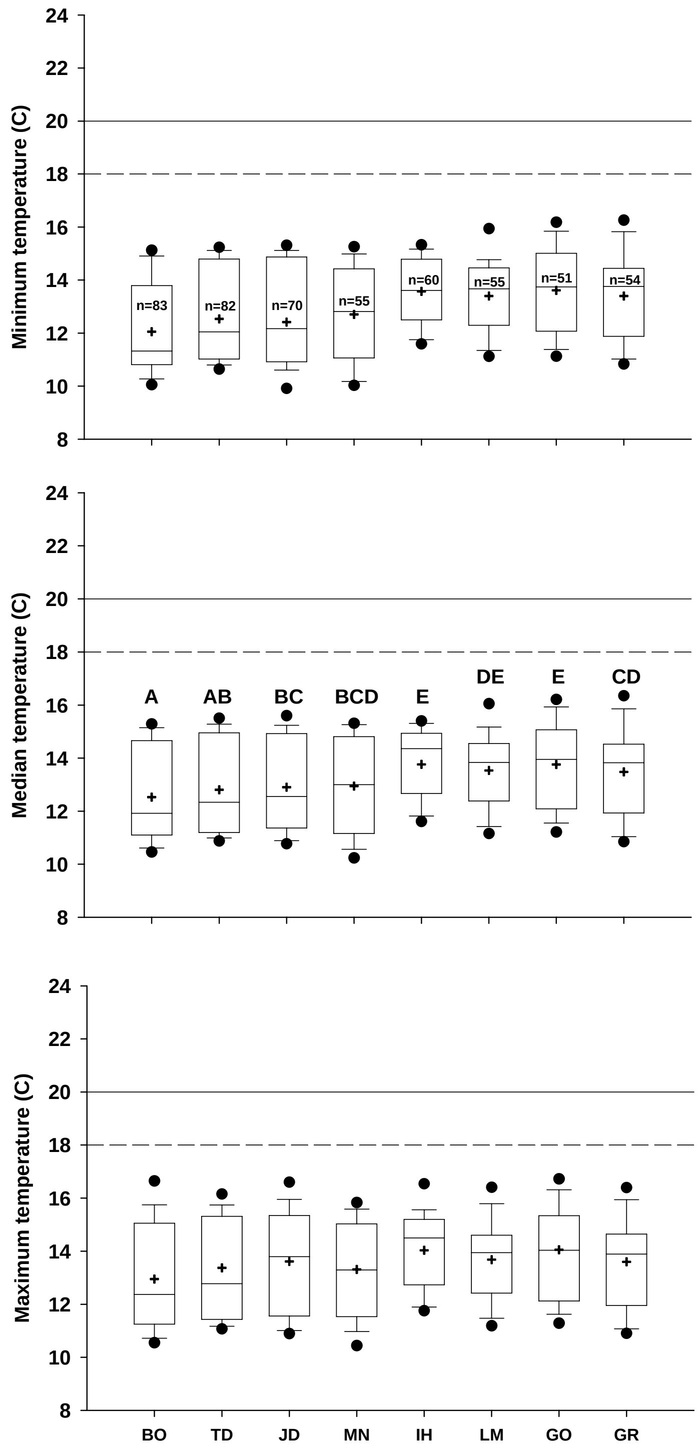


Figure 11. Spring Chinook salmon body temperature in tailraces, 2000. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and four lower Snake River tailraces in 2000. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; *P*=0.0004).

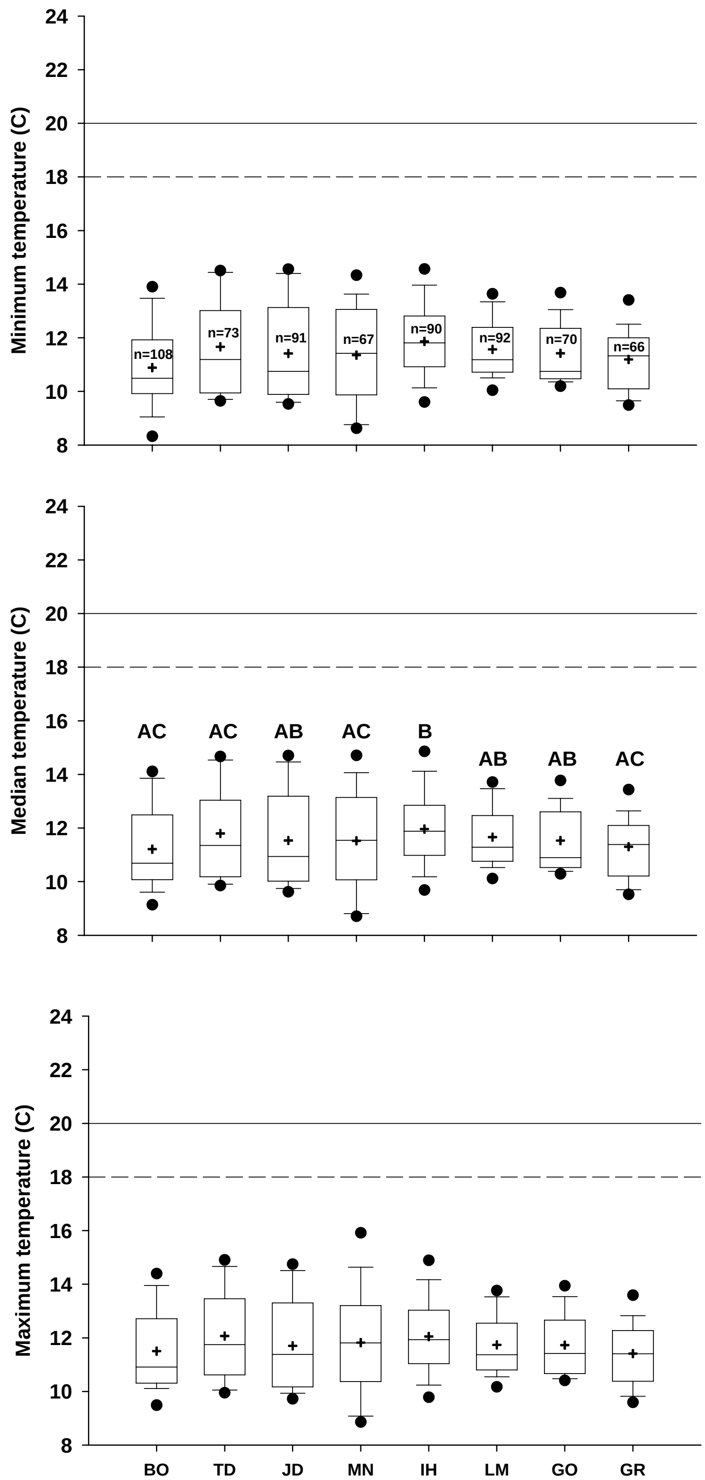


Figure 12. Spring Chinook salmon body temperature in tailraces, 2002. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and four lower Snake River tailraces in 2002. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; P=0.0004).

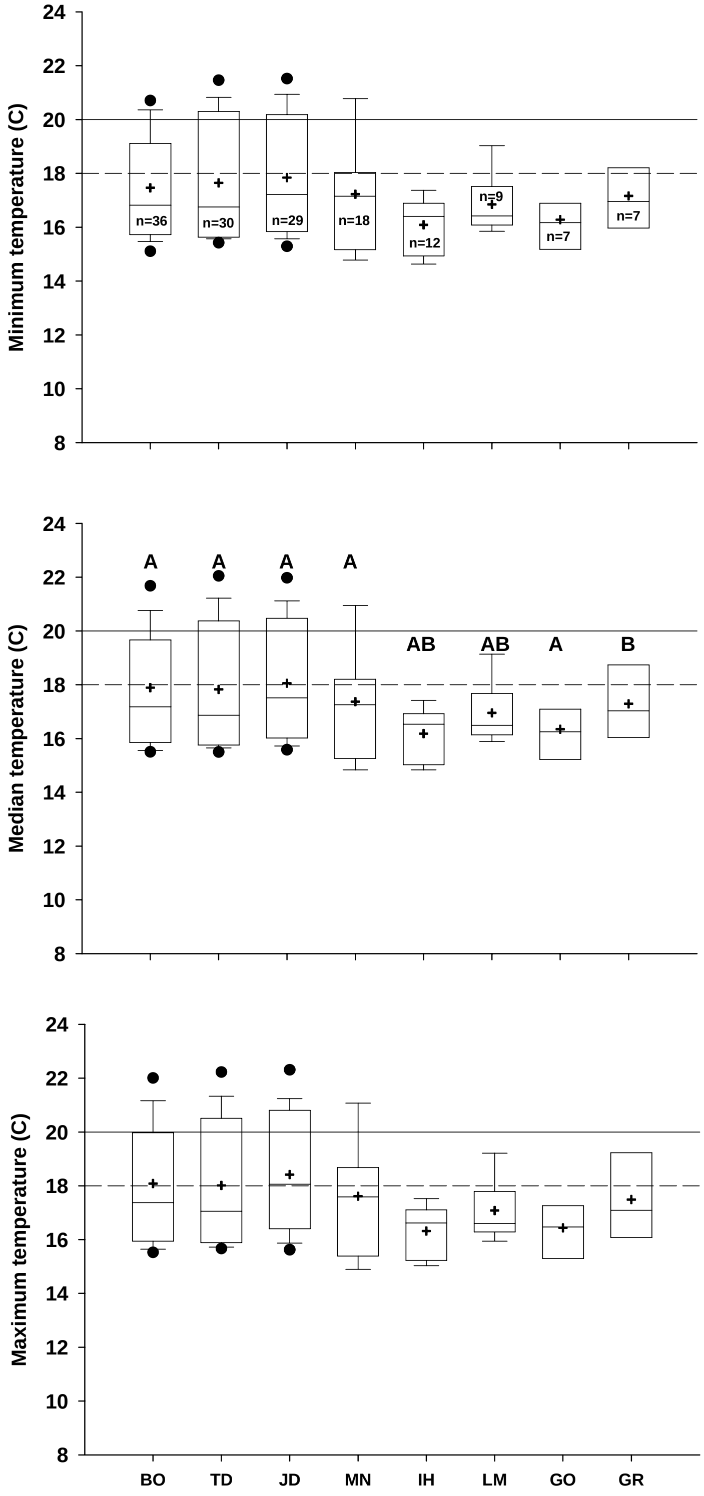


Figure 13. Summer Chinook salmon body temperature in tailraces, 2000. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and four lower Snake River tailraces in 2000. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; *P*=0.0004).

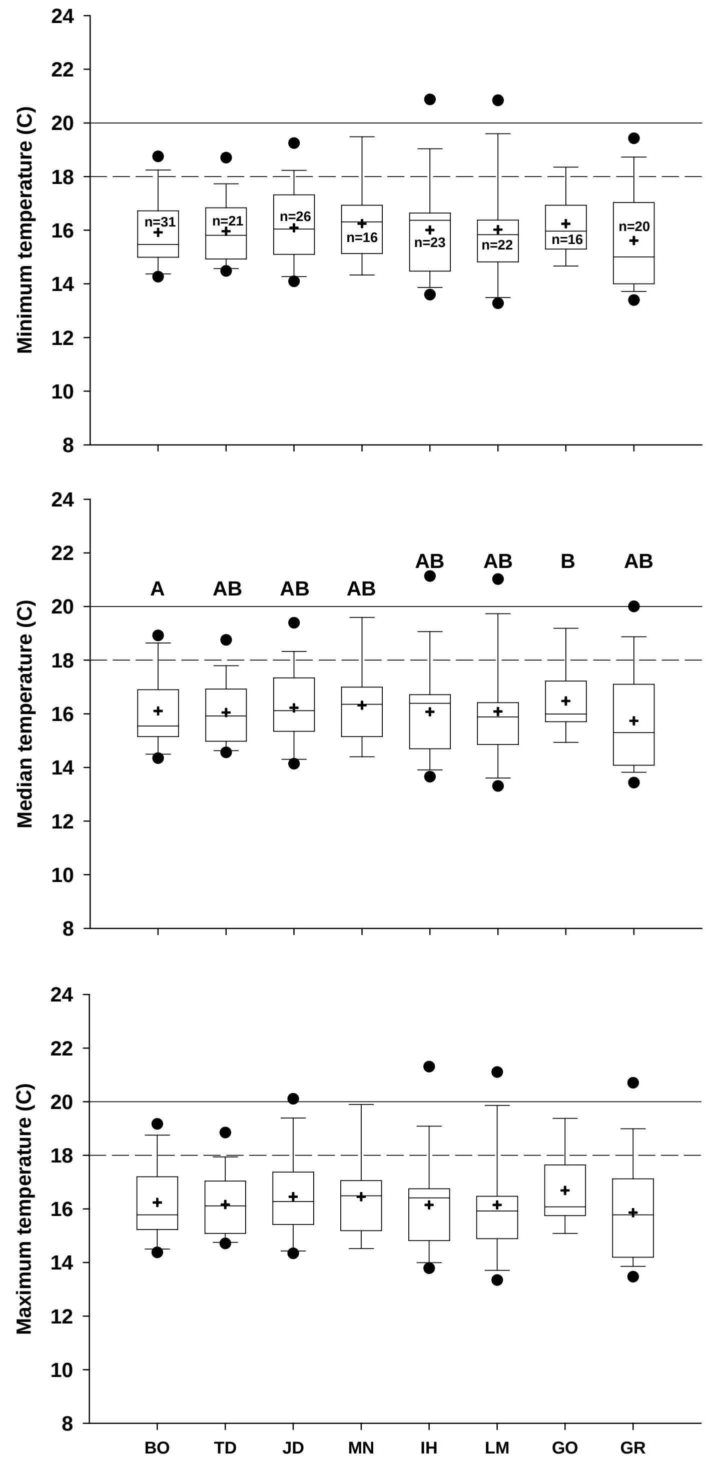


Figure 14. Summer Chinook salmon body temperature in tailraces, 2002. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and four lower Snake River tailraces in 2002. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; *P*=0.0004).

Table 13. Number and percent of fish with temperatures ≥ 20 ºC, mean and average percent of total time spent at temperatures ≥ 20 ºC and the mean consecutive time spent at temperatures ≥ 20 ºC in the tailraces of dams in 2000.

			# of Fish recorded ≥ 20 ºC		Total time ≥ 20 ºC		Consecutive time ≥ 20 ºC
Species	Tailrace	N	N	%	Mean days	Mean %	Mean days
Spring	BO	83	0	0	0	0	0
Chinook	TD	82	0	0	0	0	0
	JD	70	0	0	0	0	0
	MN	55	0	0	0	0	0
	IH	60	0	0	0	0	0
	LM	55	0	0	0	0	0
	GO	51	1	2.0	0.1	3.4	0.1
	GR	54	0	0	0	0	0
					3.3		0.4
Summer	BO	36	9	25.0		74.2	
Chinook	TD	30	9	30.0	0.3	90.6	0.3
	JD	29	8	27.6	0.9	100.0	0.9
	MN	18	3	16.6	0.1	100.0	0.1
	IH	12	0	0	0	0	0
	LM	9	0	0	0	0	0
	GO	7	0	0	0	0	0
	GR	7	0	0	0	0	0
Fall	BO	33	19	57.5	1.0	74.2	0.7
Chinook	TD	27	14	51.6	0.5	96.8	0.2
	JD	17	9	52.9	0.3	100.0	0.3
	MN	7	3	42.9	1.3	92.0	0.2
	IH	9	4	44.4	0.1	75.5	0.1
	LM	7	1	14.3	1.1	99.6	0.4
	GO	10	1	10.0	<0.1	0.2	<0.1
	GR	6	0	0	0	0	0
Steelhead	BO	107	49	45.8	1.0	97.5	0.3
	TD	64	24	37.5	0.3	75.8	0.3
	JD	45	15	33.3	0.4	92.2	0.4
	MN	23	6	26.1	0.3	96.1	0.3
	IH	23	4	17.4	0.6	90.8	0.3
	LM	14	3	21.4	0.3	100.0	0.3
	GO	9	1	11.1	0.4	100.0	0.4
	GR	13	0	0	0	0	0

Table 14. Number and percent of fish with temperatures ≥ 20 ºC, mean and average percent of total time spent at temperatures ≥ 20 ºC and the mean consecutive time spent at temperatures ≥ 20 ºC in the tailraces of dams in 2002.

Species	Tailrace	N	# of Fish recorded ≥ 20 ºC N	# of Fish recorded ≥ 20 ºC %	Total time ≥ 20 ºC Mean days	Total time ≥ 20 ºC Mean %	Consecutive time ≥ 20 ºC Mean days
Spring Chinook	BO	77	0	0	0	0	0
	TD	52	0	0	0	0	0
	JD	65	0	0	0	0	0
	MN	51	0	0	0	0	0
	IH	67	0	0	0	0	0
	LM	70	0	0	0	0	0
	GO	54	0	0	0	0	0
	GR	46	0	0	0	0	0
Summer Chinook	BO	31	0	0	0	0	0
	TD	21	0	0	0	0	0
	JD	26	1	3.8	0.4	0.1	0.1
	MN	16	1	6.3	0.0	0.5	0.0
	IH	23	2	8.7	0.2	1.0	0.2
	LM	22	2	9.1	0.1	1.0	0.1
	GO	16	1	6.3	0.6	1.0	0.6
	GR	20	1	5.0	0.4	0.5	0.1
Fall Chinook	BO	18	12	66.7	0.9	85.0	0.5
	TD	6	4	66.7	1.1	99.5	0.6
	JD	15	9	60.0	0.3	99.1	0.1
	MN	5	0	0	0	0	0
	IH	9	0	0	0	0	0
	LM	11	0	0	0	0	0
	GO	8	0	0	0	0	0
	GR	4	0	0	0	0	0
Steelhead	BO	147	97	66.0	1.4	85.0	0.7
	TD	71	30	42.3	0.4	97.8	0.3
	JD	81	44	54.3	1.3	98.1	1.2
	MN	37	12	32.4	0.4	86.2	0.3
	IH	60	16	26.7	0.3	97.3	0.3
	LM	47	9	19.1	0.3	70.1	0.2
	GO	30	0	0	0	0	0
	GR	27	0	0	0	0	0

Fall Chinook salmon

The average median fall Chinook salmon temperature in 2000 and 2002 was 19.4 ºC (range 10.1-22.4 ºC) in lower Columbia River tailraces and 17.8 ºC (range 8.8-21.7 ºC) in lower Snake River dam tailraces (Appendix B Tables 1-2). In 2000, 43-58% of fall Chinook salmon encountered water temperatures ≥ 20 ºC in the tailraces of lower Columbia River dams as did 10-44% in lower Snake River dams (Table 13; Figure 15; Appendix B Table 7). In 2002, about a third of fall Chinook salmon encountered water temperatures ≥ 20 ºC in the tailraces of Bonneville, The Dalles, and John Day dams, and none did at other dams (Table 14; Figure 16; Appendix B Table 8). In both years, most fish spent < 1 d above the 20 ºC threshold in each tailrace. The maximum number of consecutive days an individual fish spent at temperatures ≥ 20 ºC was 2.8 d in 2000 and 6.2 d in 2002 in the Bonneville tailrace.

Steelhead

The average median steelhead temperatures in 2000 and 2002 were 18.9 ºC (range 8.3-23.1 ºC) in lower Columbia River reservoirs and 17.1 ºC (range 8.0-22.0 ºC) in lower Snake River tailraces (Appendix B Tables 1-2). In 2000, the percentage of fish with temperature records ≥ 20 ºC decreased as steelhead progressed upriver, from 46% in the Bonneville tailrace to11% in the Little Goose tailrace (Table 13: Figure 17; Appendix B Table 9), reflecting seasonal temperature patterns and the tendency for fish migrating during the warmest times not to reach upriver sites with available RDST storage space. The patterns was similar in 2002, except percentages were generally higher and ranged from 66% in the Bonneville tailrace to 19% in the Little Goose tailrace (Table 14; Figure 18; Appendix B Table 10). As with other runs, most steelhead spent < 1 d in each tailrace at temperatures ≥ 20 ºC. The average consecutive number of days at temperatures ≥ 20 ºC ranged from 0.3 d (McNary) to 0.4 d (John Day) in 2000 and from 0.2 d (Lower Monumental) to 1.2 d (John Day) in 2002 (Tables 13-14). The maximum number of consecutive days an individual fish spent at temperatures ≥ 20 ºC was 5.1 d in 2000 in Bonneville tailrace and 24.8 d in 2002 in the John Day tailrace.

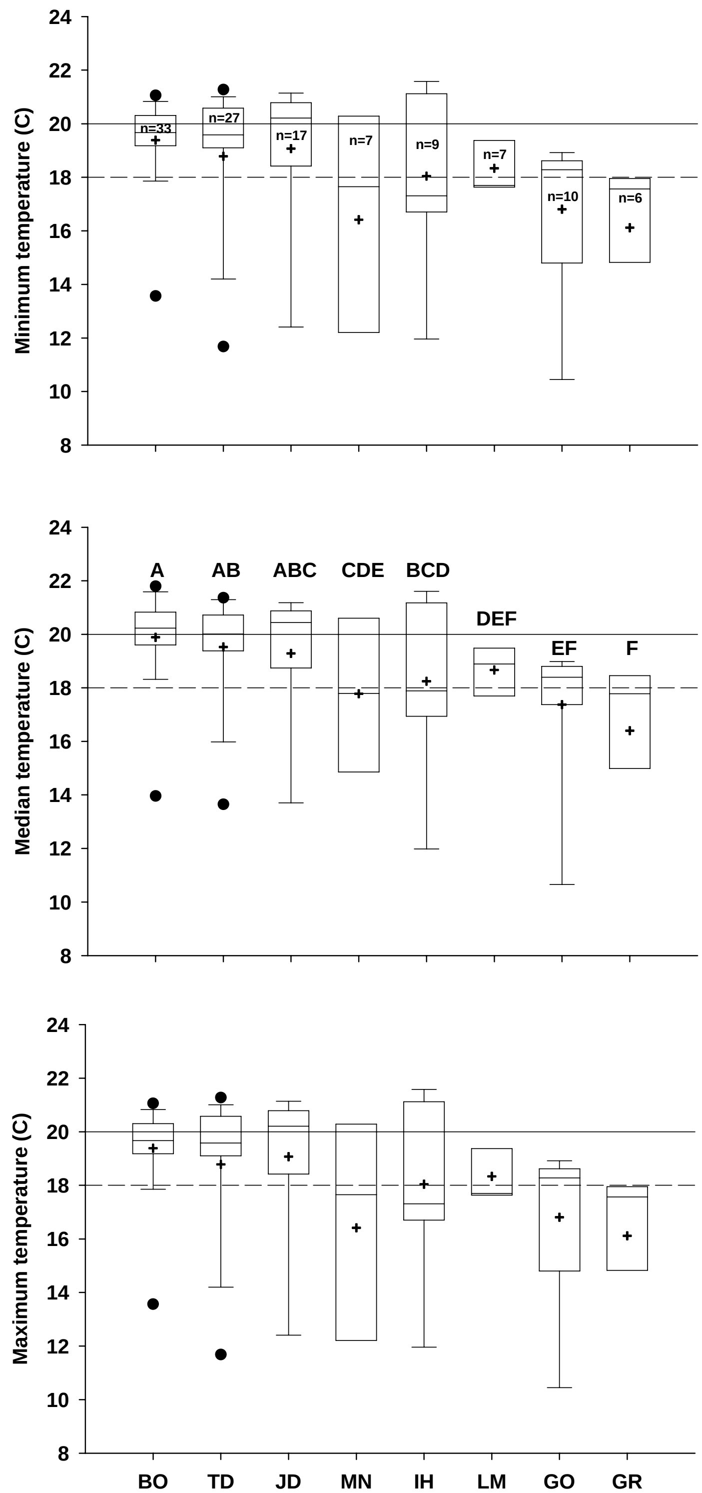


Figure 15. Fall Chinook salmon body temperature in tailraces, 2000. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and four lower Snake River tailraces in 2000. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; P=0.0004).

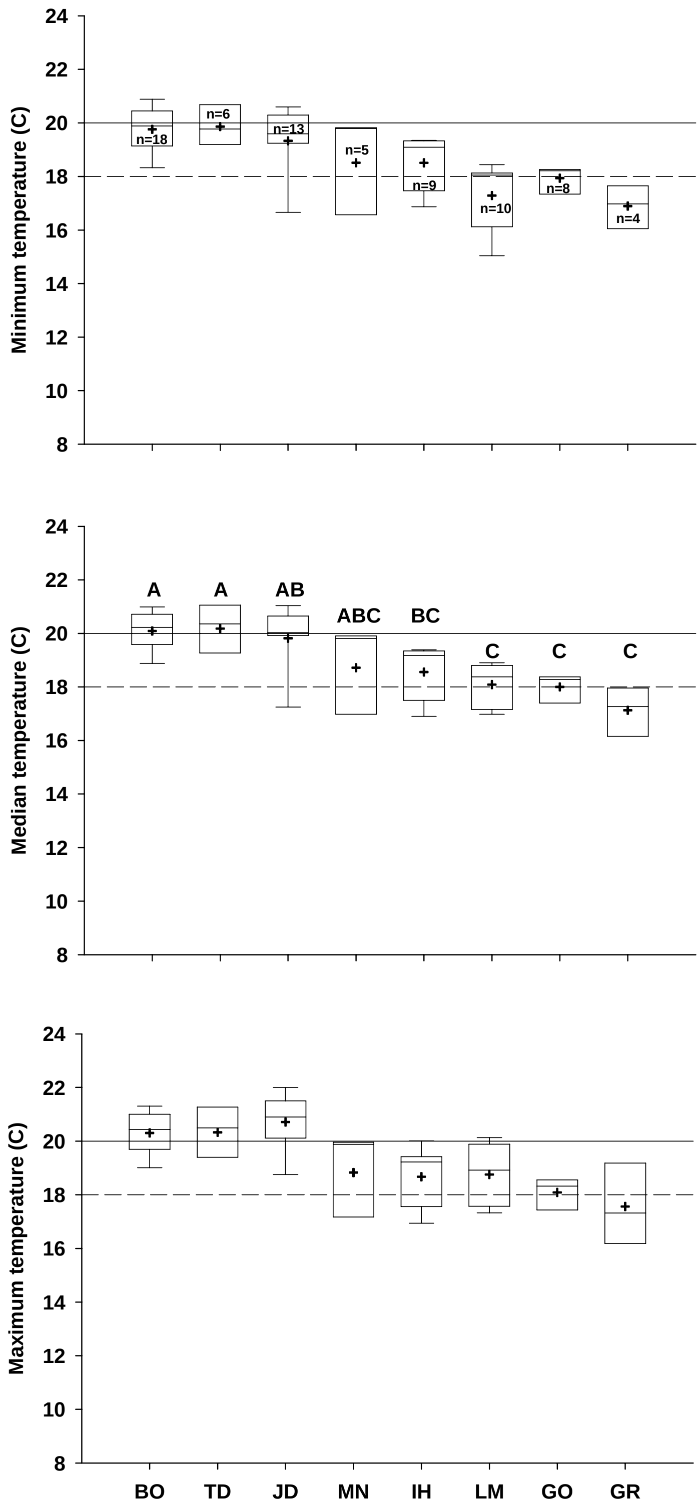


Figure 16. Fall Chinook salmon body temperature in tailraces, 2002. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and four lower Snake River tailraces in 2002. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; *P*=0.0004).

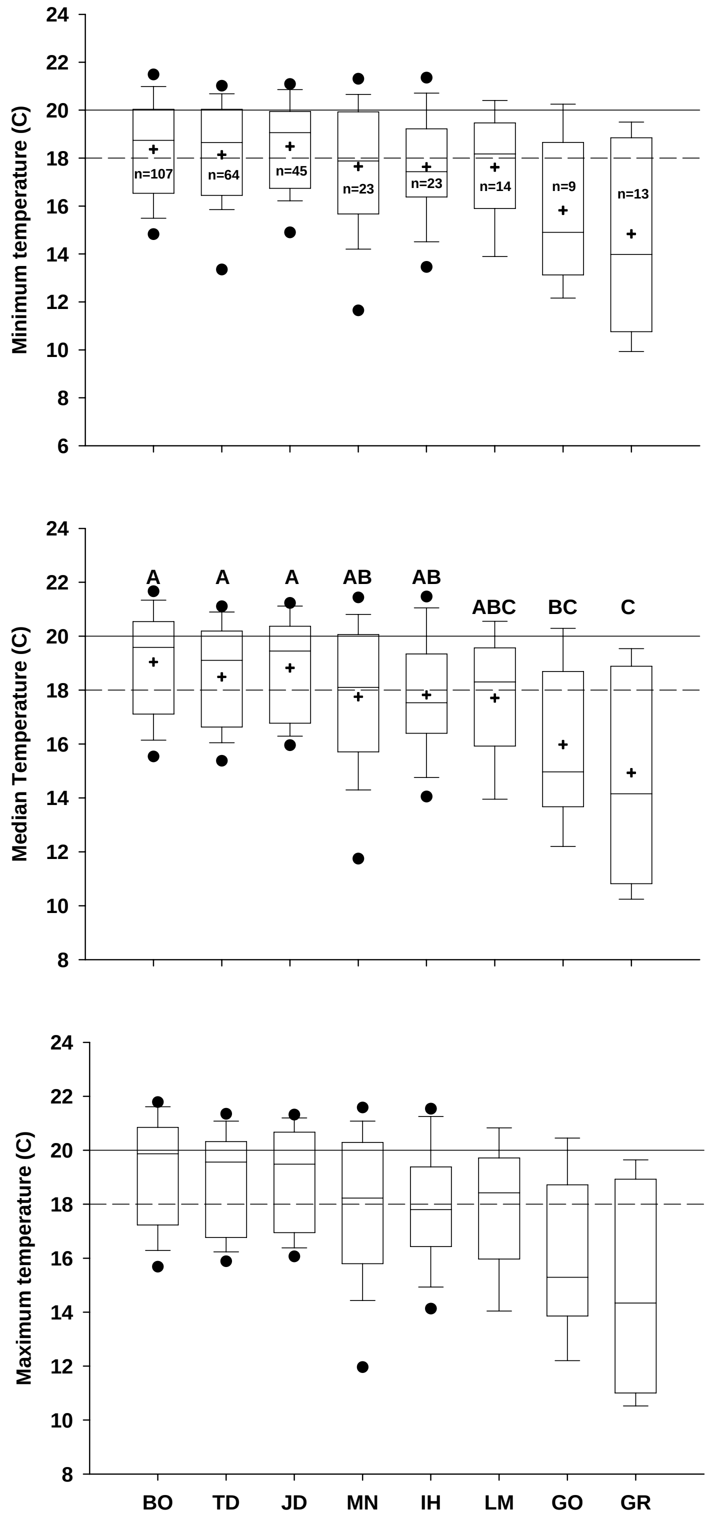


Figure 17. Steelhead body temperature in tailraces, 2000. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and four lower Snake River tailraces in 2000. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; *P*=0.0004).

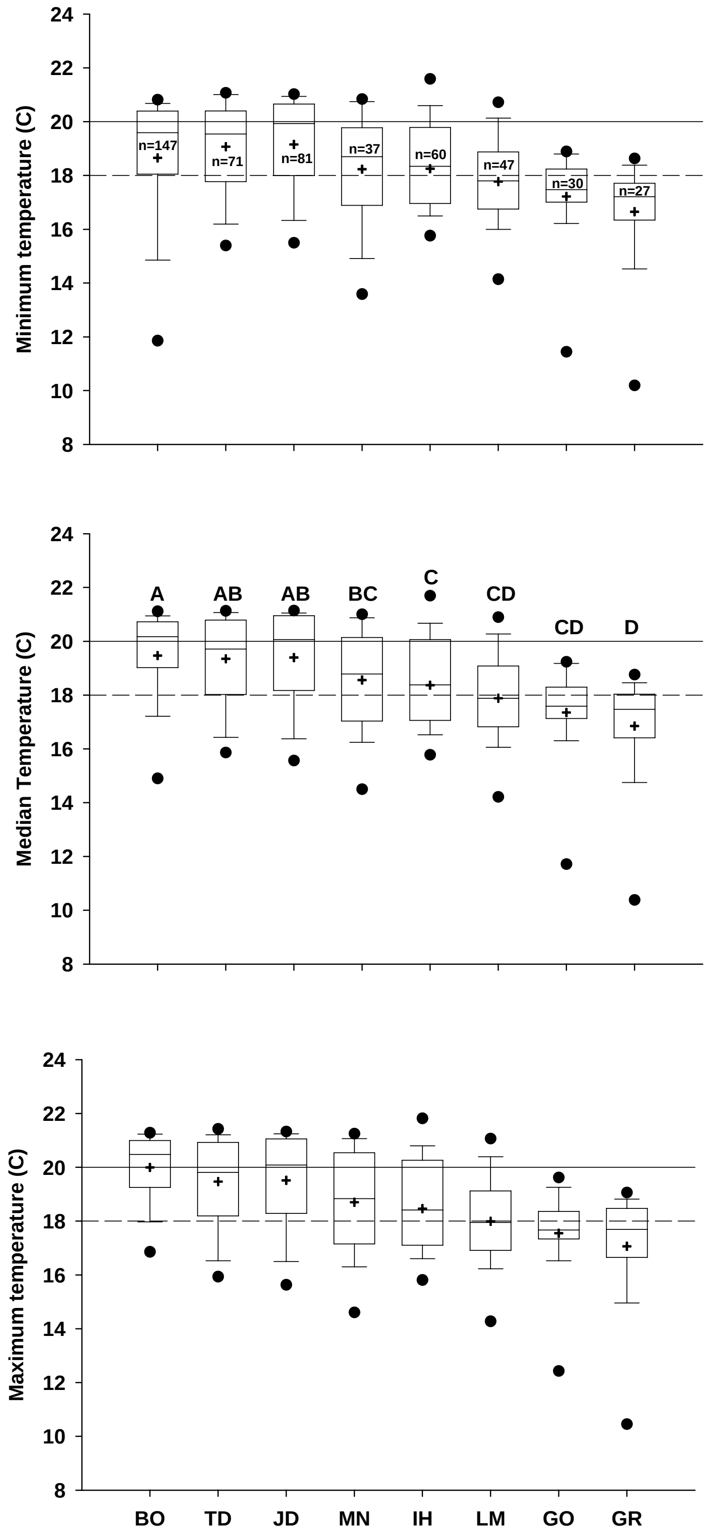


Figure 18. Steelhead body temperature in tailraces, 2002. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and four lower Snake River tailraces in 2002. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; *P*=0.0004).

Ladders

Spring Chinook salmon

The average median spring Chinook salmon temperatures in 2000 and 2002 in lower Columbia River dam fish ladders did not exceed 20 °C. Average fish temperatures were 12.5 ºC (range 8.4-16.9 ºC) in the lower Columbia River ladders and 13.0 ºC (range 9.6-18.6 ºC) in the lower Snake River ladders (Appendix B Tables 11-12). We found significant (P<0.0001) differences in fish temperatures in ladders between ladders in both years, reflecting seasonal temperature patterns (Table 4). Average median fish temperatures tended to be significantly warmer at lower Snake River dams than at lower Columbia river dams and temperatures overall were progressively warmer as fish moved upstream (Figures 19-20; Appendix B Tables 13-14).

Summer Chinook salmon

The average median summer Chinook salmon temperatures in 2000 and 2002 were 17.5 ºC (range 13.4-22.9 ºC) in lower Columbia River ladders and 16.9ºC (range 13.3-22.1 ºC) in lower Snake River ladders (Appendix B Tables 11-12). In 2000, 23-34% of fish at lower Columbia ladders and 0-9% of fish at lower Snake River ladders encountered water temperature ≥ 20 ºC (Figure 21; Table 15). Most of these fish spent the majority of their time in ladders at temperatures ≥ 20 ºC. In the cooler 2002, 0-15% of summer Chinook salmon encountered water temperature ≥ 20 ºC in ladders at all dams (Figure 22; Table 16). As in 2000, the fish that encountered water ≥ 20 ºC in ladders spent most of their time above that threshold.

We found significant (P<0.0001) differences in fish temperatures in ladders between dams in both years (Table 5). Average median fish temperatures tended to be cooler at Snake River dams than at lower Columbia River dams, reflecting differences in summer Chinook salmon stock timing. Snake River summer Chinook salmon migrated much earlier, on average, than summer Chinook from other populations (Appendix Tables 15-16).

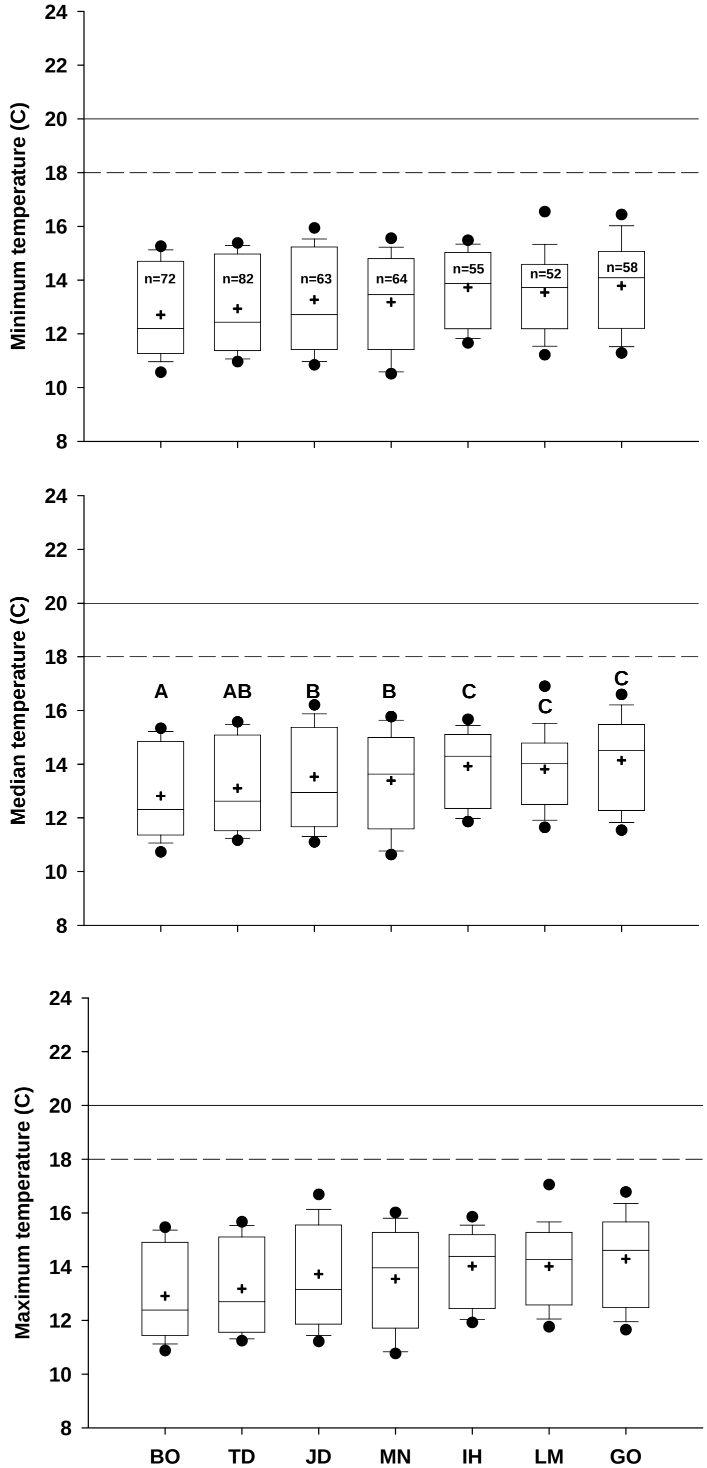


Figure 19. Spring Chinook salmon body temperature in ladders, 2000. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and three lower Snake River ladders in 2000. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; *P*=0.0004).

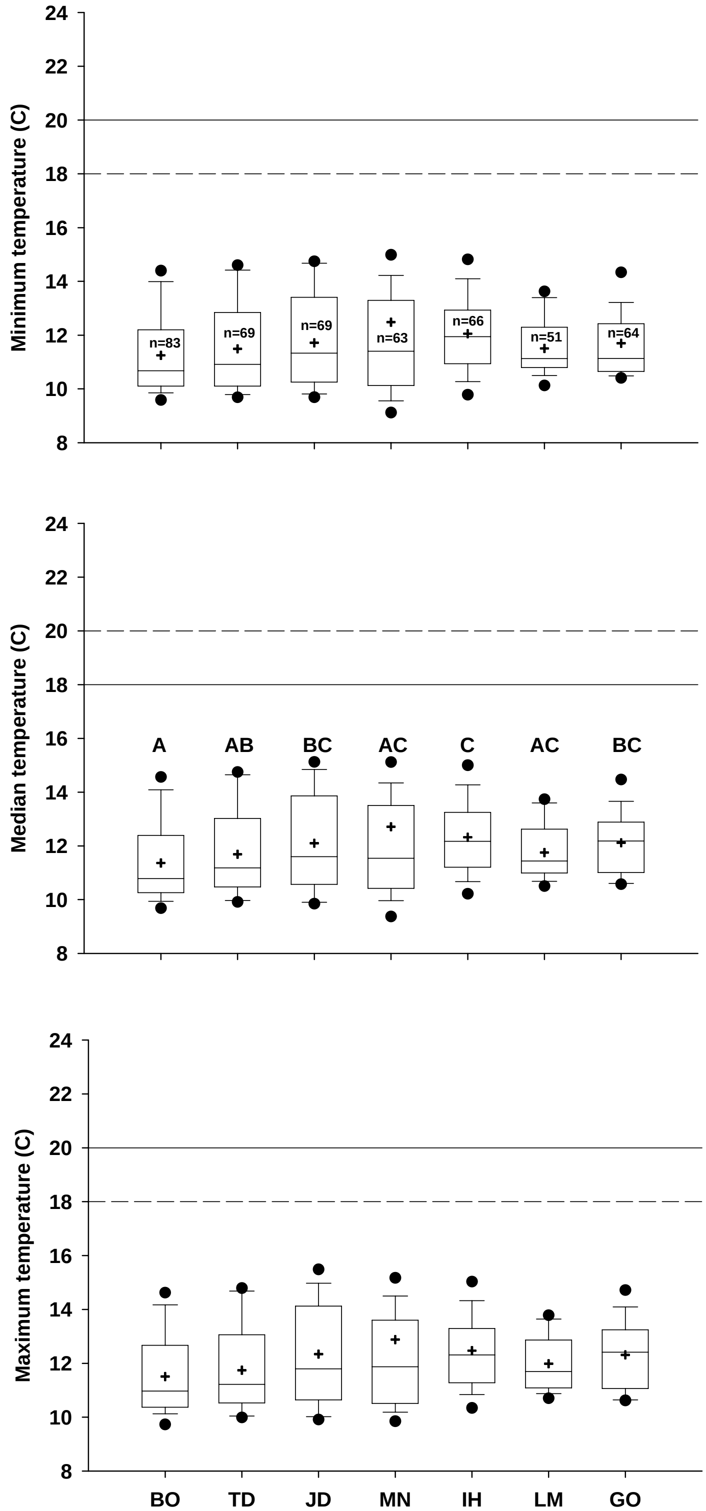


Figure 20. Spring Chinook salmon body temperature in ladders, 2002. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of bodt temperatures during migration through the four lower Columbia River and three lower Snake River ladders in 2002. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; P=0.0004).

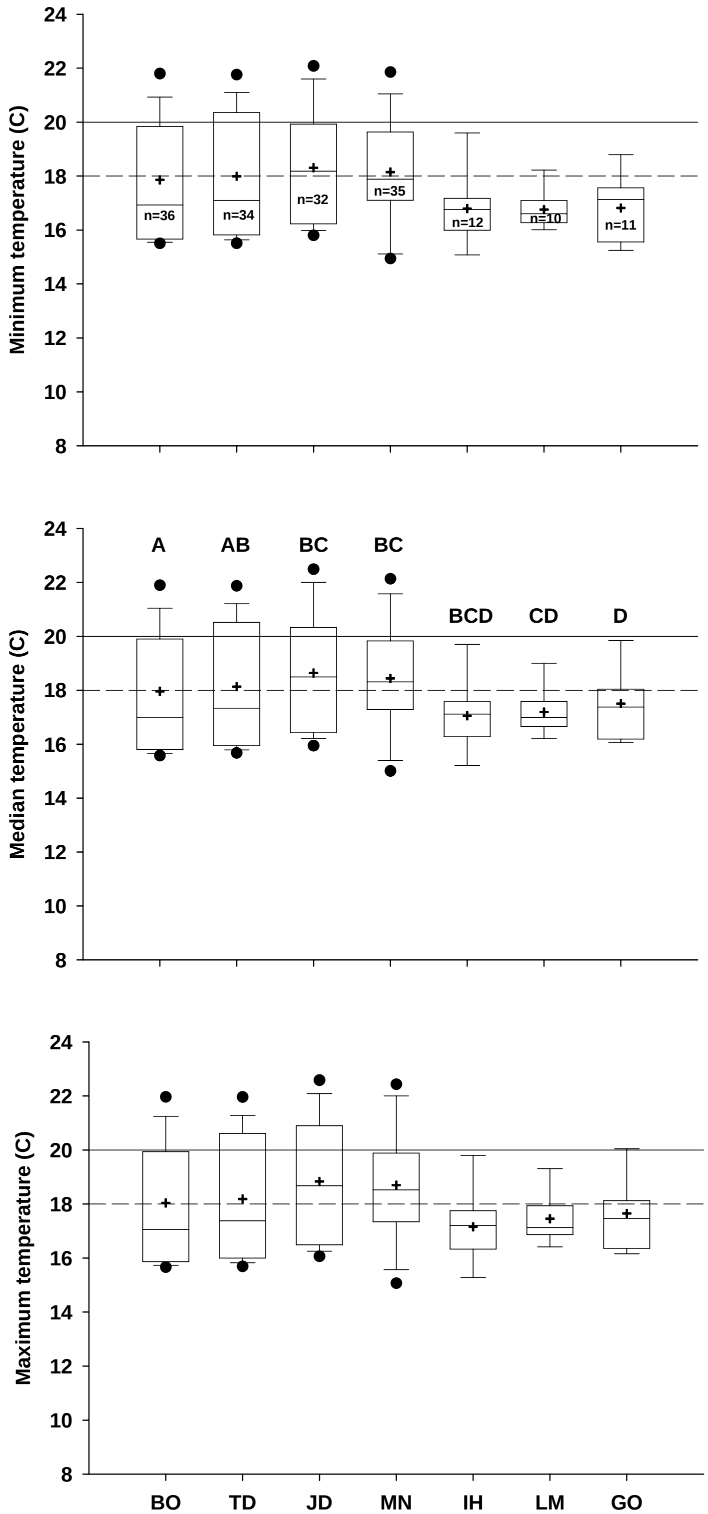


Figure 21. Summer Chinook salmon body temperature in ladders, 2000. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and three lower Snake River ladders in 2000. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; *P*=0.0004).

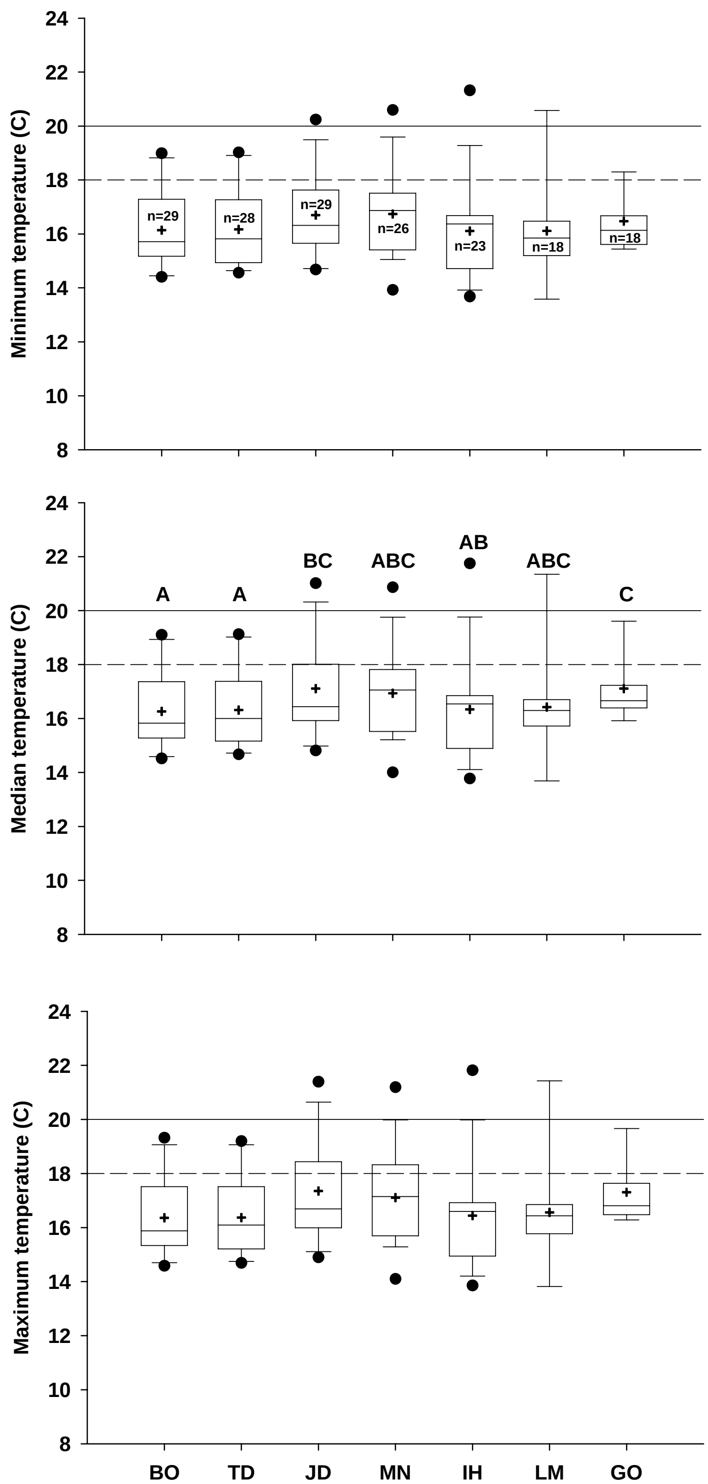


Figure 22. Summer Chinook salmon body temperature in ladders, 2002. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and three lower Snake River ladders in 2002. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; P=0.0004).

Table 15. Number and percent of fish with temperatures ≥ 20 ºC, mean and average percent of total time spent at temperatures ≥ 20 ºC and the mean consecutive time spent at temperatures ≥ 20 ºC in the ladders of dams in 2000.

			# of Fish recorded ≥ 20 ºC		Total time ≥ 20 ºC		Consecutive time ≥ 20 ºC
Species	Tailrace	N	N	%	Mean hours	Mean %	Mean hours
Summer Chinook	BO	36	9	25.0	3.7	98.2	3.4
	TD	34	9	26.5	3.2	100.0	3.2
	JD	32	11	34.4	3.3	89.9	3.1
	MN	35	9	22.9	2.4	94.3	2.2
	IH	12	1	8.3	1.5	100.0	1.5
	LM	10	0	0	0	0	0
	GO	11	1	9.1	0.5	33.7	0.3
Fall Chinook	BO	31	18	58.1	2.7	98.0	2.6
	TD	26	16	61.5	2.2	100.0	2.2
	JD	17	13	76.5	3.0	98.5	3.0
	MN	16	7	43.8	1.8	78.8	1.6
	IH	12	8	66.7	2.3	87.3	2.1
	LM	12	5	41.7	4.0	97.7	4.0
	GO	8	0	0	0	0	0
Steelhead	BO	105	48	45.7	5.1	99.6	5.1
	TD	46	24	52.2	1.9	92.4	1.8
	JD	42	14	33.3	3.1	79.9	2.7
	MN	43	13	30.2	2.5	96.7	2.4
	IH	26	5	19.2	1.8	88.5	1.8
	LM	18	2	11.1	3.0	100.0	3.0
	GO	22	1	4.5	1.5	100.0	1.5

Table 16. Number and percent of fish with temperatures ≥ 20 ºC, mean and average percent of total time spent at temperatures ≥ 20 ºC and the mean consecutive time spent at temperatures ≥ 20 ºC in the ladders of dams in 2002.

			# of Fish recorded ≥ 20 ºC		Total time ≥ 20 ºC		Consecutive time ≥ 20 ºC
Species	Tailrace	N	N	%	Mean hours	Mean %	Mean hours
Summer Chinook	BO	29	0	0	0	0	0
	TD	28	0	0	0	0	0
	JD	29	4	13.8	3.0	78.3	3.0
	MN	26	4	15.4	1.8	95.7	2.1
	IH	23	2	8.7	2.1	100.0	2.1
	LM	18	2	11.1	2.6	100.0	2.6
	GO	18	1	5.6	1.7	100.0	1.7
Fall Chinook	BO	15	10	66.7	3.7	90.0	3.3
	TD	15	12	80.0	1.9	100.0	1.9
	JD	13	11	84.6	3.1	97.8	3.1
	MN	13	6	46.2	2.2	82.4	1.6
	IH	13	3	23.1	2.1	89.4	2.1
	LM	5	0	0	0	0	0
	GO	7	0	0	0	0	0
Steelhead	BO	136	86	63.2	4.4	98.1	4.4
	TD	99	55	55.6	1.8	99.6	1.8
	JD	74	42	56.8	3.1	95.3	3.0
	MN	69	31	44.9	2.2	95.7	2.1
	IH	60	18	30.0	2.0	98.2	2.0
	LM	38	5	13.2	2.2	98.4	2.2
	GO	41	2	4.9	0.8	100.0	0.8

Fall Chinook salmon

The average median fall Chinook salmon temperatures in 2000 and 2002 were 19.9 ºC (range 12.3-22.4 ºC) in lower Columbia River ladders and 18.5ºC (range 10.1-22.0 ºC) in lower Snake River ladders (Appendix B Tables 11-12). In 2000, 41-77% of fish encountered water temperatures ≥ 20 ºC in all ladders except the Little Goose ladder where none passed this threshold (Table 15). In 2002, 66-85% of fall Chinook encountered ≥ 20 ºC water in ladders at Bonneville, The Dalles, and John Day dams as did 21-43% at McNary and Ice Harbor dams; no fish were recorded above this threshold at Lower Monumental or Little Goose ladders (Table

16). In both years, fish that encountered ≥ 20 ºC water spent the majority of their time in ladders above that temperature.

We found significant (P<0.0001) differences in fish temperatures between ladders at dams in both years (Table 6). Average median fish temperatures were significantly (P<0.0001) warmer in the ladders of Bonneville Dam and The Dalles than the ladders of McNary, Lower Monumental, and Little Goose dams in 2000 (Figure 23; Appendix B Table 17). Temperatures encountered in the Little Goose ladder were also lower than at John Day, McNary, and Ice Harbor ladders. In 2002, average median fish temperatures were significantly warmer (P<0.0001) in the ladders of Bonneville, The Dalles, and John Day than Lower Monumental and Little Goose ladders (Figure 24; Appendix B Table 18). These patterns reflect both within-season migration timing effects and likely stock differences. We note, also, that fall Chinook salmon sample sizes were quite small.

Steelhead

The average median steelhead temperatures in 2000 and 2002 were 19.3 ºC (range 11.0-22.8 ºC) in lower Columbia River ladders and 17.8ºC (range 12.1-22.5 ºC) in lower Snake River ladders (Appendix B Tables 11-12). In both years, the percentages of steelhead that encountered water temperature ≥ 20 ºC in ladders decreased as fish progressed upstream reflecting seasonal patterns, arrival timing and the tendency for RDSTs to fill before steelhead reached the Snake River during warm periods. In 2000, 30-52% of steelhead encountered ladder temperatures ≥ 20 ºC at lower Columbia dams as did 5-19% at lower Snake River dams (Table 15; Figure 25). Percentages were 45-63% at lower Columbia dams and 5-30% at lower Snake dams in 2002. In both years, fish that encountered ≥ 20 ºC water in ladders were above that threshold for the majority of their time in ladders (Table 16; Figure 26).

We found significant (P<0.0001) differences in fish temperatures in ladders between dams in both years (Table 7). Temperatures tended to be highest at Bonneville Dam and cooler at upstream sites (Appendix B Tables 19-20). Differences were greatest between fish temperatures at Snake River dams and those at lower Columbia River dams, again reflecting migration timing differences (Figure 10).

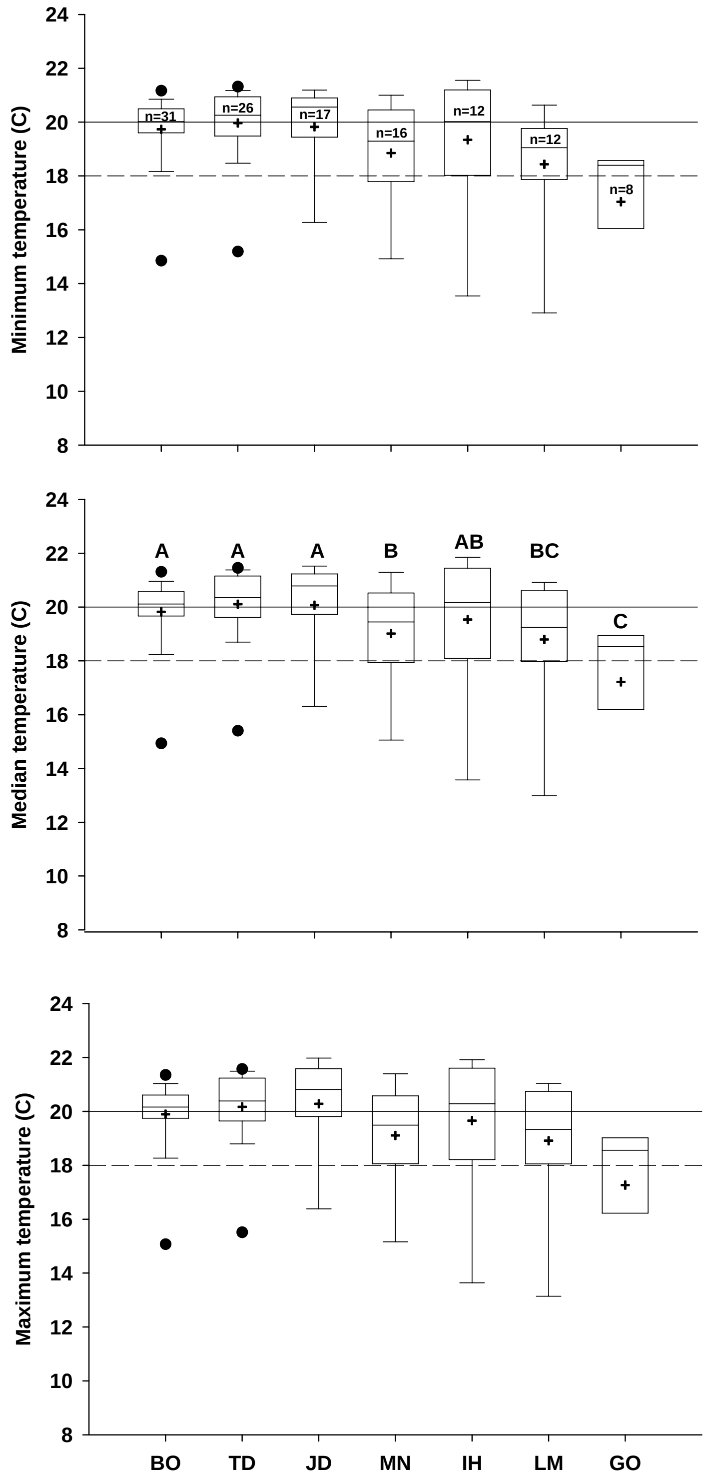


Figure 23. Fall Chinook salmon body temperature in ladders, 2000. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and three lower Snake River ladders in 2000. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; *P*=0.0004).

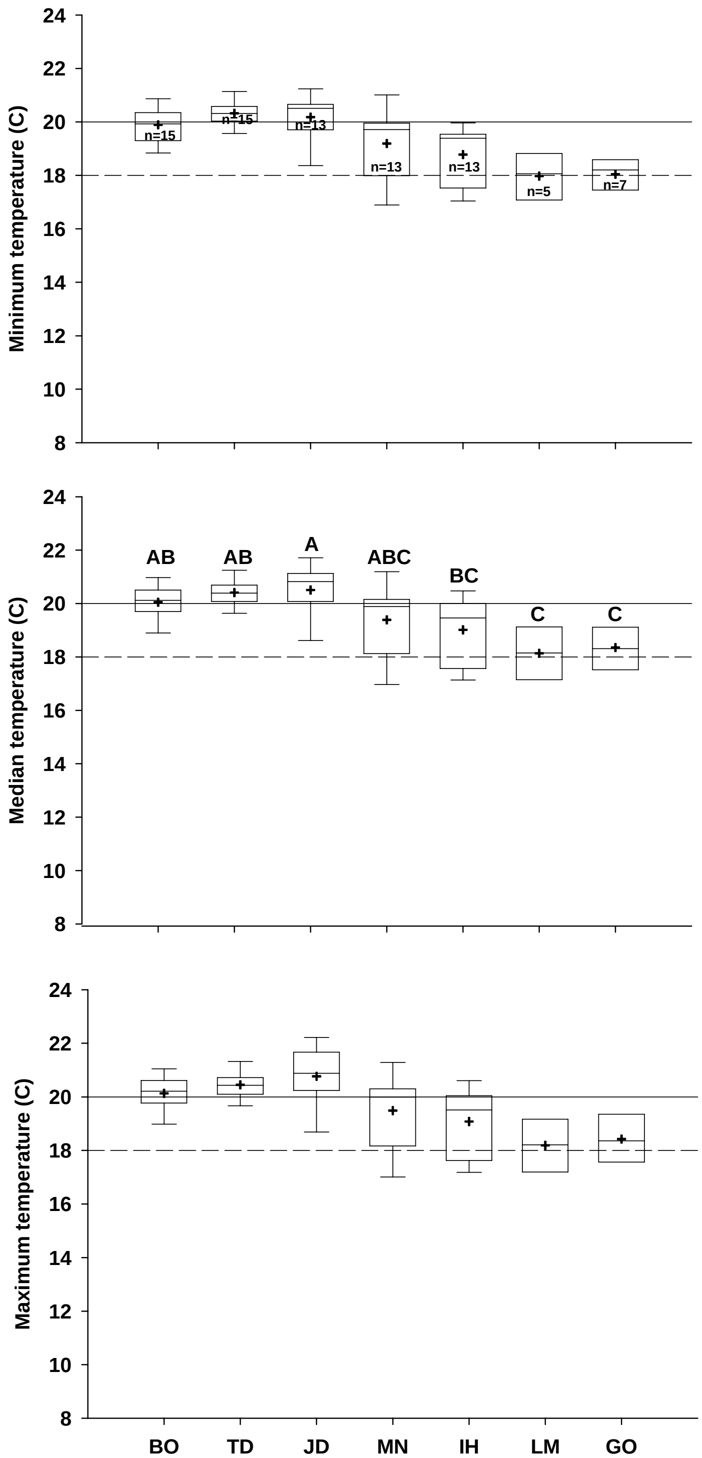


Figure 24. Fall Chinook salmon body temperature in ladders, 2002. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and three lower Snake River ladders in 2002. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; P=0.0004).

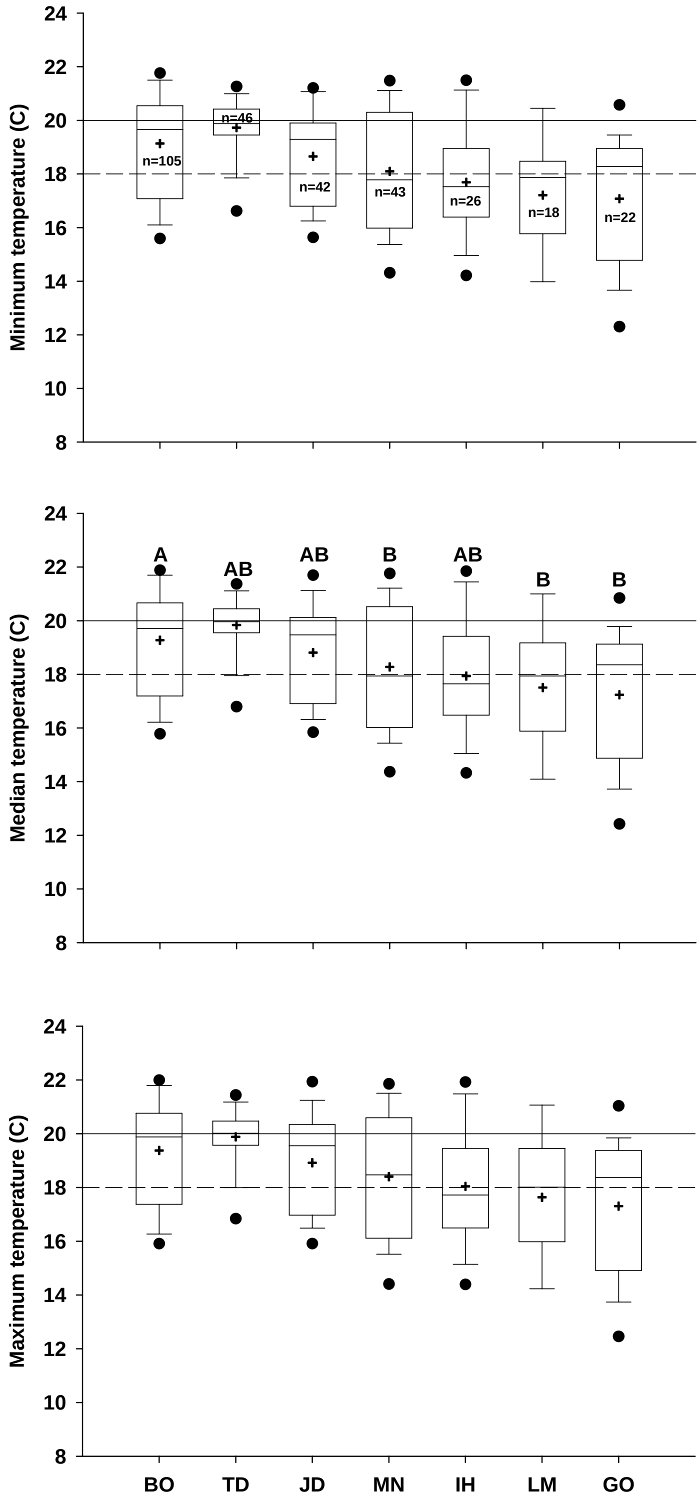


Figure 25. Steelhead body temperature in ladders, 2000. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and three lower Snake River ladders in 2000. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; *P*=0.0004).

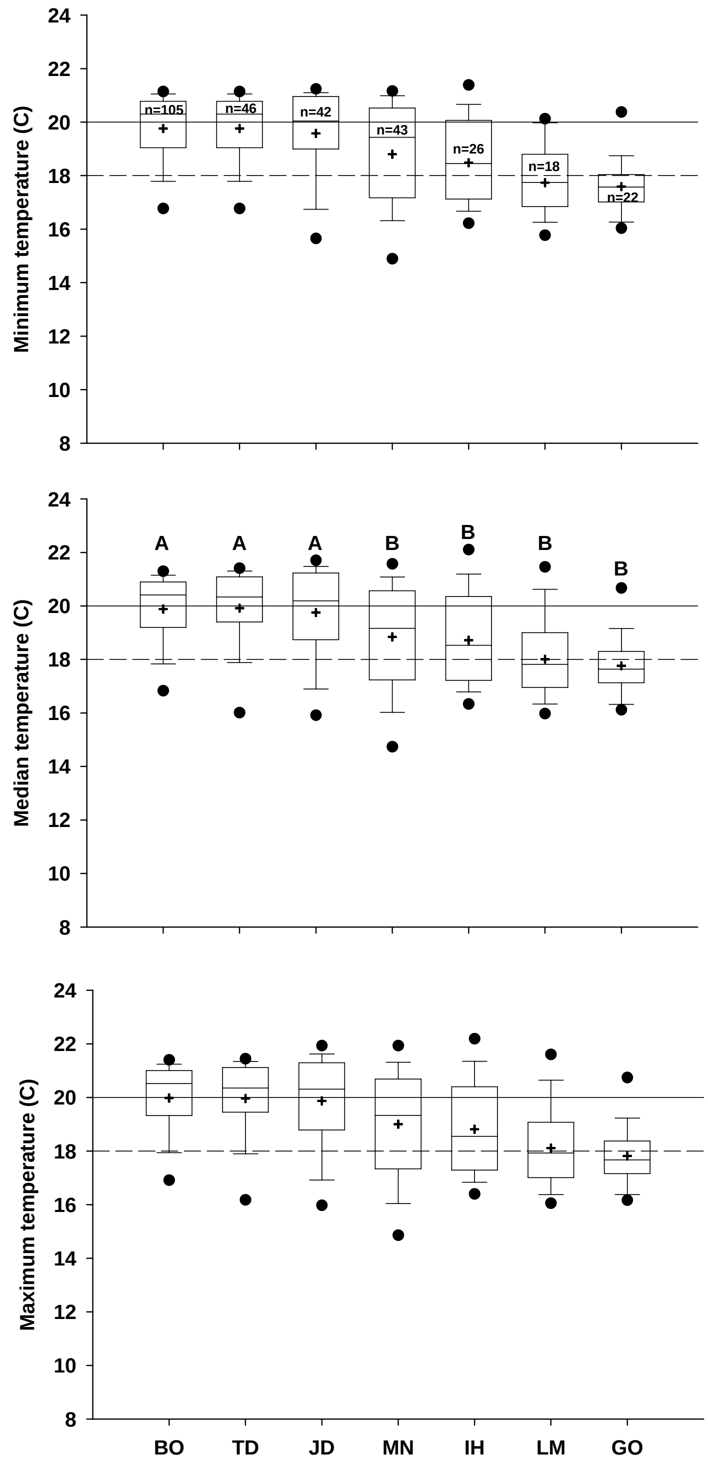


Figure 26. Steelhead body temperature in ladders, 2002. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and three lower Snake River ladders in 2002. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; P=0.0004).

Reservoirs

Spring Chinook salmon

The average median spring Chinook salmon temperatures in 2000 and 2002 were 12.4 ºC (range 8.3-21.2ºC) in lower Columbia River reservoirs and 12.7ºC (range 9.2-18.8 ºC) in lower Snake River reservoirs (Appendix B Tables 21-22). All estimates excluded time fish spent inside tributaries, as evidenced by telemetry records. In 2000, the only spring Chinook to encounter water temperatures ≥ 20 ºC were two fish (3%) in the John Day reservoir (Figure 27; Table 17). No fish were recorded encountering ≥ 20 ºC water in reservoirs in 2002 (Figure 28; Table 18).

We found significant (P<0.0001) differences in fish temperatures between reservoirs in both years, with a typical progression of warmer temperatures encountered as fish moved upstream in 2000 (Table 5; Appendix B Tables 23-24). This pattern was less pronounced in the cooler 2002, when average median fish temperatures were significantly warmer in McNary reservoir than Bonneville reservoir (P<0.0001) reservoir, but no other comparisons were significant.

Summer Chinook salmon

The average median summer Chinook salmon temperatures in 2000 and 2002 were 17.0 ºC (range 13.7-22.9 ºC) in lower Columbia River reservoirs and 16.5ºC (range 12.4-22.3 ºC) in lower Snake River reservoirs (Appendix B Tables 21-22). In 2000, 23-24% of summer Chinook encountered water temperature ≥ 20 ºC in the Bonneville, The Dalles, and John Day reservoirs while 0-8% did so in the remaining reservoirs (Figure 29; Table 17). Total time above the 20 ºC threshold was generally < 1 d at all sites. In cooler 2002, percentages ranged from 0% (Bonneville and The Dalles reservoirs) to 14% (John Day and McNary reservoirs (Figure 30; Table 18).

We found significant (P<0.0001) differences in fish temperatures between reservoirs in both years, reflecting seasonal changes and timing differences among populations (Table 7, Figure 10). In 2000, average median fish temperatures were significantly (P<0.0001) warmer in Bonneville reservoir than in Ice Harbor, Lower Monumental, and Little Goose reservoirs (Figure 28; Appendix B Table 25). Other significant differences were also related, at least in part, to early migration timing for Snake River summer Chinook salmon. There were no significant differences in 2002 (Figure 30; Appendix B Table 26).

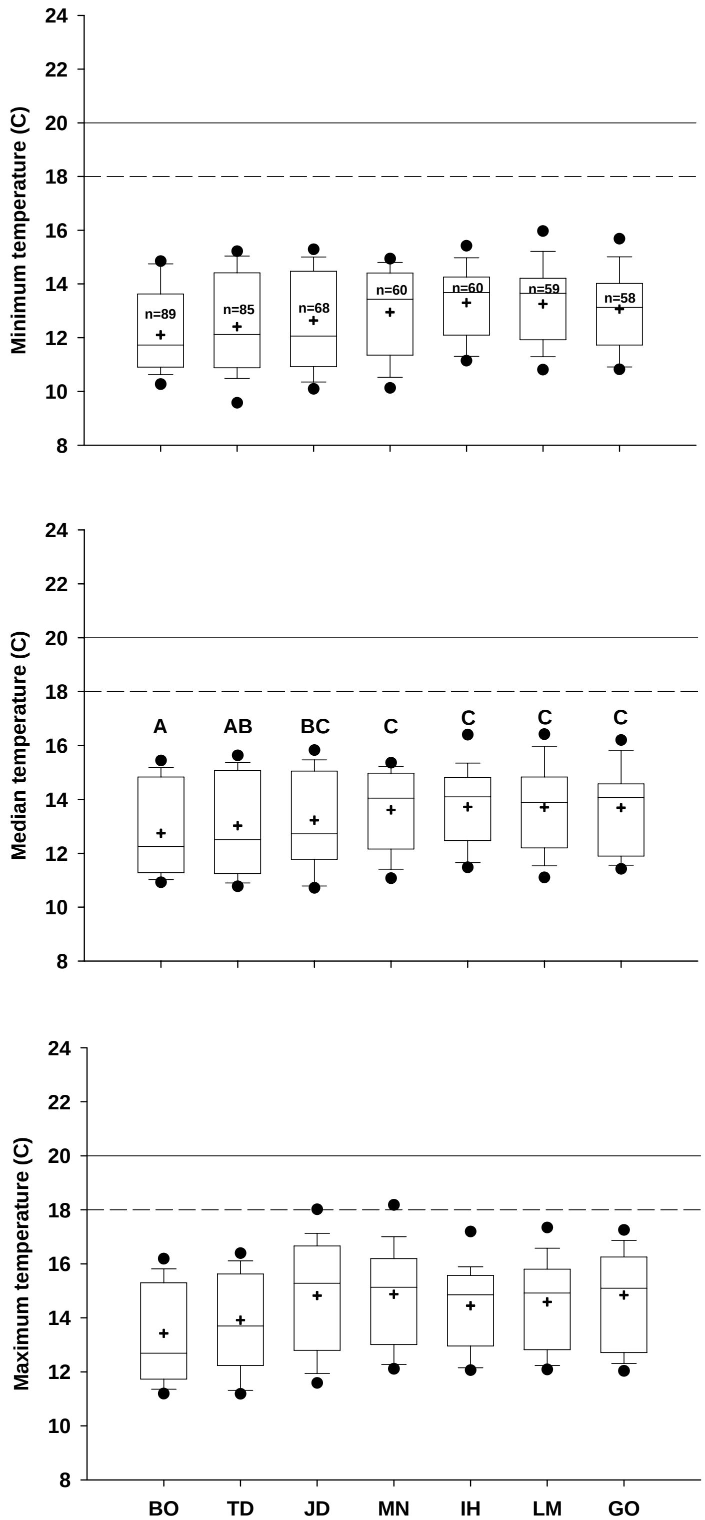


Figure 27. Spring Chinook salmon body temperature in reservoirs, 2000. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and three lower Snake River reservoirs in 2000. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; *P*=0.0004).

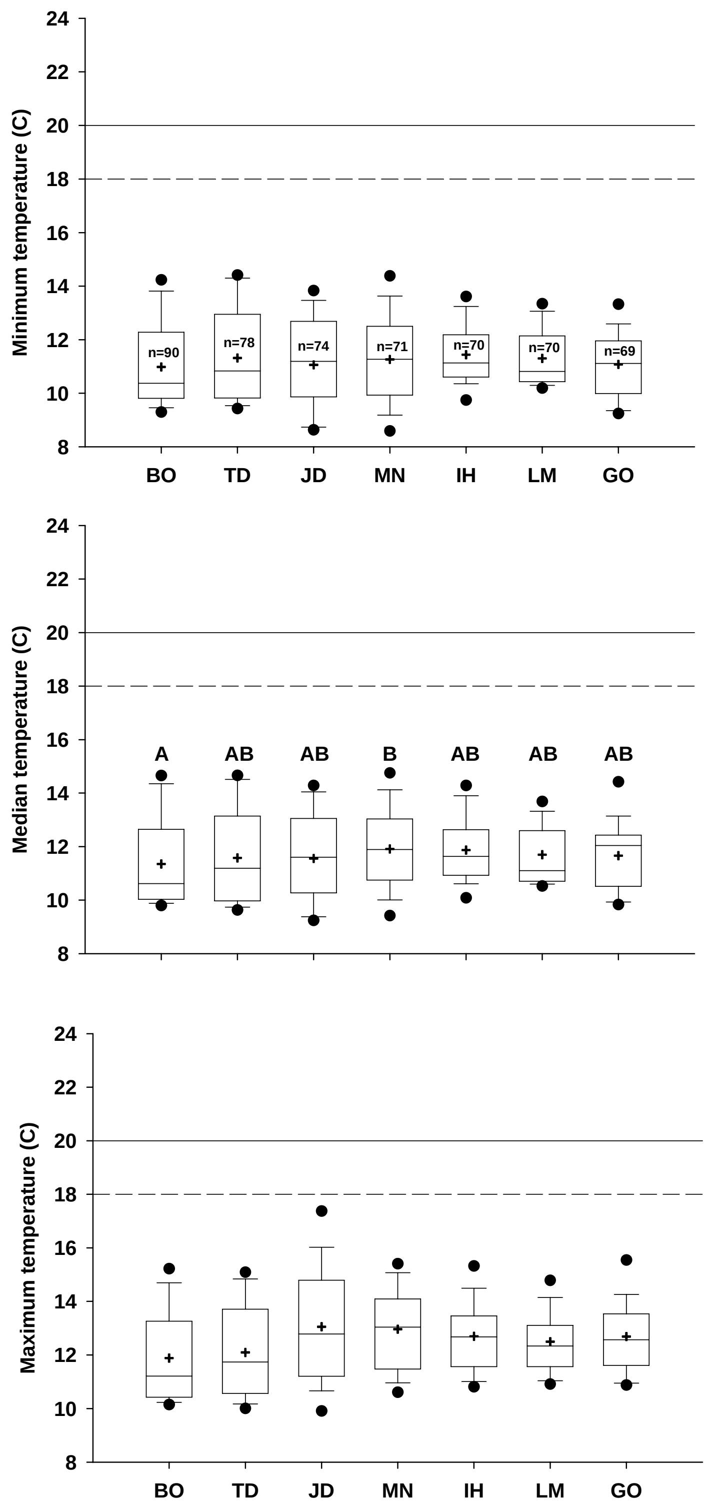


Figure 28. Spring Chinook salmon body temperature in reservoirs, 2002. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and three lower Snake River reservoirs in 2002. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; P=0.0004).

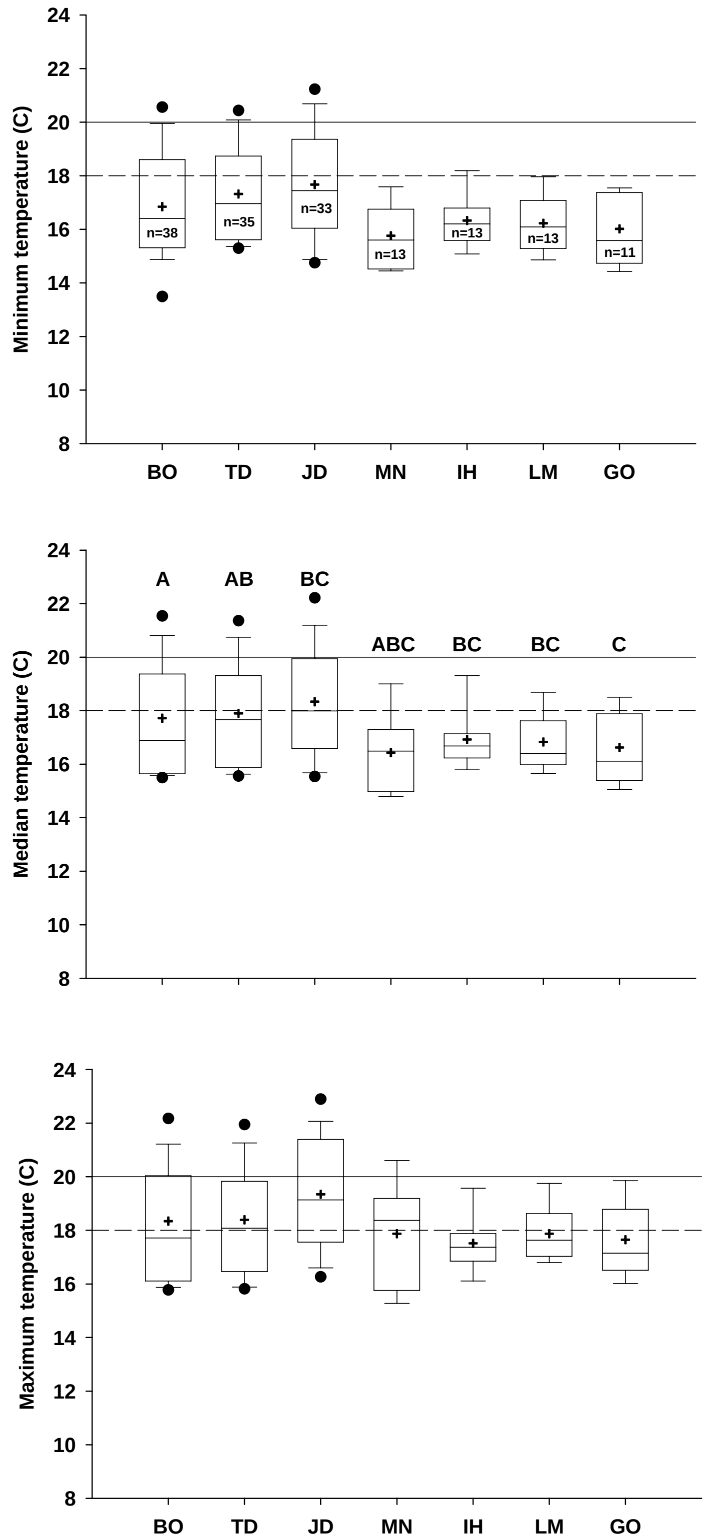


Figure 29. Summer Chinook salmon body temperature in reservoirs, 2000. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and three lower Snake River reservoirs in 2000. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; P=0.0004).

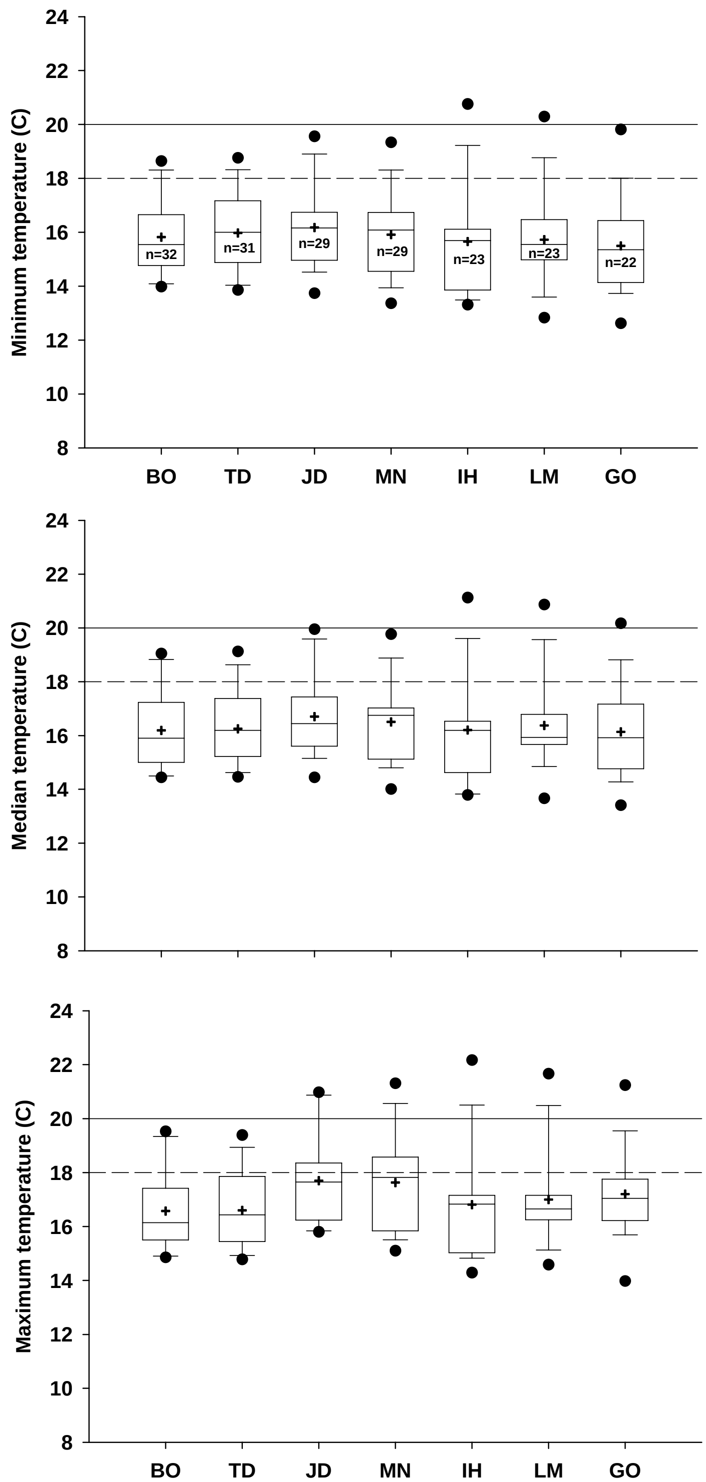


Figure 30. Summer Chinook salmon body temperature in reservoirs, 2002. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and three lower Snake River reservoirs in 2002. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; *P*=0.0004).

Table 17. Number and percent of fish with temperatures ≥ 20 ºC, mean and average percent of total time spent at temperatures ≥ 20 ºC and the mean consecutive time spent at temperatures ≥ 20 ºC in the reservoirs of dams in 2000.

			# of Fish recorded ≥ 20 ºC		Total time ≥ 20 ºC		Consecutive time ≥ 20 ºC
Species	Tailrace	N	N	%	Mean days	Mean %	Mean days
Spring Chinook	BO	89	0	0	0	0	0
	TD	85	0	0	0	0	0
	JD	68	2	2.9	0.1	3.4	0.1
	MN	60	0	0	0	0	0
	IH	60	0	0	0	0	0
	LM	59	0	0	0	0	0
	GO	58	0	0	0	0	0
Summer Chinook	BO	38	9	23.7	1.0	78.2	0.5
	TD	35	8	22.9	0.8	81.4	0.5
	JD	33	8	24.2	0.9	65.5	1.0
	MN	13	0	0	0	0	0
	IH	13	1	7.7	0.7	59.0	0.7
	LM	13	1	7.7	<0.1	0.1	<0.1
	GO	11	0	0	0	0	0
Fall Chinook	BO	36	22	61.1	1.2	18.9	0.4
	TD	22	13	59.1	0.6	70.0	0.4
	JD	13	9	69.2	1.1	62.1	0.8
	MN	11	4	36.4	0.6	93.1	0.5
	IH	11	6	54.5	0.4	50.1	0.4
	LM	11	4	36.6	0.4	13.7	<0.1
	GO	11	1	9.1	<0.1	0.9	<0.1
Steelhead	BO	112	61	54.5	0.8	18.9	0.3
	TD	63	28	44.4	1.4	41.3	0.3
	JD	41	20	48.8	1.4	49.4	0.9
	MN	30	11	36.7	1.9	44.2	0.4
	IH	26	7	26.9	0.6	46.0	0.6
	LM	26	4	15.4	1.0	50.6	0.4
	GO	24	5	20.8	0.4	26.0	0.1

Table 18. Number and percent of fish with temperatures ≥ 20 ºC, mean and average percent of total time spent at temperatures ≥ 20 ºC and the mean consecutive time spent at temperatures ≥ 20 ºC in the reservoirs of dams in 2002.

			# of Fish recorded ≥ 20 ºC		Total time ≥ 20 ºC		Consecutive time ≥ 20 ºC
Species	Tailrace	N	N	%	Mean days	Mean %	Mean days
Spring Chinook	BO	90	0	0	0	0	0
	TD	78	0	0	0	0	0
	JD	74	0	0	0	0	0
	MN	71	0	0	0	0	0
	IH	70	0	0	0	0	0
	LM	70	0	0	0	0	0
	GO	69	0	0	0	0	0
Summer Chinook	BO	32	0	0	0	0	0
	TD	31	0	0	0	0	0
	JD	29	4	13.8	0.4	0.3	0.4
	MN	29	4	13.8	0.2	0.2	<0.1
	IH	23	2	8.7	0.5	1.0	0.5
	LM	23	2	8.7	0.5	1.0	0.3
	GO	22	1	4.5	0.6	1.0	0.6
Fall Chinook	BO	20	15	75.0	0.8	78.1	0.5
	TD	17	13	76.0	0.5	79.0	0.4
	JD	14	12	85.7	1.0	74.0	0.5
	MN	14	9	64.3	0.4	21.9	0.2
	IH	13	4	30.8	0.2	17.8	0.1
	LM	13	1	7.7	<0.1	1.0	<0.1
	GO	13	0	0		0	0
Steelhead	BO	167	116	69.5	1.2	29.9	0.4
	TD	118	63	53.4	1.6	43.4	0.3
	JD	89	48	54.0	1.5	62.3	1.0
	MN	75	34	45.3	2.1	51.5	0.6
	IH	62	19	30.6	1.0	65.5	0.5
	LM	59	15	25.4	0.5	36.9	0.2
	GO	54	12	22.2	0.4	24.1	0.1

Fall Chinook salmon

The average median fall Chinook salmon temperatures in 2000 and 2002 were 19.2ºC (range 7.7-22.4 ºC) in lower Columbia River reservoirs and 17.8ºC (range 8.7-22.1 ºC) in lower Snake River reservoirs (Appendix B Tables 21-22). In 2000, 37-69% of fall Chinook encountered water temperatures ≥ 20 ºC in all reservoirs except the Little Goose reservoir (9%) (Table 17; Figure 31). Patterns were similar in 2002, with 31-86% of fish encountering 20 ºC water in all reservoirs except Lower Monumental (8%) and Little Goose (0%) (Table 18; Figure 32). Total times spent above the 20 ºC threshold were generally < 1 d in both years. The average consecutive number of days at temperatures ≥ 20 ºC ranged from <0.1 d (Little Goose) to 0.8 d (John Day) in 2000 and from <0.1 d (Lower Monumental) to 0.5 d (John Day) in 2002.

We found significant (*P*<0.0001) differences in fish temperatures between reservoirs in both years (Table 9). Average median fish temperatures were generally cooler at Snake River dams than at lower Columbia River dams, reflecting seasonal cooling during the fall Chinook salmon migration in both migration years (Figures 31 and 32; Appendix B Tables 27-28).

Steelhead

The average median steelhead temperatures in 2000 and 2002 were 17.7 ºC (range 6.2-22.8 ºC) in lower Columbia reservoirs and 17.2ºC (range 8.2-23.0 ºC) in lower Snake River reservoirs (Appendix B Tables 21-22). In 2000, steelhead encountered water temperature ≥ 20 ºC in all reservoirs with the percentages ranging from 37-55% in lower Columbia River reservoirs and from 15-27% in lower Snake River reservoirs (Table 17; Figure 33). Slightly more fish encountered ≥ 20 ºC water in 2002, with percentages ranging from 45-70% in lower Columbia and 22-31% in lower Snake reservoirs (Table 18; Figure 34). In both years, percentages generally decreased as fish progressed upstream indicating seasonal changes and relatively late arrival timing at Snake River dams. For those steelhead that encountered water ≥ 20 ºC in reservoirs, most were above this threshold for 0.5-2.0 d (Tables 17 and 18). Mean consecutive times above ≥ 20 ºC were generally < 1 d in each reservoir and ranged from 2.7 h (Little Goose) to 21.4 h (John Day) in 2000 and from 1.7 h (Little Goose) to 24.8 h (John Day) in 2002.

We found significant (*P*<0.0001) differences in steelhead temperatures between reservoirs in both years (Table 11), again reflecting migration timing differences but also the influence of cool water discharge from tributaries. Average median fish temperatures were consistently warmer in

The Dalles, John Day, McNary and Ice Harbor reservoirs than in Bonneville reservoir in 2000, likely a result of cool water tributary influence (Figure 33; Appendix B Table 29). Steelhead also tended to be cooler in Snake River reservoirs compared to in lower Columbia reservoirs in 2002, largely reflecting the effects of migration timing at these sites. In 2002, steelhead were coolest in the Bonneville reservoir and warmest in the John Day reservoir (Figure 34; Appendix B Table 30). In both years, sample sizes were much larger at lower river sites and fish migrating during the warmest times tended to fill up RDST storage before reaching upstream dams.

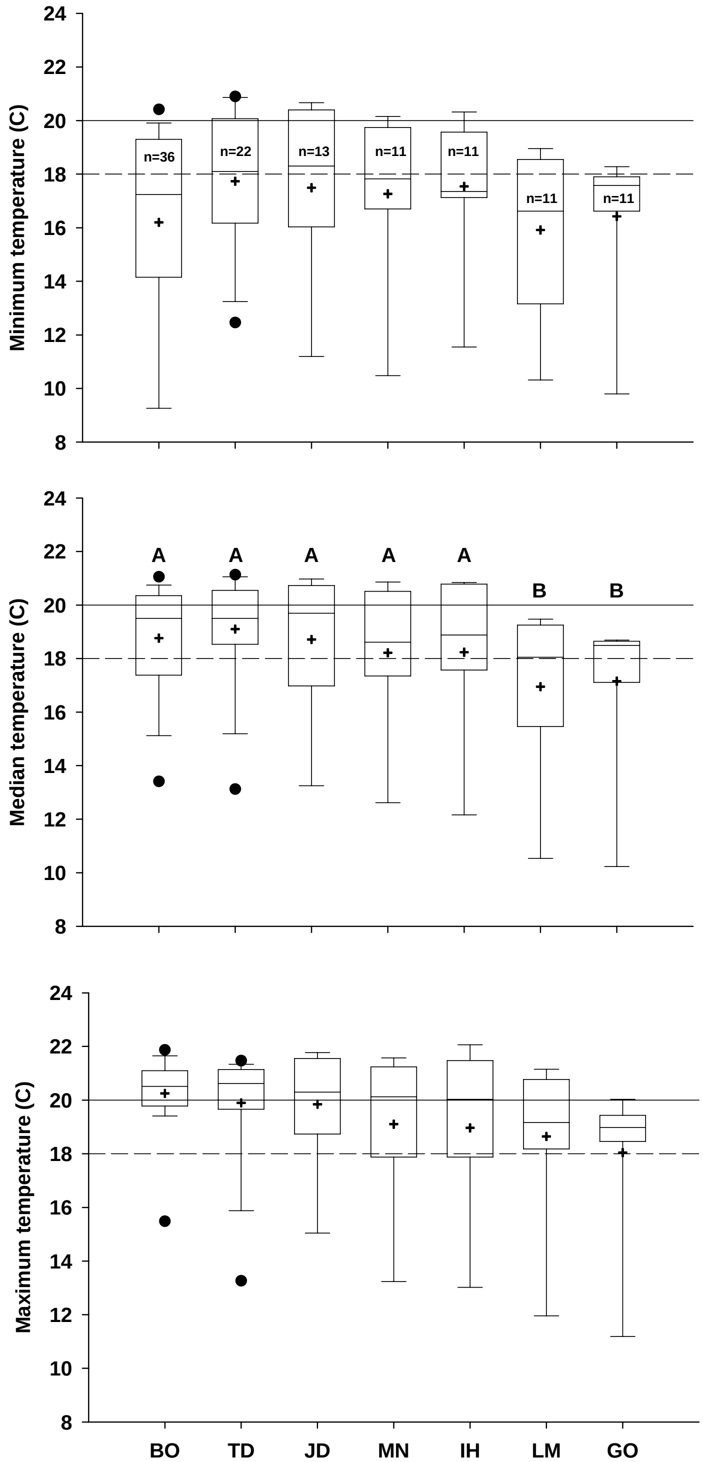


Figure 31. Fall Chinook salmon body temperature in reservoirs, 2000. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and three lower Snake River reservoirs in 2000. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; P=0.0004).

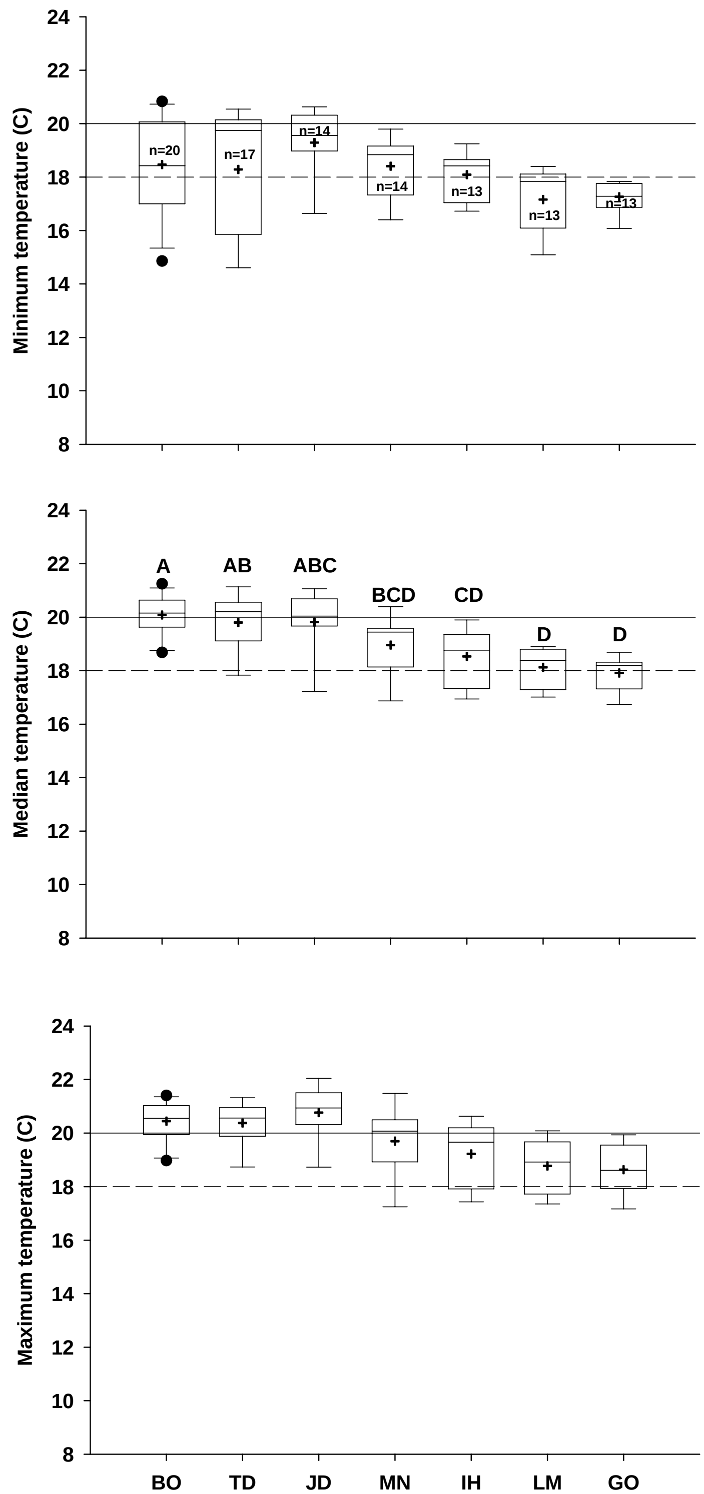


Figure 32. Fall Chinook salmon body temperature in reservoirs, 2002. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and three lower Snake River reservoirs in 2002. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; P=0.0004)

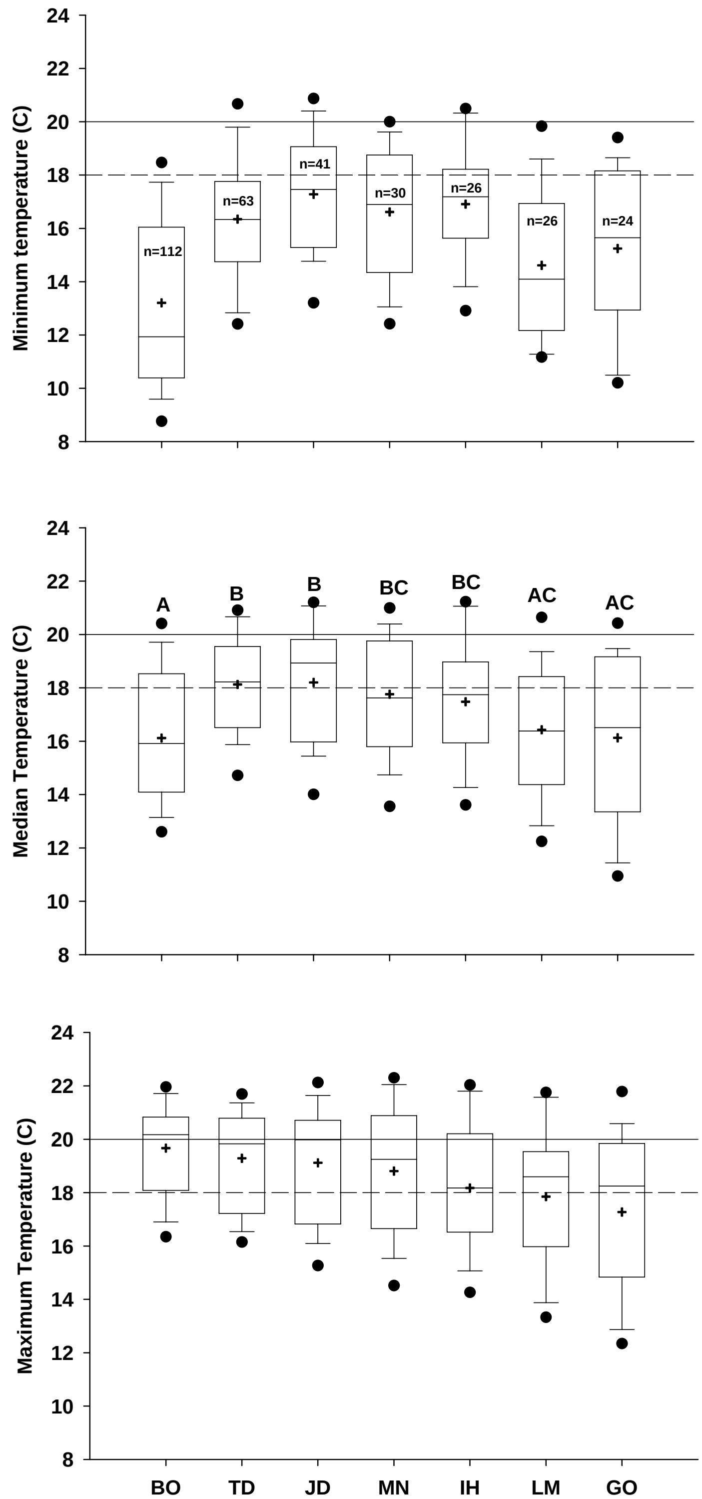


Figure 33. Steelhead body temperature in reservoirs, 2000. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and three lower Snake River reservoirs in 2000. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; P=0.0004)

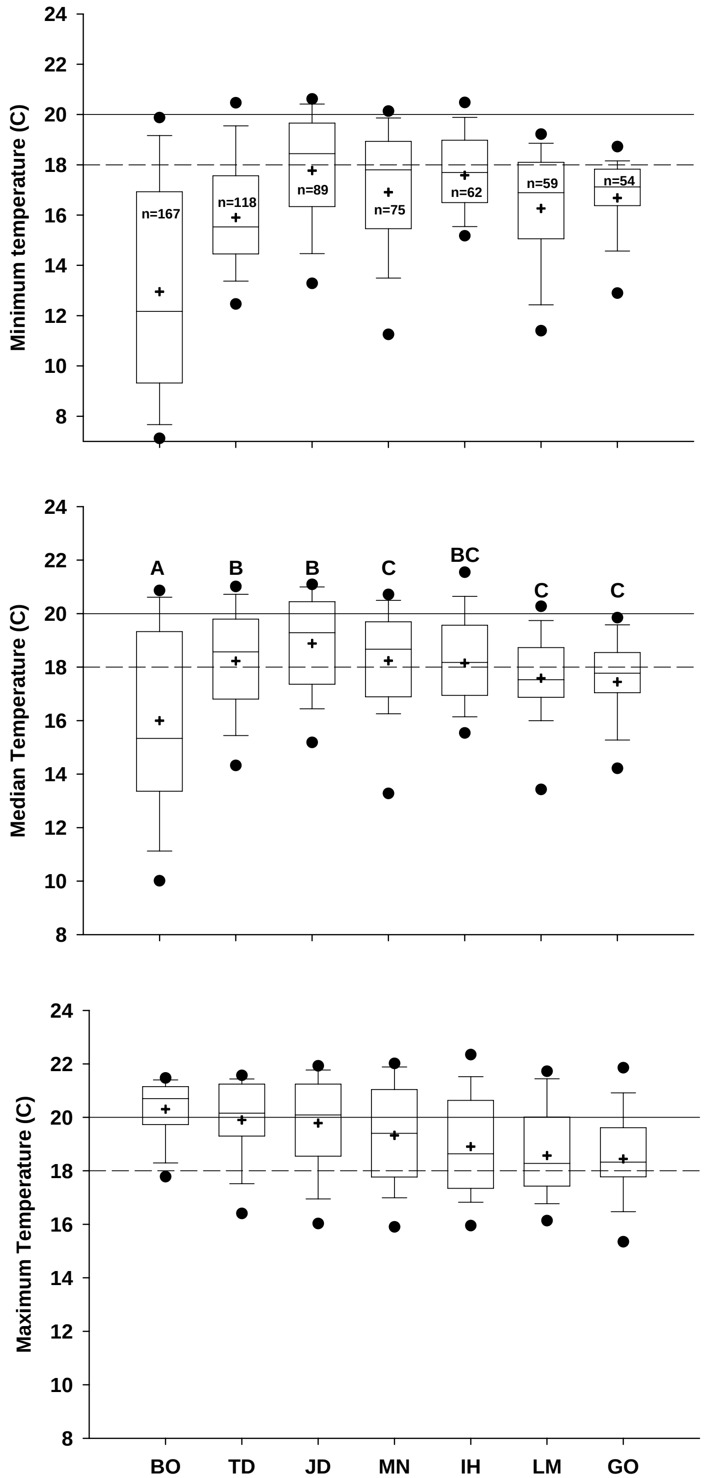


Figure 34. Steelhead body temperature in reservoirs, 2002. Means (crosses within boxes), medians (horizontal lines within boxes), quartiles (upper and lower bounds of boxes), 10th and 90th percentiles (ends of whiskers), and 5th and 95th percentiles (circles) of body temperatures during migration through the four lower Columbia River and three lower Snake River reservoirs in 2002. Medians that are significantly different are indicated by different letters (Turkey's post hoc test with Dunn-Sidak correction; P=0.0004).

Stock-specific ladder temperatures

The preceding sections summarized the temperature histories of RDST-tagged fish at individual sites, but with all fish within each run pooled together. This type of grouping gives an incomplete picture of the patterns individual populations experienced during migration because all stocks within a run were combined despite often substantial differences in run timing. Separation of the temperature results by stock (e.g., Figures 35-37) more clearly shows the importance of seasonal patterns within year as well as inter- and intra-population variability within each run.

For these summaries, stocks were selected based on final fish locations within major tributaries or spawning areas; these groups potentially included multiple spawning aggregations that could be considered separate stocks (i.e., further refinement was possible but sample sizes were limiting). Only sites with relatively large numbers of fish were included (see Table 2). Presented results are for median temperatures in dam ladders, but patterns were generally similar in tailrace and reservoir environments.

Several patterns were evident for spring Chinook salmon (Figure 35). Most spring Chinook experienced warmer temperatures in 2000 than in 2002 and this was consistent across stocks. In each year, temperatures generally increased as each population progressed upstream coincident with spring warming. In addition, among-stock differences in median temperatures at individual dams were often more than 2 ºC, reflecting migration timing differences at each site. Finally, some stocks like the Salmon River group showed much more variability within year than others (e.g., Grande Ronde or upper Columbia), almost certainly reflecting greater stock diversity.

Summer Chinook salmon stocks also experienced increasing temperatures in ladders as they progressed upstream and all groups encountered generally cooler ladders in 2002 (Figure 36). As with the spring groups, median temperature differences among stocks often differed by 2 ºC or more at individual dams. The later-timed upper Columbia summer stocks encountered much warmer temperatures than those returning to Snake River sites.

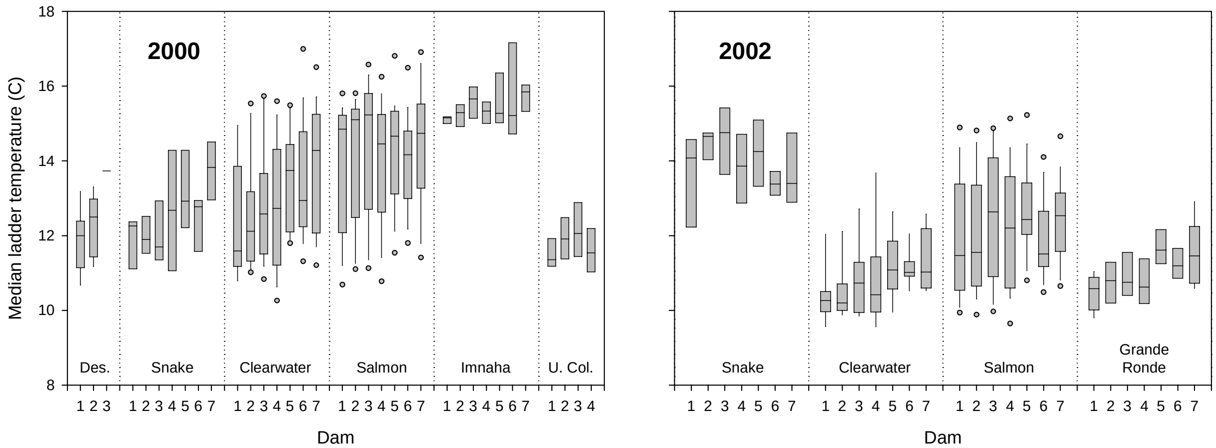


Figure 35. Selected stock-specific distributions of the median temperatures RDST-tagged spring Chinook salmon encountered while ascending ladders at dams. Dam numbers: 1) Bonneville, 2) The Dalles, 3) John Day, 4) McNary, 5) Ice Harbor, 6) Lower Monumental, and 7) Little Goose. The 'Snake' stock includes all fish that passed Lower Granite Dam but were not recorded in tributaries.

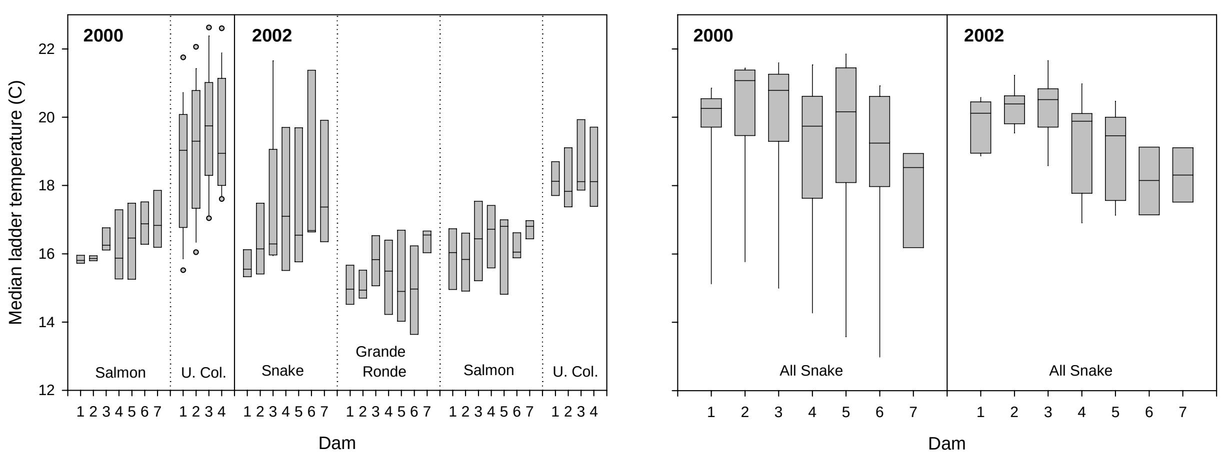


Figure 36. Selected stock-specific distributions of the median temperatures RDST-tagged summer Chinook salmon (left figure) and fall Chinook salmon (right figure) encountered while ascending ladders at dams. Fall Chinook summary includes all fish last recorded upstream from Ice Harbor Dam, a mixture of Lyons Ferry, Clearwater River, and Snake River groups. Dam numbers: 1) Bonneville, 2) The Dalles, 3) John Day, 4) McNary, 5) Ice Harbor, 6) Lower Monumental, and 7) Little Goose.

Due to small sample sizes, only one fall Chinook salmon 'stock' was identified, and it included all fish that returned to the Snake River basin. Most of these fish returned to the Clearwater River, to the Snake River mainstem upstream from Lower Granite reservoir, or were last recorded in reservoirs. Ladder temperatures for Snake River fish generally tracked seasonal patterns (Figure 36), with cooler temperatures encountered at Snake River dams compared to at lower Columbia River dams.

Ladder temperature patterns for individual steelhead stocks indicated that this run generally encountered warmer temperatures in 2002 than in 2000 (Figure 37). Steelhead temperature distributions at individual sites were quite variable, reflecting the protracted migrations for this run even within population. Clearwater steelhead, generally considered later migrants, tended to have cooler temperatures than the earlier-timed Grande Ronde and Salmon groups while the 'Snake' stock was intermediate. The latter included a mix of stocks, but were not detected inside tributaries after passing Lower Granite Dam (many were not retagged after RDSTs were removed). Finally, an important caveat to the steelhead stock results is that many fish migrating during the warmest periods in each year did not have complete temperature histories because RDSTs were filled. As a result, these results are biased towards fish migrating during cooler periods (generally early and late in migrations), especially at the Snake River sites.

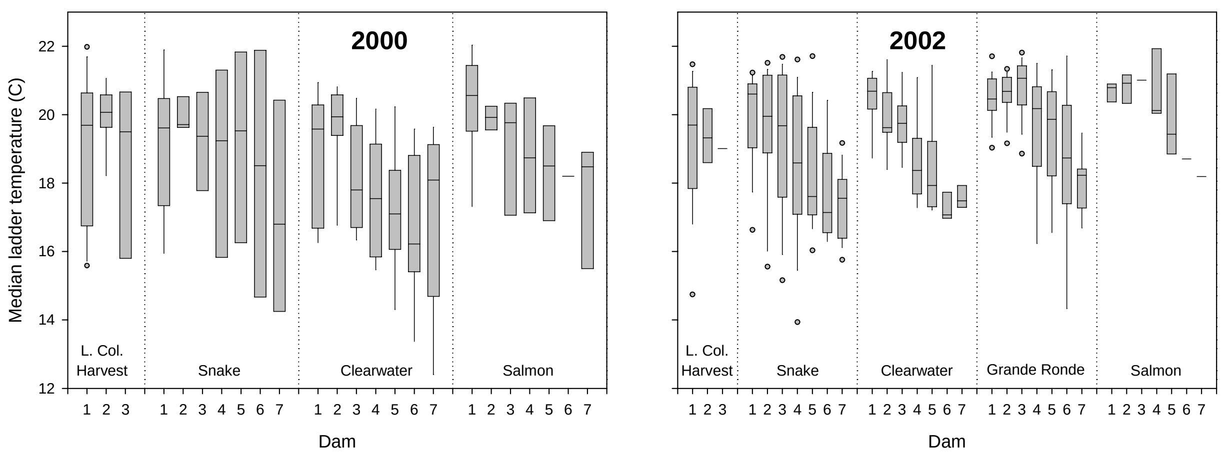


Figure 37. Selected stock-specific distributions of the median temperatures RDST-tagged steelhead encountered while ascending ladders at dams. Dam numbers: 1) Bonneville, 2) The Dalles, 3) John Day, 4) McNary, 5) Ice Harbor, 6) Lower Monumental, and 7) Little Goose. Note: relatively few steelhead migrating at the warmest times reached Snake River dams with available RDST storage space and as a result samples were skewed toward fish migrating during cooler times.

Final fates

We indirectly tested for temperature-dependent mortality and the potential for bias in the sample causing underestimation of body temperature by examining associations between run-timing and fate of salmon and steelhead. We compared distributions of tag date between successful and unsuccessful Chinook salmon (Figures 38-41) using logistic regression, and qualitatively compared steelhead distributions (Figure 41). All fish reported harvested in the mainstem Columbia or Snake rivers were excluded. After combining both years for each species, there was a significant difference between years and a significant year×tag date interaction for summer Chinook salmon (P=0.0006) and fall Chinook salmon (P=0.031); therefore, years were analyzed individually. Unsuccessful summer Chinook salmon were tagged significantly later in the season in 2000, consistent with a temperature-dependent mortality hypothesis, but significantly earlier in 2002 (Figure 39). Unsuccessful fall Chinook salmon were tagged significantly later in 2000 (Figure 41), contrary to the prediction of higher mortality early in the run season in this stock.

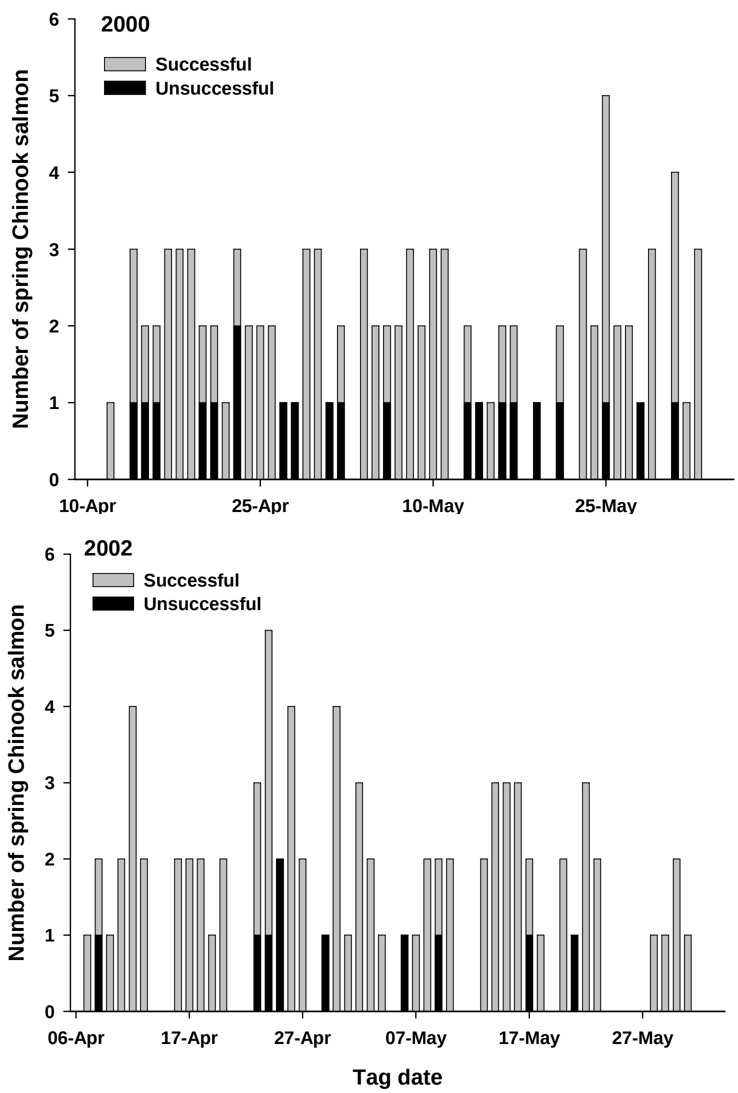
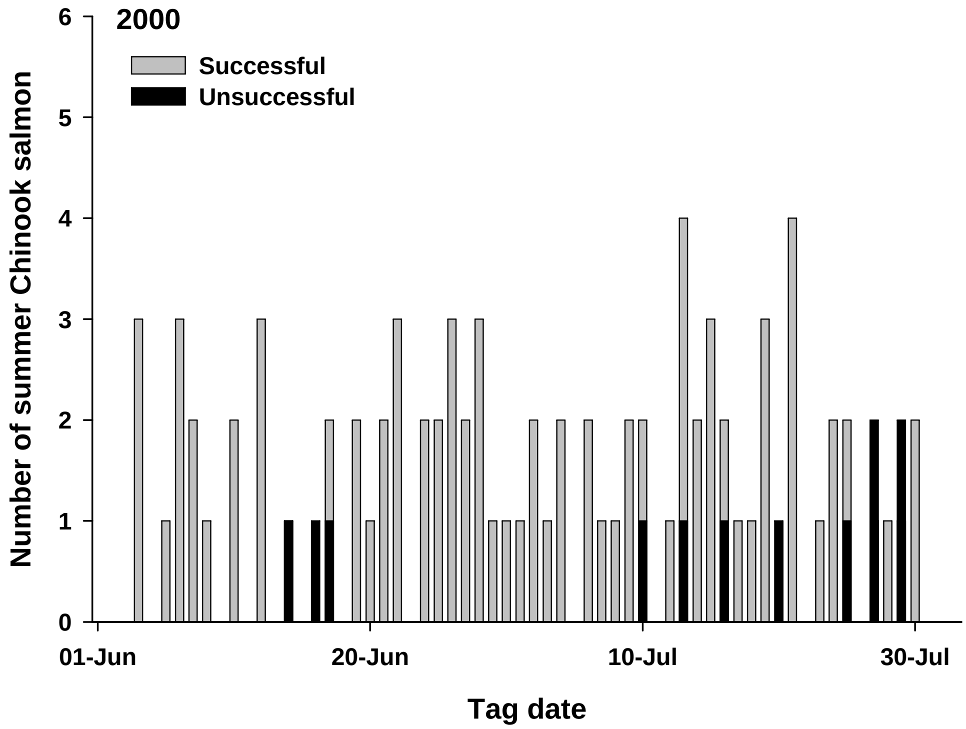


Figure 38. Final fates of RDST spring Chinook salmon by tag date in 2000 and 2002.



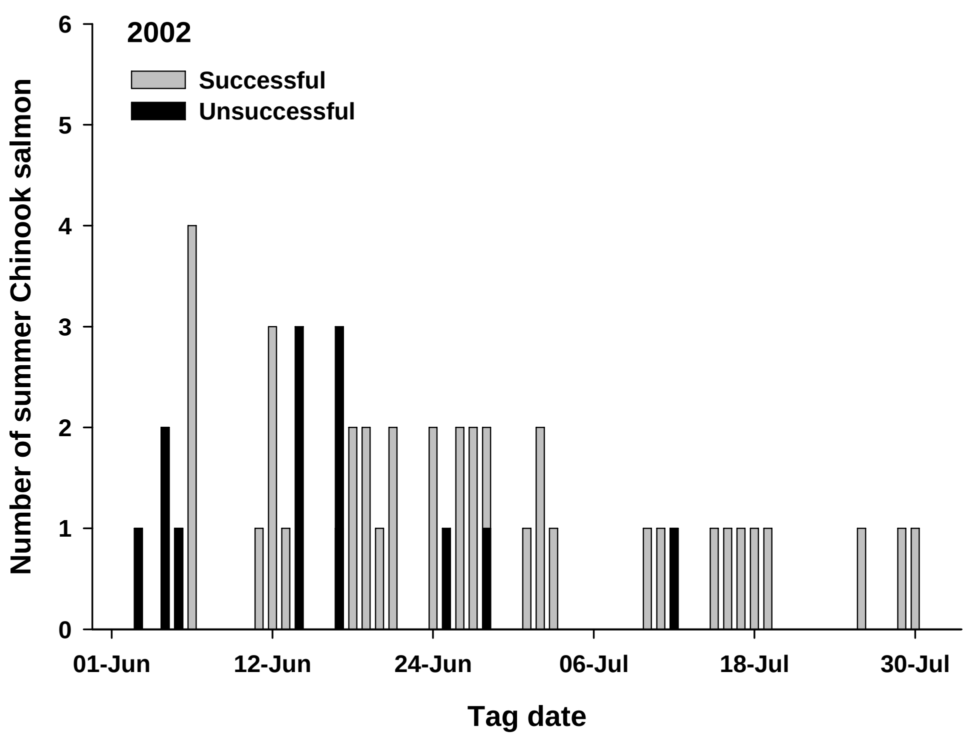


Figure 39. Final fates of RDST summer Chinook salmon by tag date in 2000 and 2002.

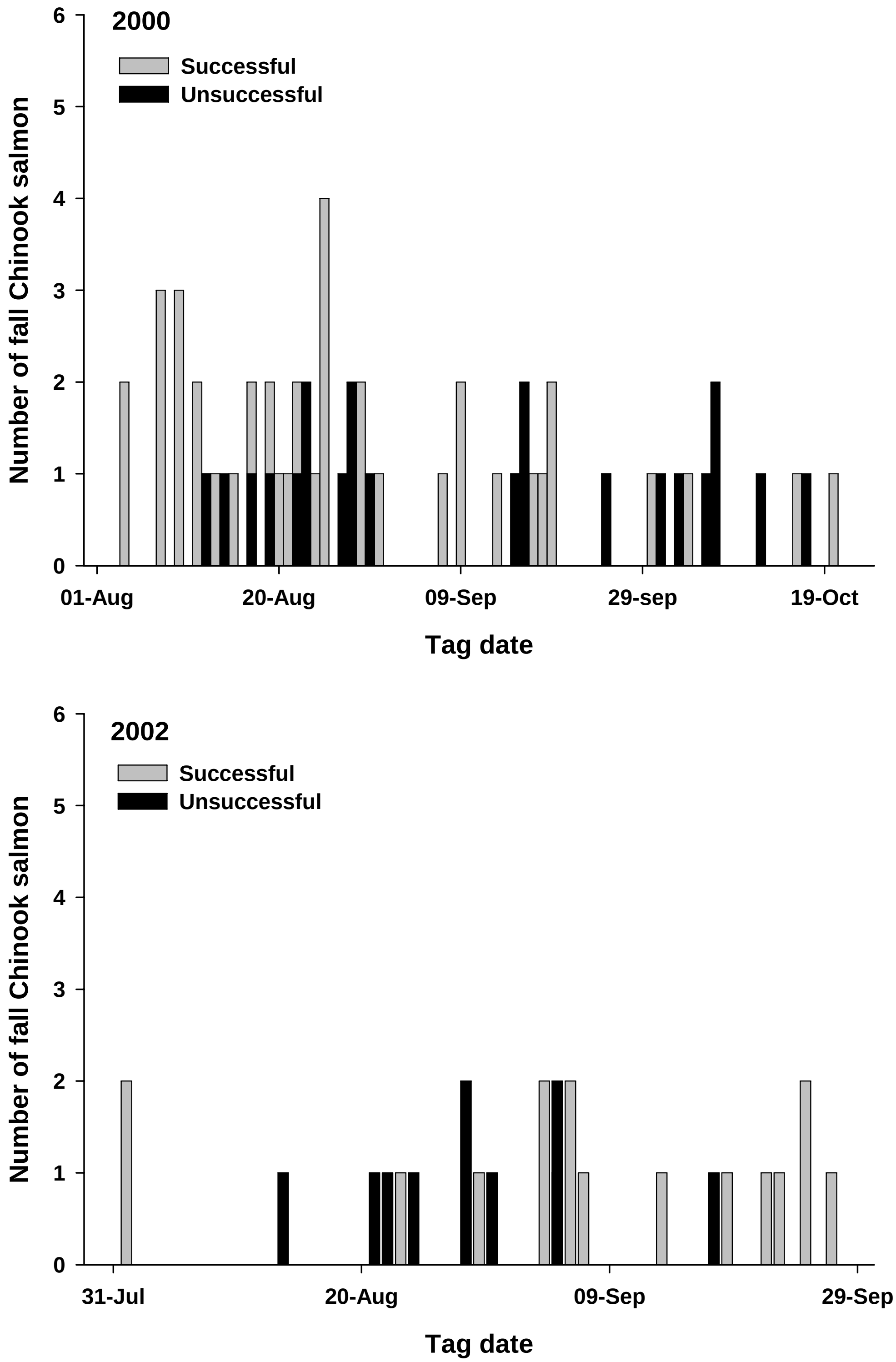
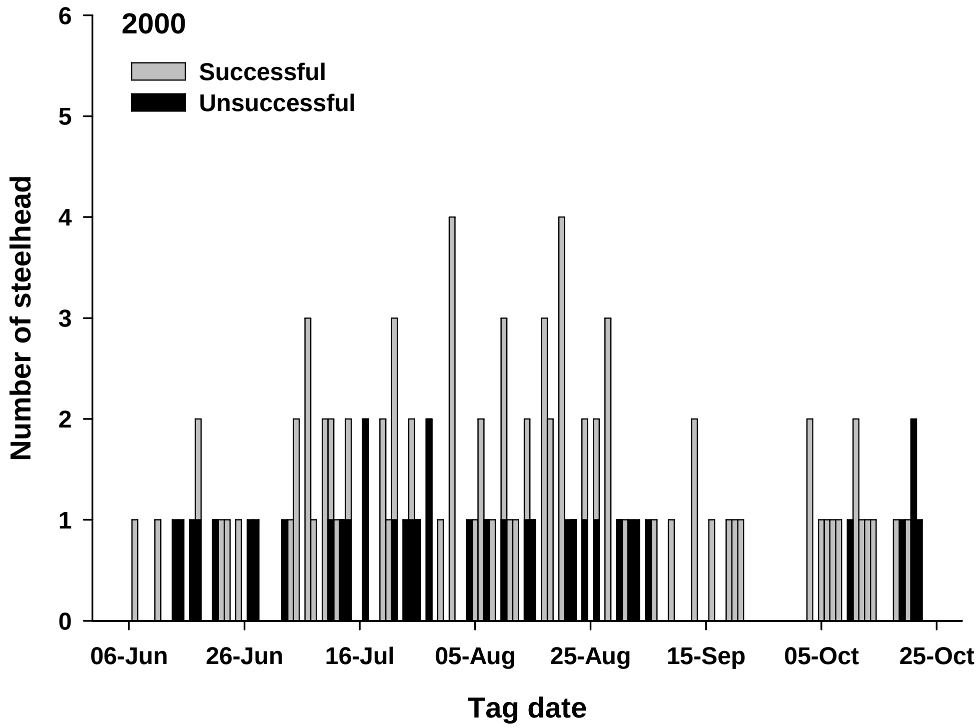


Figure 40. Final fates of RDST fall Chinook salmon by tag date in 2000 and 2002.



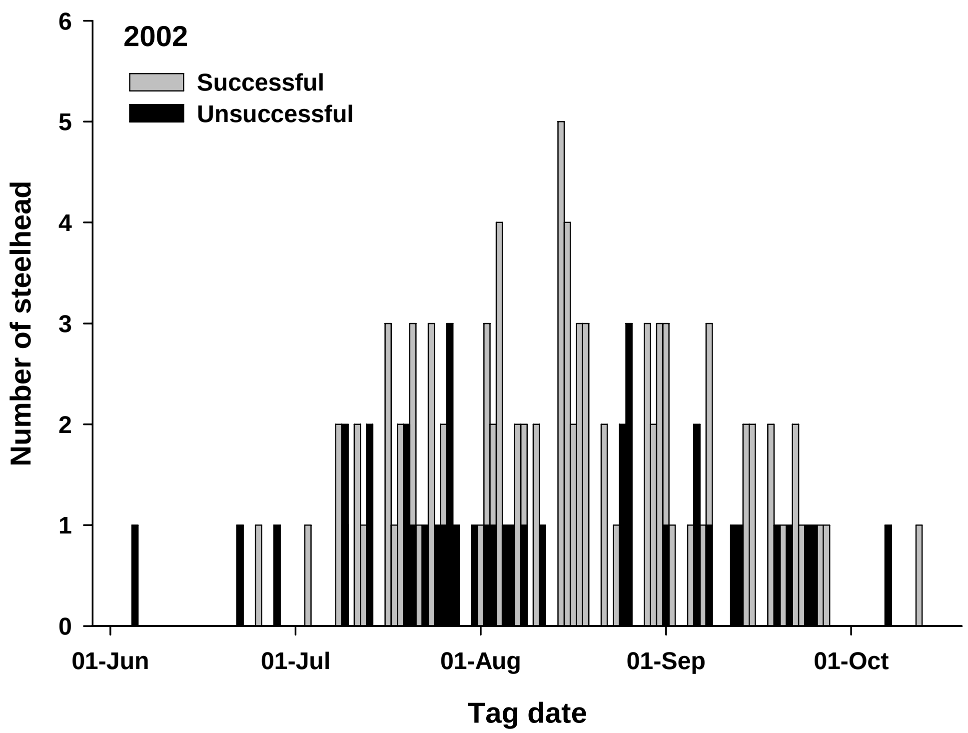


Figure 41. Final fates of RDST steelhead by tag date in 2000 and 2002.

Discussion

The combined use of radiotelemetry and temperature data storage tags in this study provided unprecedented continuous temperature histories for the upstream migrations of adult Chinook salmon and steelhead. Data storage tags have been used to reconstruct thermal histories of salmonids in the ocean (e.g., Walker et al. 2000; Friedland et al. 2001; Reddin et al. 2004; Azumaya and Ishida 2005) and in lakes (Newell and Quinn 2005) but use of the technology has been rare in rivers. Our focus here was on describing adult body temperatures as they moved upstream through the tailraces, ladders and reservoirs of the Columbia-Snake Hydrosystem, and on quantifying the time fish spent migrating in potentially stressful thermal conditions. In general, adult body temperatures tracked seasonal patterns in environmental temperature conditions among Hydrosystem sections, though many fish moved into cooler tributaries and tributary plumes during warm periods. We restricted analyses on the environments where tagged fish were unlikely to be thermoregulating (e.g., tailraces, ladders, and reservoirs) because of the potential for Hydrosystem management activities to more directly affect migrants in these areas.

The observed differences in adult body temperature among hydrosystem sections were consistent with patterns of environmental temperatures that were probably present in tailraces, ladders and reservoirs. Seasonal temperature variations were much larger than interannual differences, with the warmest temperatures usually occurring in July, August, and September in each year. Therefore, conditions experienced by salmon and steelhead were strongly dependent on run timing. Summer Chinook salmon, early fall Chinook salmon and steelhead experienced the highest body temperatures during their upstream migration. Within these runs, the temperatures encountered by individual stocks were quite variable within year. For example, upper Columbia River summer Chinook salmon experienced much warmer conditions than the earlier-timed summer-run fish returning to the Snake River basin. Similarly, early (‘A-group) steelhead migrating in July-August tended to experience warmer temperatures than later (‘B-group’) fish migrating later in the fall.

Body temperature in adult salmonids reflects both environmental conditions and behavioral thermoregulation, whereby body temperature departs from the average environmental condition as individuals select areas with preferred temperatures (Berman and Quinn 1991; Clabough et al. 2006, 2007). The scope for behavioral thermoregulation in the Columbia-Snake hydrosystem is greatest in reservoirs where individual adults can select among water masses differing by as much as 5 °C by moving vertically in the water column (Cook et al. 2006; Caudill et al. 2006) or by seeking cooler tributary sources (Goniea et al. 2006; High et al 2006). In vertically well-mixed tailraces and ladders, there is little opportunity for behavioral thermoregulation and body temperature appears to equilibrate to surrounding conditions relatively rapidly (e.g., during ladder passage, Caudill et al. 2006). Thus, the observed pattern of relatively lower body temperatures in some reservoirs (e.g., Bonneville and The Dalles) appears to have been related to the higher range of temperatures available there, and the commensurate increase in opportunities for temperature selection and thermoregulation, compared to in ladders and tailraces. Notably, all runs experienced slightly higher water temperatures in fish ladders compared to tailrace and reservoir sites. This may have been because many ladders receive warm forebay surface water during summer (Caudill et al. 2006) and because adults are far more likely to pass ladders during daytime (Keefer et al. 2004).

Although salmon and steelhead were exposed to relatively higher temperatures in fish ladders, the time fish spent in ladders was relatively short. This does not imply that ladder temperatures are unimportant. The cumulative temperature effects of short, consecutive periods of time spent at warm temperatures are unknown, and ascending fish ladders is energetically demanding for salmonids, especially compared to reservoir passage (Brown et al. 2002). Elevated temperatures in ladders also appear to present partial thermal barriers for adult passage in some cases (e.g., Keefer et al. 2003) and may increase the already-high energetic cost associated with passage. Thermal barriers in ladders may also inhibit dam passage resulting in fish overnighting at dams and fish switching between ladders while searching for a passage route (Caudill et al. 2006).

As might be expected, the detailed temperature histories for RDST-tagged fish at and near dams showed considerably more variability than the mean values collected at the water quality monitoring (WQM) sites. Direct comparisons of RDST and WQM temperatures were beyond the scope of this report. However, a cursory qualitative evaluation suggests that fish body temperatures were typically warmer than reported WQM temperatures, particularly in ladders. Further review of these data may be useful for calculating correction factors for WQM data so that they can be used for more accurately estimating adult temperature exposures at dams.

Although 2000 and 2002 were relatively cool years by recent standards, we observed body temperatures ≥ 20 ºC for many fish, including majorities of fall Chinook salmon and steelhead.

Adults migrating during warm water periods frequently experienced body temperatures considered suboptimal (> 18 °C) or physiologically stressful (≥ 20 °C), potentially increasing the metabolic and survival costs of migration, increasing exposure and susceptibility to disease, decreasing reproductive potential, and contributing to delayed effects such as upstream prespawn mortality.

While our study was not designed to evaluate the consequences of migration through high temperature on adult salmonids, available literature suggests several potential negative effects. Previous studies have shown that spring and summer Chinook salmon tend to migrate faster within years as water temperature increases, while fall Chinook and steelhead typically slow their migration during warm and peak temperatures (Keefer et al. 2004; High et al. 2004; Goneia et al. 2006). Additional models of adult passage rates also suggest slowed migration rates at temperatures above ~17 °C and optimal temperatures near 16 °C (Salinger and Anderson 2006). Energetic costs at higher temperatures have been reasonably well described (e.g., Rand and Hinch 1998; Lee et al. 2003; Crossin et al. 2004; Hinch et al. 2006). Disease incidence and severity also increase with temperature, including several important salmon parasitic and bacterial infections associated with elevated *en route* and prespawn mortality (Colgrove and Wood 1966; Gilhousen 1990; Cooke et al. 2004; St-Hilaire et al. 2002). Reproductive effects related to warm temperatures include delayed ovulation (Taranger and Hansen 1993) and molecular changes in egg development (Jobling et al. 1995; King et al. 2003). Low hatch rate of Lake Erie coho salmon was linked to warm water temperatures affecting ovulation and egg maturation (Flett et al. 1996). In the Columbia-Snake system, high temperatures have been associated with high mortality rates in sockeye salmon (Hyatt et al. 2003; Naughton et al. 2005; Keefer et al. *in press*) and Chinook salmon (Schreck et al. 1994; Pinson 2005). In light of these pervasive temperature effects, the current RDST results highlight the potential importance of assessing whether short-term increases in body temperature at multiple projects or chronic exposure to suboptimal and/or stressful temperatures affect reproductive development and adult fitness upstream.

Our sample of temperature histories had some important potential biases. The most significant of these was that many tagged fish migrating during the warmest time exhausted storage space on their RDST prior to reaching Lower Granite Dam or other tag recovery sites. This was especially true for steelhead because of their tendency for extended migration delays related to thermoregulation. We knew of this limitation prior to the study, but opted for 1-minute temperature intervals in order to collect high resolution data at and near dams. Future RDST studies could collect proportionately more full-migration temperature histories by reducing the data collection interval and/or excluding the atmospheric pressure component. The important consequences of this data storage limitation were that we likely underestimated both the duration of time some fish spent at or above stressful temperature thresholds and the proportions of each run that encountered these temperatures. This was particularly true at upstream sites, as most thermoregulatory behavior occurs in tributaries between Bonneville and John Day dams (Keefer et al. 2004; Goniea et al. 2006; High et al. 2006).

A third bias was that we selected for Snake River stocks to increase the likelihood or RDST recovery. For this reason, results should not be extrapolated to the runs at large. Fortunately, Snake River stocks are generally well mixed in the runs passing Bonneville Dam and we believe the results are broadly representative. The stock-specific results within run point to the importance of run timing and the variability among populations, and these patterns should be considered when making inferences about temperature exposures in the system.

Another possible, though less critical, bias was that we expected but could not confirm higher mortality in adults experiencing the highest temperatures (e.g. Naughton et al. 2005; Keefer et al. *in press*). However, RDSTs had to be physically recovered to obtain temperature data and it was therefore possible for non-random loss of RDST data. Adults experiencing the highest temperatures may have been excluded from the sample because they died *en route* to Lower Granite Dam or other collection sites. We tested for this possibility indirectly by examining fate throughout the run seasons, but found no consistent evidence of unsuccessful migration in late-run spring or summer Chinook salmon experiencing relatively high temperatures. Non-harvest mortality in these runs was higher late in one year, but earlier in the other year. Similarly, we found no evidence that mortality was higher among adult fall Chinook salmon that entered the hydrosystem relatively early, when temperatures were highest—the only seasonal trend in mortality was higher non-harvest mortality *later* in the 2000 fall Chinook salmon run. Overall, the patterns between fate groups provided little evidence that higher mortality in RDST-tagged adults migrating during the warmest periods seriously biased the estimates of body temperature during the two study years. However, we caution that such mortality may have contributed to underestimation of average experienced temperature in some cases (e.g., summer Chinook salmon in 2000), and that temperature-dependent mortality may be higher in warmer years (e.g., 2003). It is also likely that temperature tolerances differ among stocks (e.g., Lee et al. 2003). For example, thermal optima and limits in fall Chinook salmon are almost certainly higher than for spring-run groups, particularly for the Snake River population which probably experienced warm temperatures early in their runs historically. Clearly, knowledge of stock-specific differences in temperature optima and limits could aid in interpreting results. Finally, direct evidence for temperature-dependent effects may be possible with greater samples sizes, measuring reproductive success for fish with known temperature histories (e.g., for RDST fish recaptured at hatcheries), or by developing temperature exposure estimation techniques for unrecovered RDST tags (e.g., calibrating using successful fish and radiotelemetry data).

The management of temperature conditions will probably become increasingly important to recovery efforts in coming decades. Changes in the hydrograph and warming temperatures have caused run timing changes in several Columbia River salmonids (Quinn and Adams 1996; Robards and Quinn 2002; Goniea et al. 2006; Keefer et al. *in press*). With increasing global temperatures, fish habitat will be lost (e.g., Meisner 1990; Keleher and Rahel 1996) and migration conditions for anadromous stocks may become constricted for some populations. In the Klamath River basin, for example, conditions for salmonids have steadily deteriorated since the 1960s; it is estimated that temperatures have been increasing by 0.5 ºC per decade and the average length of mainstem river with cool summer temperatures has decreased by 8.2 km per decade (Bartholow 2005). Importantly, climate projections for the interior Pacific Northwest predict higher summer temperatures, less winter snowpack, and consequently, longer, warmer summers with lower stream flows (e.g., Mote et al. 2005, Stewart et al. 2005). These projections suggest a greater proportion of returning adult summer and fall Chinook salmon and steelhead will experience stressful temperatures as they ascend the Columbia-Snake hydrosystem and that increased management of the thermal regime may be required.

Management concerns should include John Day Dam where fall Chinook and steelhead body temperatures were warmest. The John Day project is of particular concern because its reservoir is the longest (123 rkm) of the Columbia River reservoirs and only receives input from warm water tributaries. The Snake Rivers dams are also of concern because water temperatures are warmer in the Snake than in the lower and upper Columbia River. Possible measures to reduce stressful water temperatures during the adult salmon and steelhead migration in the Columbia and Snake rivers may include cold water releases from upstream dams and pumping cold water into fish ladders. Cooling of the Snake River from cold water releases from Dworshak Dam has provided some thermal relief from warm waters typically experienced by adult salmon and steelhead migrating in Lower Granite Reservoir (Clabough et al. 2006, 2007). Water temperatures in fish ladders of the Columbia and Snake River dams, particularly at John Day and Lower Granite dams (Caudill et al. 2006), would likely benefit from cold water being pumped into ladders during warm summer months.

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Appendix A

We integrated depth and temperature recordings from RDST tags with telemetry records using a Visual Basic program (Fishdata.exe). Pressure was converted to depth (pressure /9.79 KPa). Each RDST tag was corrected for time drift using a polynomial provided by Lotek Wireless, Inc. The fishdata.exe program labeled depth and temperature records with locations of telemetry records that fell within 30 minutes of a telemetry record.

Fishdata.exe

```
Option Explicit
Const cDepthConv As Double = 1.42
Const cSecondsPerDay = 86400
Const cRF1 As String = "0.00000"
Const cRF2 As String = "0.00"

Dim miPFile As Integer
Dim miTFile As Integer
Dim miTeleFile As Integer
Dim miO5sFile As Integer
Dim miO1mFile As Integer
Dim miO1hFile As Integer
Dim miCombinedFile As Integer
Dim miDataFiles As Integer
Dim miTempTemperatureFile As Integer
Dim miTempPressureFile As Integer
Dim miTempCombinedFile As Integer
Dim miReservoirFile As Integer
Dim miDriftFile As Integer

Dim mbStop As Boolean

Private Sub MergeFiles()

Dim sDST As String
Dim sPLine As String
Dim sTeleLine1 As String
Dim sTeleLine2 As String
Dim stDate1, stDate2 As Variant
Dim stTime1, stTime2 As Variant
Dim sTAnten1, stAnten2 As Variant
Dim stSite1, sTSite2 As Variant
Dim sDate As String
Dim sTime As String
Dim sPreviousSecond As String
Dim sSecond As String
Dim sMinute As String
Dim rPress As Double
Dim rDepth As Double
Dim sTLine As String
Dim sOLine As String
```

```
Dim rTemp As Double
Dim rSumDm As Double
Dim rSumDh As Double
Dim rSumTh As Double
Dim rSumD2m As Double
Dim rSumD2h As Double
Dim rSumT2h As Double

Dim rAvgDm As Double
Dim rAvgDh As Double
Dim rAvgTh As Double

Dim rVarDm As Double
Dim rVarDh As Double
Dim rVarTh As Double

Dim iNDm As Long
Dim iNDh As Long
Dim iNTh As Long
Dim sElapsedTime As String
Dim dStartTime As Date
Dim iCount As Long
Dim intX As Integer
Dim intTemp As Integer
Dim intOutputCount As Long
Dim intBounceNumber As Integer
Dim intBounceDirection As Integer
Dim intDepthOffset As Integer
Dim intTempOffset As Integer

Dim sTEMP As String
Dim iTemp As String
Dim dTemp As Date
Dim strTelemDate1 As String
Dim strTelemTime1 As String
Dim strTelemAntenna1 As String
Dim strTelemSite1 As String
Dim strTelemDate2 As String
Dim strTelemTime2 As String
Dim strTelemAntenna2 As String
Dim strTelemSite2 As String
Dim strTelemAntennaTemp As String
Dim strTelemSiteTemp As String
Dim strTemp As String
Dim strTempOut As String
Dim strCorr As String
Dim strPower As String
Dim strRKM As String
Dim strJTag As String
Dim strCorr2 As String
Dim strPower2 As String
Dim strRKM2 As String
Dim strJTag2 As String
Dim strCorrTemp As String
Dim strPowerTemp As String
Dim strRKMTemp As String
```

```
Dim strJTagTemp As String
Dim strTelem1Line As String
Dim strTelem2Line As String
Dim strTempDate As String
Dim strTempTime As String
Dim strTempDateOne As String
Dim strTempTimeOne As String
Dim strSpaces As String

Dim blnFirstRecordWait As Boolean
Dim blnOutputTelem2 As Boolean

Dim varAnything As Variant

Dim Pinball(50) As String

strSpaces = ""
For varAnything = 1 To 20
   Pinball(varAnything) = strSpaces & "J"
   strSpaces = strSpaces & " "
Next varAnything

dStartTime = Now
mbStop = False
iNDm = 0
iNDh = 0
iNTh = 0
iCount = 0
rSumDm = 0#
rSumD2m = 0#
rSumDh = 0#
rSumD2h = 0#
rSumTh = 0#
rSumT2h = 0#

intBounceNumber = 0
intBounceDirection = 1

blnOutputTelem2 = True

sDST = txtDST

If Right(txtInputFolderName.Text, 1) <> "\" Then
   txtInputFolderName.Text = txtInputFolderName.Text & "\"
End If
If Right(txtOutputFolderName.Text, 1) <> "\" Then
   txtOutputFolderName.Text = txtOutputFolderName.Text & "\"
End If


' Read first telemetry file record
If Not EOF(miTeleFile) Then
   Line Input #miTeleFile, sTEMP
   Call CheckForTagRecap(sTEMP)
End If
```

```
        If Not EOF(miTeleFile) Then
          strTelemDate1 = Format(CDate(GetField(sTEMP, 3)), "mm/dd/yyyy")
          strTelemTime1 = Format(CDate(GetField(sTEMP, 4)), "hh:mm:ss")
          strTelemAntenna1 = CStr(GetField(sTEMP, 5))
          strTelemSite1 = CStr(GetField(sTEMP, 6))

          strCorr = GetField(sTEMP, 7)
          strPower = GetField(sTEMP, 8)
          strJTag = GetField(sTEMP, 10)
          strRKM = GetField(sTEMP, 9)

          strTelemAntennaTemp = strTelemAntenna1
          strTelemSiteTemp = strTelemSite1
          strCorrTemp = strCorr
          strPowerTemp = strPower
          strRKMTemp = strRKM
          strJTagTemp = strJTag

          strTelem1Line = sDST & "," & txtChannel.Text & "," & txtCode.Text & "," & txtSpecies.Text & "," &
Format(CDate(GetField(sTEMP, 3)), "mm/dd/yyyy") & "," & Format(CDate(GetField(sTEMP, 4)), "hh:mm:ss") &
"," & _
          CStr(GetField(sTEMP, 5)) & "," & CStr(GetField(sTEMP, 6)) & "," & GetField(sTEMP, 7) & "," &
GetField(sTEMP, 8) & "," & GetField(sTEMP, 9) & "," & GetField(sTEMP, 10) & ",,"

          blnFirstRecordWait = True
        End If

        ' Output record if it is a Mobile Track record, otherwise assign to Telemetry1 variables
        Do While UCase(GetField(sTEMP, 7)) = "MBT"
         sOLine = sDST & "," & txtChannel.Text & "," & txtCode.Text & "," & txtSpecies.Text & "," &
Format(CDate(GetField(sTEMP, 3)), "mm/dd/yyyy") & "," & Format(CDate(GetField(sTEMP, 4)), "hh:mm:ss") &
"," & _
         CStr(GetField(sTEMP, 5)) & "," & CStr(GetField(sTEMP, 6)) & "," & GetField(sTEMP, 7) & "," &
GetField(sTEMP, 8) & "," & GetField(sTEMP, 9) & "," & GetField(sTEMP, 10) & ",,"
         Print #miCombinedFile, sOLine
         Line Input #miTeleFile, sTEMP

          strTelemDate1 = Format(CDate(GetField(sTEMP, 3)), "mm/dd/yyyy")
          strTelemTime1 = Format(CDate(GetField(sTEMP, 4)), "hh:mm:ss")
          strTelemAntenna1 = CStr(GetField(sTEMP, 5))
          strTelemSite1 = CStr(GetField(sTEMP, 6))

          strCorr = GetField(sTEMP, 7)
          strPower = GetField(sTEMP, 8)
          strJTag = GetField(sTEMP, 10)
          strRKM = GetField(sTEMP, 9)

          strTelemAntennaTemp = strTelemAntenna1
          strTelemSiteTemp = strTelemSite1
          strCorrTemp = strCorr
          strPowerTemp = strPower
          strRKMTemp = strRKM
          strJTagTemp = strJTag
```

```
        strTelem1Line = sDST & "," & txtChannel.Text & "," & txtCode.Text & "," & txtSpecies.Text & "," & 
Format(CDate(GetField(sTEMP, 3)), "mm/dd/yyyy") & "," & Format(CDate(GetField(sTEMP, 4)), "hh:mm:ss") & 
"," & _
        CStr(GetField(sTEMP, 5)) & "," & CStr(GetField(sTEMP, 6)) & "," & GetField(sTEMP, 7) & "," & 
GetField(sTEMP, 8) & "," & GetField(sTEMP, 9) & "," & GetField(sTEMP, 10) & ",,"

        blnFirstRecordWait = True
      Loop
      Call CheckForTagRecap(sTEMP)

      ' Read second telemetry file record
      If Not EOF(miTeleFile) Then
        Line Input #miTeleFile, sTEMP
        Call CheckForTagRecap(sTEMP)
      End If

      If Not EOF(miTeleFile) Then
        strTelemDate2 = Format(CDate(GetField(sTEMP, 3)), "mm/dd/yyyy")
        strTelemTime2 = Format(CDate(GetField(sTEMP, 4)), "hh:mm:ss")
        strTelemAntenna2 = CStr(GetField(sTEMP, 5))
        strTelemSite2 = CStr(GetField(sTEMP, 6))
      End If

      ' Output record if it is a Mobile Track record, otherwise assign to Telemetry2 variables
      Do While UCase(GetField(sTEMP, 7)) = "MBT"
       sOLine = sDST & "," & txtChannel.Text & "," & txtCode.Text & "," & txtSpecies.Text & "," & 
Format(CDate(GetField(sTEMP, 3)), "mm/dd/yyyy") & "," & Format(CDate(GetField(sTEMP, 4)), "hh:mm:ss") & 
"," & _
       CStr(GetField(sTEMP, 5)) & "," & CStr(GetField(sTEMP, 6)) & "," & GetField(sTEMP, 7) & "," & 
GetField(sTEMP, 8) & "," & GetField(sTEMP, 9) & "," & GetField(sTEMP, 10) & ",,"
       Print #miCombinedFile, sOLine
       Line Input #miTeleFile, sTEMP

        strTelemDate2 = Format(CDate(GetField(sTEMP, 3)), "mm/dd/yyyy")
        strTelemTime2 = Format(CDate(GetField(sTEMP, 4)), "hh:mm:ss")
        strTelemAntenna2 = CStr(GetField(sTEMP, 5))
        strTelemSite2 = CStr(GetField(sTEMP, 6))

      Loop
      Call CheckForTagRecap(sTEMP)

      ' Read in first Temperature record
        If Not (EOF(miTFile)) Then
          Line Input #miTFile, sTLine
        End If
        strTempDateOne = Format(CDate(Left(sTLine, 10)), "mm/dd/yyyy")
        strTempTimeOne = Format(CDate(Mid(sTLine, 12, 8)), "hh:mm:ss")
        Close miTFile
        Open txtInputFolderName.Text & txtTemperatureFileName For Input Access Read As #miTFile


      Do While Not (EOF(miPFile) And EOF(miTFile))

        If Not (EOF(miPFile)) Then
          Line Input #miPFile, sPLine
        End If
```

```
            sDate = Format(CDate(Left(sPLine, 10)), "mm/dd/yyyy")
            sTime = Format(CDate(Mid(sPLine, 12, 8)), "hh:mm:ss")
            sPreviousSecond = sSecond
            sSecond = Right(sTime, 2)
            sMinute = Mid(sTime, 4, 2)
            rDepth = CDbl(GetField(sPLine, 2)) / cDepthConv
            intDepthOffset = CInt(GetField(sPLine, 3)) - (Int(CInt(GetField(sPLine, 3)) / 60) * 60)
            rSumDm = rSumDm + rDepth
            rSumD2m = rSumD2m + (rDepth * rDepth)
            iNDm = iNDm + 1
            rSumDh = rSumDh + rDepth
            rSumD2h = rSumD2h + (rDepth + rDepth)
            iNDh = iNDh + 1
            iCount = iCount + 1

            If (((Val(sSecond) - intDepthOffset = 0) Or (Val(sSecond) - intDepthOffset = 60)) And CDate(sTime & "
" & sDate) >= CDate(strTempTimeOne & " " & strTempDateOne)) Or EOF(miPFile) Then
        '   If ((Val(sPreviousSecond) >= Val(sSecond)) And CDate(sTime & " " & sDate) >=
CDate(strTempTimeOne & " " & strTempDateOne)) Or EOF(miPFile) Then
              If Not (EOF(miTFile)) Then
                Line Input #miTFile, sTLine
              End If
              strTempDate = Format(CDate(Left(sTLine, 10)), "mm/dd/yyyy")
              strTempTime = Format(CDate(Mid(sTLine, 12, 8)), "hh:mm:ss")
              Do While DateAdd("s", -1, CDate(sTime & " " & sDate)) > CDate(strTempTime & " " & strTempDate)
And Not EOF(miTFile)
                Line Input #miTFile, sTLine
                strTempDate = Format(CDate(Left(sTLine, 10)), "mm/dd/yyyy")
                strTempTime = Format(CDate(Mid(sTLine, 12, 8)), "hh:mm:ss")
              Loop
              rTemp = GetField(sTLine, 2)
              intTempOffset = CInt(GetField(sPLine, 3))
              strTemp = Format(rTemp, cRF1)
            Else
              strTemp = ""
            End If

            If sTime = "19:04:59" Then
             sTime = sTime
            End If
            sOLine = sDST & "," & sDate & "," & sTime & "," & Format(rDepth, cRF1) & "," & strTemp
            Print #miO5sFile, sOLine

          If Not EOF(miTeleFile) Then

          ' If current record date&time > Telemetry2 date&time, shift records and read in a new Telemetry2 set
            If CDate(sTime & " " & sDate) >= CDate(strTelemTime2 & " " & strTelemDate2) Then
              strTelemDate1 = strTelemDate2
              strTelemTime1 = strTelemTime2
              strTelemAntenna1 = strTelemAntenna2
              strTelemSite1 = strTelemSite2

              strCorr = GetField(sTEMP, 7)
              strPower = GetField(sTEMP, 8)
              strRKM = GetField(sTEMP, 9)
```

```
            strJTag = GetField(sTEMP, 10)

            If Not EOF(miTeleFile) Then
               Line Input #miTeleFile, sTEMP
               Call CheckForTagRecap(sTEMP)
            End If

            Do While UCase(GetField(sTEMP, 7)) = "MBT" And Not EOF(miTeleFile)
             sOLine = sDST & "," & txtChannel.Text & "," & txtCode.Text & "," & txtSpecies.Text & "," &
Format(CDate(GetField(sTEMP, 3)), "mm/dd/yyyy") & "," & Format(CDate(GetField(sTEMP, 4)), "hh:mm:ss") &
"," & _
             CStr(GetField(sTEMP, 5)) & "," & CStr(GetField(sTEMP, 6)) & "," & GetField(sTEMP, 7) & "," &
GetField(sTEMP, 8) & "," & GetField(sTEMP, 9) & "," & GetField(sTEMP, 10) & ",,"
             Print #miCombinedFile, sOLine
             Line Input #miTeleFile, sTEMP
            Loop
            Call CheckForTagRecap(sTEMP)

            strTelemDate2 = Format(CDate(GetField(sTEMP, 3)), "mm/dd/yyyy")
            strTelemTime2 = Format(CDate(GetField(sTEMP, 4)), "hh:mm:ss")
            strTelemAntenna2 = CStr(GetField(sTEMP, 5))
            strTelemSite2 = CStr(GetField(sTEMP, 6))

            strCorr2 = GetField(sTEMP, 7)
            strPower2 = GetField(sTEMP, 8)
            strRKM2 = GetField(sTEMP, 9)
            strJTag2 = GetField(sTEMP, 10)

            sOLine = sDST & "," & txtChannel.Text & "," & txtCode.Text & "," & txtSpecies.Text & "," &
strTelemDate1 & "," & strTelemTime1 & "," & _
            strTelemAntenna1 & "," & strTelemSite1 & "," & strCorr & "," & strPower & "," & strRKM & "," &
strJTag & ",,"
            Print #miCombinedFile, sOLine

            strTelem2Line = sDST & "," & txtChannel.Text & "," & txtCode.Text & "," & txtSpecies.Text & "," &
strTelemDate2 & "," & strTelemTime2 & "," & _
            strTelemAntenna2 & "," & strTelemSite2 & "," & strCorr2 & "," & strPower2 & "," & strRKM2 & ","
& strJTag2 & ",,"
          End If

          DoEvents

          strTelemAntennaTemp = strTelemAntenna1
          strTelemSiteTemp = strTelemSite1
          strCorrTemp = strCorr
          strPowerTemp = strPower
          strRKMTemp = strRKM
          strJTagTemp = strJTag

        ' If current record date&time < Telemetry1 date&time, set fields to blank
          If CDate(sTime & " " & sDate) < CDate(strTelemTime1 & " " & strTelemDate1) Then
            strTelemSite1 = ""
            strTelemAntenna1 = ""
            strCorr = ""
            strPower = ""
            strRKM = ""
```

```
                strJTag = ""
              Else
               ' If first time through, output the Telemetry1 record and set temps to first record fields
                If blnFirstRecordWait = True Then
                  Print #miCombinedFile, strTelem1Line
                  strTelemSiteTemp = GetField(strTelem1Line, 8)
                  strTelemAntennaTemp = GetField(strTelem1Line, 7)
                  strCorrTemp = GetField(strTelem1Line, 9)
                  strPowerTemp = GetField(strTelem1Line, 10)
                  strRKMTemp = GetField(strTelem1Line, 11)
                  strJTagTemp = GetField(strTelem1Line, 12)
                  blnFirstRecordWait = False
                End If
               ' Move values back to variables if the current record date&time > Telemetry1 record
                strTelemSite1 = strTelemSiteTemp
                strTelemAntenna1 = strTelemAntennaTemp
                strCorr = strCorrTemp
                strPower = strPowerTemp
                strRKM = strRKMTemp
                strJTag = strJTagTemp
              End If

              If (Val(Right(sTime, 2)) - intDepthOffset = 0) Or (Val(Right(sTime, 2)) - intDepthOffset = 60) Then
            '   If Val(Right(sTime, 2)) - intDepthOffset <> 0 Then
            '   If (Val(sPreviousSecond) >= Val(sSecond)) Then
                  strTempOut = strTemp
              Else
                  strTempOut = ""
              End If

            ' If the gap between Telemetry1 and Telemetry2 > 30 minutes, do not fill the fields
              If CDate(strTelemDate2 & " " & strTelemTime2) > DateAdd("n", 30, CDate(strTelemTime1 & " " &
strTelemDate1)) Then
                sOLine = sDST & "," & txtChannel.Text & "," & txtCode.Text & "," & txtSpecies.Text & "," & sDate
& "," & sTime & "," & _
                "" & "," & "" & "," & "" & "," & "" & "," & "" & "," & "" & "," & Format(rDepth, cRF1) & "," &
strTempOut
              Else
                sOLine = sDST & "," & txtChannel.Text & "," & txtCode.Text & "," & txtSpecies.Text & "," & sDate
& "," & sTime & "," & _
                strTelemAntenna1 & "," & strTelemSite1 & ",," & strPower & "," & strRKM & "," & strJTag & "," &
Format(rDepth, cRF1) & "," & strTempOut
            '     strTelemAntenna1 & "," & strTelemSite1 & "," & strCorr & "," & strPower & "," & strRKM & "," &
strJTag & "," & Format(rDepth, cRF1) & "," & strTempOut
              End If

              If intOutputCount = 500 Then
                 intOutputCount = 0
                 Call UpdateBallBounce(intBounceNumber, intBounceDirection, Pinball())
              Else
                 intOutputCount = intOutputCount + 1
              End If

              Print #miCombinedFile, sOLine
            Else
```

```
            If intOutputCount = 500 Then
               intOutputCount = 0
               Call UpdateBallBounce(intBounceNumber, intBounceDirection, Pinball())
            Else
               intOutputCount = intOutputCount + 1
            End If

            If (Val(Right(sTime, 2)) - intDepthOffset = 0) Or (Val(Right(sTime, 2)) - intDepthOffset = 60) Then
'           If Val(Right(sTime, 2)) - intDepthOffset <> 0 Then
'           If (Val(sPreviousSecond) >= Val(sSecond)) Then
                strTempOut = strTemp
            Else
                strTempOut = ""
            End If

             If blnOutputTelem2 = True Then
                If CDate(sTime & " " & sDate) >= CDate(strTelemTime2 & " " & strTelemDate2) Then
                   Print #miCombinedFile, strTelem2Line
                   blnOutputTelem2 = False
                   sOLine = sDST & "," & txtChannel.Text & "," & txtCode.Text & "," & txtSpecies.Text & "," &
sDate & "," & sTime & "," & _
                   "" & "," & "" & "," & "" & "," & "" & "," & "" & "," & "" & "," & Format(rDepth, cRF1) & "," &
strTempOut
                   Print #miCombinedFile, sOLine
                Else
                ' If the gap between Telemetry1 and Telemetry2 > 30 minutes, do not fill the fields
'                  If (CDate(strTelemDate2 & " " & strTelemTime2) > DateAdd("n", 30, CDate(strTelemTime1 & " "
& strTelemDate1)) Or EOF(miTeleFile)) And blnOutputTelem2 = False Then
                   If (CDate(strTelemDate2 & " " & strTelemTime2) > DateAdd("n", 30, CDate(strTelemTime1 & " "
& strTelemDate1)) Or EOF(miTeleFile)) Then
                      sOLine = sDST & "," & txtChannel.Text & "," & txtCode.Text & "," & txtSpecies.Text & "," &
sDate & "," & sTime & "," & _
                      "" & "," & "" & "," & "" & "," & "" & "," & "" & "," & "" & "," & Format(rDepth, cRF1) & "," &
strTempOut
                   Else
                      sOLine = sDST & "," & txtChannel.Text & "," & txtCode.Text & "," & txtSpecies.Text & "," &
sDate & "," & sTime & "," & _
                      strTelemAntenna1 & "," & strTelemSite1 & ",," & strPower & "," & strRKM & "," & strJTag &
"," & Format(rDepth, cRF1) & "," & strTempOut
'                     strTelemAntenna1 & "," & strTelemSite1 & "," & strCorr & "," & strPower & "," & strRKM &
"," & strJTag & "," & Format(rDepth, cRF1) & "," & strTempOut
                   End If
                   Print #miCombinedFile, sOLine
                End If
             Else
                sOLine = sDST & "," & txtChannel.Text & "," & txtCode.Text & "," & txtSpecies.Text & "," & sDate
& "," & sTime & "," & _
                "" & "," & "" & "," & "" & "," & "" & "," & "" & "," & "" & "," & Format(rDepth, cRF1) & "," &
strTempOut
                Print #miCombinedFile, sOLine
             End If
          End If

            If (((Val(sSecond) - intDepthOffset = 0) Or (Val(sSecond) - intDepthOffset = 60)) And CDate(sTime & "
" & sDate) >= CDate(strTempTimeOne & " " & strTempDateOne)) Then
```

```
'   If ((Val(sPreviousSecond) >= Val(sSecond)) And CDate(sTime & " " & sDate) >=
CDate(strTempTimeOne & " " & strTempDateOne)) Then
          rAvgDm = rSumDm / iNDm
          If (iNDm > 1) Then
            rVarDm = (rSumD2m - (rSumDm * rSumDm / iNDm)) / (iNDm - 1)
          Else
            rVarDm = 0#
          End If
          sOLine = sDST & "," & sDate & "," & sTime & "," & Format(rAvgDm, cRF1) & "," & strTemp & ","
& Format(rVarDm, cRF2)
          Print #miO1mFile, sOLine
          rSumTh = rSumTh + rTemp
          rSumT2h = rSumT2h + (rTemp * rTemp)
          iNTh = iNTh + 1
          rSumDm = 0#
          rSumD2m = 0#
          iNDm = 0
          If (sMinute = "00") Then
            rAvgDh = rSumDh / iNDh
            rAvgTh = rSumTh / iNTh
            If (iNDh > 1) Then
              rVarDh = (rSumD2h - (rSumDh * rSumDh / iNDh)) / (iNDh - 1)
            Else
              rVarDh = 0#
            End If
            If (iNTh > 1) Then
              rVarTh = (rSumT2h - (rSumTh * rSumTh / iNTh)) / (iNTh - 1)
            Else
              rVarTh = 0#
            End If
            sOLine = sDST & "," & sDate & "," & sTime & "," & Format(rAvgDh, cRF1) & "," &
Format(rAvgTh, cRF1) & "," & Format(rVarDh, cRF2) & "," & Format(rVarTh, cRF2)
            Print #miO1hFile, sOLine
            rSumDh = 0#
            rSumD2h = 0#
            rSumTh = 0#
            rSumT2h = 0#
            iNDh = 0
            iNTh = 0
            txtProgress = sDate & "  " & sTime & "  " & Format(iCount, "#,###,###") & "  " &
Format(CDate(DateDiff("s", dStartTime, Now) / cSecondsPerDay), "hh:mm:ss")
            DoEvents
            If (mbStop) Then Exit Do
          End If
        End If
      Loop

      If Not (mbStop) Then
         ' Need to print the Telemetry2 record before quitting
        If blnOutputTelem2 = True Then
          Print #miCombinedFile, strTelem2Line
        End If

         ' If there are more telemetry records left, dump them out
         Do While Not EOF(miTeleFile)
            Line Input #miTeleFile, sTEMP
```

```
        sOLine = sDST & "," & txtChannel.Text & "," & txtCode.Text & "," & txtSpecies.Text & "," &
Format(CDate(GetField(sTEMP, 3)), "mm/dd/yyyy") & "," & Format(CDate(GetField(sTEMP, 4)), "hh:mm:ss") &
"," & _
        CStr(GetField(sTEMP, 5)) & "," & CStr(GetField(sTEMP, 6)) & "," & GetField(sTEMP, 7) & "," &
GetField(sTEMP, 8) & "," & GetField(sTEMP, 9) & "," & GetField(sTEMP, 10) & ",,"
        Print #miCombinedFile, sOLine
      Loop
    End If

    End Sub

    Private Sub OpenFiles()
    Dim sInputFolder As String
    Dim sOutputFolder As String

    sInputFolder = txtInputFolderName
    sOutputFolder = txtOutputFolderName

    miPFile = FreeFile
    Open sInputFolder & txtPressureFileName For Input Access Read As #miPFile
    miTFile = FreeFile
    Open sInputFolder & txtTemperatureFileName For Input Access Read As #miTFile
    miTeleFile = FreeFile
    Open sInputFolder & txtTelemetryFileName For Input Access Read As #miTeleFile
    miO5sFile = FreeFile
    Open sOutputFolder & txt5SecondFileName For Output Access Write As #miO5sFile
    miO1mFile = FreeFile
    Open sOutputFolder & txt1MinuteFileName For Output Access Write As #miO1mFile
    miO1hFile = FreeFile
    Open sOutputFolder & txt1HourFileName For Output Access Write As #miO1hFile
    miCombinedFile = FreeFile
    Open sOutputFolder & txtCombinedFileName For Output Access Write As #miCombinedFile

    End Sub

    Private Sub CloseFiles()

    On Error Resume Next

    Close miPFile
    Close miTFile
    Close miTeleFile
    Close miO5sFile
    Close miO1mFile
    Close miO1hFile
    Close miCombinedFile

    Close miTempTemperatureFile
    Close miTempPressureFile
    Close miTempCombinedFile
    Close miReservoirFile
    Close miDriftFile
    End Sub

    Private Sub WriteHeaders()
    Dim sLabels As String
```

```
sLabels = "DST, Date, Time, Depth, Temperature"
Print #miO5sFile, sLabels

sLabels = "DST, Date, Time, Average Depth (1 minute), Temperature, Depth Variance"
Print #miO1mFile, sLabels

sLabels = "DST, Date, Time, Average Depth (1 hour), Average Temperature (1 hour), Depth Variance,
Temperature Variance"
Print #miO1hFile, sLabels

sLabels = "DST, CHAN, CODE, SPECIES, DATE, TIME, ANTEN, SITE, CORR, POWER, RKM, JTAG,
DEPTH, TEMPERATURE"
Print #miCombinedFile, sLabels

End Sub

Private Sub cmdRun_Click()
  Dim strPressureFile As String, strTemperatureFile As String, strTelemetryFile As String, sInputFolder
As String
  Dim strDSTfield As String, strChannelField As String, strCodeField As String, strSpeciesField As String
  Dim varAnything As Variant
  Dim intCurrentRecNum As Integer, intLoopNum As Integer

  Screen.MousePointer = vbHourglass
  sInputFolder = txtInputFolderName

  If chkDatafiles.Value = 1 Then
    intCurrentRecNum = 1
    miDataFiles = FreeFile
    Open txtInputFolderName & "DataFiles.txt" For Input Access Read As #miDataFiles
    Do While Not EOF(miDataFiles)
'      For intLoopNum = 1 To intCurrentRecNum
        Input #miDataFiles, strPressureFile, strTemperatureFile, strTelemetryFile
        Input #miDataFiles, strDSTfield, strChannelField, strCodeField, strSpeciesField
'      Next intLoopNum

      txtPressureFileName.Text = Trim(strPressureFile)
      txtTemperatureFileName.Text = Trim(strTemperatureFile)
      txtTelemetryFileName.Text = Trim(strTelemetryFile)

      txtDST.Text = strDSTfield
      txtChannel.Text = strChannelField
      txtCode.Text = strCodeField
      txtSpecies.Text = strSpeciesField

      Call txtDST_LostFocus

      Call OpenFiles
      Call WriteHeaders
      Call ApplyPolynomial
      Call MergeFiles
      Call CloseFiles
'      Close 'all open files

      Kill sInputFolder & txtDST.Text & "_Ttemp.txt"
```

```
            Kill sInputFolder & txtDST.Text & "_Ptemp.txt"

            If mnuRKM.Checked Or mnuRemoveTelem.Checked Then
                Call ComputeRKM_RES
            End If

            intCurrentRecNum = intCurrentRecNum + 1
        Loop
        Close 'all open files
    Else
        Call OpenFiles
        Call WriteHeaders
        Call ApplyPolynomial
'MsgBox ("Finished applying polynomial")
        Call MergeFiles
'       Call CloseFiles
        Close 'all open files

        If mnuRemoveTemp.Checked Then
            Kill sInputFolder & txtDST.Text & "_Ttemp.txt"
            Kill sInputFolder & txtDST.Text & "_Ptemp.txt"
        End If

        If mnuRKM.Checked Or mnuRemoveTelem.Checked Then
            Call ComputeRKM_RES
        End If
    End If

    varAnything = MsgBox("Done with record merging!!", vbInformation, "Merge Complete")
    Screen.MousePointer = vbDefault

End Sub

Private Sub cmdStop_Click()
    mbStop = True
End Sub

Private Sub Form_Load()

End Sub

Private Sub mnuAbout_Click()
    MsgBox ("Fishdata Program date 03/11/03")
End Sub

Private Sub mnuRemoveTelem_Click()
    mnuRemoveTelem.Checked = Not (mnuRemoveTelem.Checked)
    If mnuRemoveTelem.Checked Then
        mnuRKM.Checked = False
    End If
End Sub

Private Sub mnuRemoveTemp_Click()
    mnuRemoveTemp.Checked = Not (mnuRemoveTemp.Checked)
End Sub
```

```
Private Sub mnuRKM_Click()
   mnuRKM.Checked = Not (mnuRKM.Checked)
   If mnuRKM.Checked Then
      mnuRemoveTelem.Checked = False
   End If
End Sub

Private Sub Timer1_Timer()
   If txtBallBounce.Text = "Applying Polynomial" Then
      txtBallBounce.Text = ""
   Else
      txtBallBounce.Text = "Applying Polynomial"
   End If
End Sub

Private Sub txtDST_Change()
   If chkDatafiles.Value = 0 Then
      txtPressureFileName.Text = txtDST.Text & "p.csv"
      txtTemperatureFileName.Text = txtDST.Text & "t.csv"
      txtTelemetryFileName.Text = txtDST.Text & ".csv"
   End If
End Sub

Private Sub txtDST_LostFocus()
If (txtDST <> "") Then
      txt5SecondFileName = txtDST & "_Output_5s.txt"
      txt1MinuteFileName = txtDST & "_Output_1m.txt"
      txt1HourFileName = txtDST & "_Output_1h.txt"
      txtCombinedFileName = txtDST & "_Output_Combined.txt"
End If
End Sub

Private Function GetField(strLine As String, intFieldNum As Integer) As Variant
   ' Search the given string for field intFieldNum
   ' Strip quotes from the field if there are some

   Dim intCommaBefore As Integer, intCommaAfter As Integer
   Dim intCurrentComma As Integer, blnFieldFound As Boolean
   Dim intCount As Integer, strField As String
   Dim strLineArray() As String

'   blnFieldFound = False
'   intCount = 0

'   strLine = strLine & ","

'   While Not blnFieldFound
'      intCount = intCount + 1
'      intCommaBefore = intCurrentComma
'      intCurrentComma = InStr(intCurrentComma + 1, strLine, ",")
'      intCommaAfter = intCurrentComma
'      If intCount = intFieldNum Then
'         blnFieldFound = True
'         strField = Mid(strLine, intCommaBefore + 1, intCommaAfter - intCommaBefore - 1)
'      End If
'   Wend
```

```
    If strLine = "" Then
'       MsgBox ("Blank line detected.")
        Exit Function
    End If

    strLineArray = Split(strLine, ",")
    strField = strLineArray(intFieldNum - 1)

    If Left(strField, 1) = Chr(34) Then
        strField = Mid(strField, 2, Len(strField) - 2)
    End If

    GetField = strField
End Function

Private Sub txtInputFolderName_Change()
    txtOutputFolderName.Text = txtInputFolderName.Text
End Sub

Private Sub txtInputFolderName_LostFocus()
    If Right(txtInputFolderName.Text, 1) <> "\" Then
        txtInputFolderName.Text = txtInputFolderName.Text & "\"
    End If
End Sub

Private Sub txtOutputFolderName_LostFocus()
    If Right(txtOutputFolderName.Text, 1) <> "\" Then
        txtOutputFolderName.Text = txtOutputFolderName.Text & "\"
    End If
End Sub

Private Sub UpdateBallBounce(intBounceNumber As Integer, intBounceDirection As Integer, Pinball() As
String)

    DoEvents

    If intBounceNumber = 15 Then
        intBounceDirection = -1
    End If

    If intBounceNumber = 1 Then
        intBounceDirection = 1
    End If

    intBounceNumber = intBounceNumber + intBounceDirection

    txtBallBounce.Text = Pinball(intBounceNumber)

End Sub

Private Sub ApplyPolynomial()
    Dim strTemperatureLine As String, strRecordDate As String, strRecordTime As String
    Dim strPressureLine As String
    Dim lngIntervals As Long, lngCounter As Long
    Dim dblAverageTemp() As Double, dblTemp As Double, dblTemp1 As Double, dblTemp2 As Double
```

```
        Dim dblPressure As Double
        Dim dblSecondOrderCoefficient As Double, dblLinearCoefficient As Double, dblConstant As Double
        Dim dblIntervalDriftPPM As Double, dblIntervalDriftSeconds As Double, dblTotalDriftSeconds As
Double
        Dim dtDate As Date, dtDate1 As Date, dtDate2 As Date, dtNewDate As Date, dtAverageTempTime()
As Date
        Dim sInputFolder As String, sOutputFolder As String

        Timer1.Enabled = True
        txtBallBounce.Alignment = 2
        txtBallBounce.Font = "Arial"
        txtBallBounce.Text = "Applying Polynomial"

        sInputFolder = txtInputFolderName
        sOutputFolder = txtOutputFolderName

        Data1.DatabaseName = App.Path & "\Polynomials.mdb"
        Data1.RecordSource = "SELECT * FROM Polynomials WHERE [Tag Serial Number] = " & Chr(34) &
Left(txtDST.Text, 4) & Chr(34) & ";"
        Data1.Refresh

        dblSecondOrderCoefficient = Data1.Recordset.Fields("2nd Order Coefficient").Value
        dblLinearCoefficient = Data1.Recordset.Fields("Linear  Coefficient").Value
        dblConstant = Data1.Recordset.Fields("Constant").Value

        lngIntervals = 0
        Do While Not EOF(miTFile)
          DoEvents
          Line Input #miTFile, strTemperatureLine
          lngIntervals = lngIntervals + 1
        Loop

        ReDim dblAverageTemp(lngIntervals)
        ReDim dtAverageTempTime(lngIntervals, 2)

        Close miTFile
        miTFile = FreeFile
        Open sInputFolder & txtTemperatureFileName For Input Access Read As #miTFile

        If Not EOF(miTFile) Then
          Line Input #miTFile, strTemperatureLine
          dblTemp1 = Mid(strTemperatureLine, InStr(strTemperatureLine, ",") + 1)
          dtDate1 = Left(strTemperatureLine, InStr(strTemperatureLine, ",") - 1)
          lngCounter = 1
        End If

        Do While Not EOF(miTFile)
          DoEvents
          Line Input #miTFile, strTemperatureLine
          dblTemp2 = Mid(strTemperatureLine, InStr(strTemperatureLine, ",") + 1)
          dtDate2 = Left(strTemperatureLine, InStr(strTemperatureLine, ",") - 1)

          dblAverageTemp(lngCounter) = (dblTemp1 + dblTemp2) / 2
          dtAverageTempTime(lngCounter, 1) = FormatDateTime(dtDate1, vbGeneralDate)
          dtAverageTempTime(lngCounter, 2) = FormatDateTime(dtDate2, vbGeneralDate)
```

```
        dblTemp1 = dblTemp2
        dtDate1 = dtDate2
        lngCounter = lngCounter + 1
    Loop

    Close miTFile

    'Process Temperature File
    miTempTemperatureFile = FreeFile
    Open sInputFolder & txtDST.Text & "_Ttemp.txt" For Output Access Write As
#miTempTemperatureFile
    miTFile = FreeFile
    Open sInputFolder & txtTemperatureFileName For Input Access Read As #miTFile

    'Need to skip first Temperature line
    Line Input #miTFile, strTemperatureLine
    Print #miTempTemperatureFile, strTemperatureLine & ",0"

    dblTotalDriftSeconds = 0

    Line Input #miTFile, strTemperatureLine
    dblTemp = Mid(strTemperatureLine, InStr(strTemperatureLine, ",") + 1)
    dtDate = FormatDateTime(Left(strTemperatureLine, InStr(strTemperatureLine, ",") - 1), vbGeneralDate)

    For lngCounter = 2 To lngIntervals - 1
        Do While dtDate >= dtAverageTempTime(lngCounter, 1) And dtDate <
dtAverageTempTime(lngCounter, 2)
            DoEvents
            dblIntervalDriftPPM = dblSecondOrderCoefficient * dblAverageTemp(lngCounter) ^ 2 +
dblLinearCoefficient * dblAverageTemp(lngCounter) + dblConstant
            dblIntervalDriftSeconds = (dblIntervalDriftPPM / 1000000) * 60
            dblTotalDriftSeconds = dblTotalDriftSeconds + dblIntervalDriftSeconds

            dtNewDate = DateAdd("s", -Round(dblTotalDriftSeconds), dtDate)
            strRecordDate = Format(dtNewDate, "yyyy/mm/dd")
            strRecordTime = Format(dtNewDate, "hh:mm:ss")

            Print #miTempTemperatureFile, strRecordDate & " " & strRecordTime & "," & dblTemp & "," & -
Round(dblTotalDriftSeconds)

            Line Input #miTFile, strTemperatureLine
            dblTemp = Mid(strTemperatureLine, InStr(strTemperatureLine, ",") + 1)
            dtDate = FormatDateTime(Left(strTemperatureLine, InStr(strTemperatureLine, ",") - 1),
vbGeneralDate)
        Loop
    Next lngCounter

    'Output last record
    dblIntervalDriftPPM = dblSecondOrderCoefficient * dblAverageTemp(lngCounter - 1) ^ 2 +
dblLinearCoefficient * dblAverageTemp(lngCounter - 1) + dblConstant
    dblIntervalDriftSeconds = (dblIntervalDriftPPM / 1000000) * 60
    dblTotalDriftSeconds = dblTotalDriftSeconds + dblIntervalDriftSeconds

    dtNewDate = DateAdd("s", -Round(dblTotalDriftSeconds), dtDate)
    strRecordDate = Format(dtNewDate, "yyyy/mm/dd")
    strRecordTime = Format(dtNewDate, "hh:mm:ss")
```

```
        Print #miTempTemperatureFile, strRecordDate & " " & strRecordTime & "," & dblTemp & "," & -
Round(dblTotalDriftSeconds)

        txtMessages.Text = "Total Drift = " & Round(dblTotalDriftSeconds, 2) & " seconds."

        'Process Pressure File
        miTempPressureFile = FreeFile
        Open sInputFolder & txtDST.Text & "_Ptemp.txt" For Output Access Write As #miTempPressureFile

        Close miPFile
        miPFile = FreeFile
        Open sInputFolder & txtPressureFileName For Input Access Read As #miPFile

        'Need to skip first Pressure line
        Line Input #miPFile, strPressureLine
        Print #miTempPressureFile, strPressureLine & ",0"

        dblTotalDriftSeconds = 0

        Line Input #miPFile, strPressureLine
        dblPressure = Mid(strPressureLine, InStr(strPressureLine, ",") + 1)
        dtDate = FormatDateTime(Left(strPressureLine, InStr(strPressureLine, ",") - 1), vbGeneralDate)

        For lngCounter = 1 To lngIntervals - 1
          Do While dtDate >= dtAverageTempTime(lngCounter, 1) And dtDate <
dtAverageTempTime(lngCounter, 2)
            DoEvents
            dblIntervalDriftPPM = dblSecondOrderCoefficient * dblAverageTemp(lngCounter) ^ 2 +
dblLinearCoefficient * dblAverageTemp(lngCounter) + dblConstant
            dblIntervalDriftSeconds = (dblIntervalDriftPPM / 1000000) * 5
            dblTotalDriftSeconds = dblTotalDriftSeconds + dblIntervalDriftSeconds

            dtNewDate = DateAdd("s", -Round(dblTotalDriftSeconds), dtDate)
            strRecordDate = Format(dtNewDate, "yyyy/mm/dd")
            strRecordTime = Format(dtNewDate, "hh:mm:ss")

'           If Left(strRecordTime, 5) = "13:36" And strRecordDate = "2000/05/17" Then
'             DoEvents
'           End If

            Print #miTempPressureFile, strRecordDate & " " & strRecordTime & "," & dblPressure & "," & -
Round(dblTotalDriftSeconds)

            If Not EOF(miPFile) Then
              Line Input #miPFile, strPressureLine
              dblPressure = Mid(strPressureLine, InStr(strPressureLine, ",") + 1)
              dtDate = FormatDateTime(Left(strPressureLine, InStr(strPressureLine, ",") - 1), vbGeneralDate)
            Else
              Exit Do
            End If
          Loop
        Next lngCounter

        'Output last record
```

```
        dblIntervalDriftPPM = dblSecondOrderCoefficient * dblAverageTemp(lngCounter - 1) ^ 2 +
dblLinearCoefficient * dblAverageTemp(lngCounter - 1) + dblConstant
        dblIntervalDriftSeconds = (dblIntervalDriftPPM / 1000000) * 60
        dblTotalDriftSeconds = dblTotalDriftSeconds + dblIntervalDriftSeconds

        dtNewDate = DateAdd("s", -Round(dblTotalDriftSeconds), dtDate)
        strRecordDate = Format(dtNewDate, "yyyy/mm/dd")
        strRecordTime = Format(dtNewDate, "hh:mm:ss")

        Print #miTempPressureFile, strRecordDate & " " & strRecordTime & "," & dblPressure & "," & -
Round(dblTotalDriftSeconds)

        txtMessages.Text = "Total Drift = " & Round(dblTotalDriftSeconds, 2) & " seconds."

        miDriftFile = FreeFile
        Open sOutputFolder & "TagDrifts.txt" For Append As #miDriftFile
        Print #miDriftFile, txtDST.Text & "," & dblTotalDriftSeconds
        Close miDriftFile

        Close miTempTemperatureFile
        Close miTempPressureFile

        txtBallBounce.Text = ""
        txtBallBounce.Alignment = 0
        txtBallBounce.Font = "Wingdings"
        Timer1.Enabled = False

        txtTemperatureFileName = txtDST.Text & "_Ttemp.txt"
        txtPressureFileName = txtDST.Text & "_Ptemp.txt"

        Close miPFile
        miPFile = FreeFile
        Open sInputFolder & txtPressureFileName For Input Access Read As #miPFile
        Close miTFile
        miTFile = FreeFile
        Open sInputFolder & txtTemperatureFileName For Input Access Read As #miTFile

    End Sub

    Private Sub CheckForTagRecap(strTemp As String)
        If Left(GetField(strTemp, 7), 3) = "RCP" Then
            If Not EOF(miTeleFile) Then
                Line Input #miTeleFile, strTemp
            End If
        End If
        If GetField(strTemp, 7) = "TAG" Then
            Print #miCombinedFile, strTemp
            If Not EOF(miTeleFile) Then
                Line Input #miTeleFile, strTemp
            End If
        End If
    End Sub

    Private Sub ComputeRKM_RES()
        Dim strTemp As String, sDEPTH As String
        Dim sPrevRKM As String, sRKM As String, sCorr As String
```

```
    Dim intLoopNum As Integer
    Dim intBounceNumber As Integer
    Dim intBounceDirection As Integer
    Dim dblPoolOffset As Double
    Dim Pinball(50) As String
    Dim strSpaces As String

    strSpaces = ""
    For intLoopNum = 1 To 20
       Pinball(intLoopNum) = strSpaces & "J"
       strSpaces = strSpaces & " "
    Next intLoopNum

    intBounceNumber = 0
    intBounceDirection = 1

    txtMessages.Text = "Processing for Reservoir values"

    miCombinedFile = FreeFile
    Open txtOutputFolderName.Text & txtCombinedFileName For Input Access Read As #miCombinedFile

    If Not EOF(miCombinedFile) Then
       miTempCombinedFile = FreeFile
       Open txtOutputFolderName.Text & "Combined.tmp" For Output Access Write As
#miTempCombinedFile

       Line Input #miCombinedFile, strTemp 'read header line
       Print #miTempCombinedFile, strTemp & ", RESERVOIR" 'write header line

       If Not EOF(miCombinedFile) Then
          Do 'skip leading records with no RKM
             Line Input #miCombinedFile, strTemp
             sRKM = GetField(strTemp, 11)
             If mnuRemoveTelem.Checked Then 'remove telemetry records
                sDEPTH = GetField(strTemp, 13)
                If sRKM = "" And sDEPTH <> "" Then
                   Print #miTempCombinedFile, strTemp & ","
                End If
             Else
                If sRKM = "" Then
                   Print #miTempCombinedFile, strTemp & ","
                End If
             End If
          Loop Until EOF(miCombinedFile) Or sRKM <> ""

          sPrevRKM = sRKM
          If mnuRemoveTelem.Checked Then 'remove telemetry records
             sDEPTH = GetField(strTemp, 13)
             If sDEPTH <> "" Then
                Print #miTempCombinedFile, strTemp & "," & FindReservoir(sRKM)
             End If
          Else
             Print #miTempCombinedFile, strTemp & "," & FindReservoir(sRKM)
          End If

          dblPoolOffset = 0
```

```
            If mnuRemoveTelem.Checked Then 'remove telemetry records
                Do While Not EOF(miCombinedFile)
                    Line Input #miCombinedFile, strTemp
                    sCorr = GetField(strTemp, 9)
                    sRKM = GetField(strTemp, 11)
                    sDEPTH = GetField(strTemp, 13)
                    If sDEPTH <> "" Then 'this is not a telemetry record
                        If sCorr > "" And (UCase(sCorr) <> "LT" And UCase(sCorr) <> "ULT") Then
                            dblPoolOffset = 0
                        End If
                        If sRKM <> "" Then
                            Print #miTempCombinedFile, IncrementRKM(strTemp, sRKM, 0 + dblPoolOffset) & ","
& FindReservoir(sRKM + dblPoolOffset)
                            sPrevRKM = sRKM
                        Else
                            Print #miTempCombinedFile, IncrementRKM(strTemp, sPrevRKM, 0.1 + dblPoolOffset)
& "," & FindReservoir(sPrevRKM + 0.1 + dblPoolOffset)
                        End If
                    ElseIf UCase(sCorr) = "LT" Or UCase(sCorr) = "ULT" Then
                        'following records should have RKM incremented by an additional .1 as they are pool
records
                        dblPoolOffset = 0.2
'                   ElseIf sCorr > "" Then
                        'reset offset back to 0
'                       dblPoolOffset = 0
                    End If

                    If intLoopNum >= 500 Then
                        Call UpdateBallBounce(intBounceNumber, intBounceDirection, Pinball())
                        intLoopNum = 0
                    Else
                        intLoopNum = intLoopNum + 1
                    End If
                Loop
            Else 'do not remove telemetry records
                Do While Not EOF(miCombinedFile)
                    Line Input #miCombinedFile, strTemp
                    sCorr = GetField(strTemp, 9)
                    sRKM = GetField(strTemp, 11)
                    If sCorr > "" And (UCase(sCorr) <> "LT" And UCase(sCorr) <> "ULT") Then
                        dblPoolOffset = 0
                    End If
                    If sRKM <> "" Then
                        Print #miTempCombinedFile, IncrementRKM(strTemp, sRKM, 0 + dblPoolOffset) & "," &
FindReservoir(sRKM + dblPoolOffset)
                        sPrevRKM = sRKM
                    Else
                        Print #miTempCombinedFile, IncrementRKM(strTemp, sPrevRKM, 0.1 + dblPoolOffset) &
"," & FindReservoir(sPrevRKM + 0.1 + dblPoolOffset)
                    End If

                    If UCase(sCorr) = "LT" Or UCase(sCorr) = "ULT" Then
                        'following records should have RKM incremented by an additional .1 as they are pool
records
                        dblPoolOffset = 0.2
```

```
'                ElseIf sCorr > "" Then
                    'reset offset back to 0
'                    dblPoolOffset = 0
                End If

                If intLoopNum >= 500 Then
                    Call UpdateBallBounce(intBounceNumber, intBounceDirection, Pinball())
                    intLoopNum = 0
                Else
                    intLoopNum = intLoopNum + 1
                End If
            Loop
        End If
    End If
Else
    Close miCombinedFile
End If

'Rename temp to combined file
Close miTempCombinedFile
Close miCombinedFile
Kill txtOutputFolderName.Text & txtCombinedFileName
Name txtOutputFolderName.Text & "Combined.tmp" As txtOutputFolderName.Text &
txtCombinedFileName

End Sub

Private Function IncrementRKM(strLine As String, sPrevRKM As String, dblIncrement As Double) As
String
    Dim sLineValues() As String

    'Add .1 to RKM (which is field 11)
    sLineValues = Split(strLine, ",")
    sLineValues(10) = CStr(CDbl(sPrevRKM) + dblIncrement)
    IncrementRKM = Join(sLineValues, ",")

End Function

Private Function FindReservoir(sRKM As String)
    Static dblRKM() As Double
    Static strReservoirs() As String
    Dim strTemp As String
    Dim intLoop As Integer, intCount As Integer

    If NumElements(dblRKM()) = 0 Then 'read file into array
        'Count RKM file records
        miReservoirFile = FreeFile
        Open txtInputFolderName.Text & txtReservoirLookupFileName.Text For Input Access Read As
#miReservoirFile

        intCount = 0
        Do While Not EOF(miReservoirFile)
            Line Input #miReservoirFile, strTemp
            intCount = intCount + 1
        Loop
        Close miReservoirFile
```

```
            ReDim dblRKM(1 To intCount, 1 To 2)
            ReDim strReservoirs(1 To intCount)

            miReservoirFile = FreeFile
            Open txtInputFolderName.Text & txtReservoirLookupFileName.Text For Input Access Read As
#miReservoirFile

            intLoop = 1
            Do While Not EOF(miReservoirFile)
               Input #miReservoirFile, dblRKM(intLoop, 1)
               Input #miReservoirFile, dblRKM(intLoop, 2)
               Input #miReservoirFile, strReservoirs(intLoop)
               intLoop = intLoop + 1
            Loop
            Close miReservoirFile
         End If

         For intLoop = 1 To UBound(dblRKM)
            If CDbl(sRKM) >= dblRKM(intLoop, 1) And CDbl(sRKM) <= dblRKM(intLoop, 2) Then
               Exit For
            End If
         Next intLoop

         If intLoop > UBound(dblRKM) Then
            txtMessages.Text = "Unable to find RESERVOIR"
            FindReservoir = "Error"
         ElseIf CDbl(sRKM) > dblRKM(intLoop, 2) Then
            txtMessages.Text = "RKM not in RESERVOIR range."
            FindReservoir = "Error"
         Else
            FindReservoir = strReservoirs(intLoop)
         End If

      End Function
      Function NumElements(dblArray() As Double)
         Dim intElements As Integer

         intElements = 0
         On Error GoTo Done
         intElements = UBound(dblArray())
      Done:
         NumElements = intElements
      End Function
```

Appendix B

Appendix B Table 1. The minimum, maximum, and average temperature (°C) of RDST spring, summer, and fall Chinook salmon, and steelhead in the tailraces of the four Columbia and Snake river dams in 2000.

Species	Dam	N	Min of Min	Avg of Min	Max of Max	Avg of Max	Avg of Median	Avg of Mean	Avg of Stdev
Spring Chinook	BO	83	9.3	12.1	17.2	12.9	12.5	12.5	0.21
	TD	82	10.4	12.5	17.5	13.4	12.8	12.8	0.22
	JD	70	9.2	12.4	17.6	13.6	12.9	12.9	0.29
	MN	55	9.9	12.7	17.8	13.3	12.9	13.0	0.13
	IH	60	10.4	13.6	17.4	14.0	13.8	13.8	0.11
	LM	55	11.1	13.4	16.6	13.7	13.5	13.5	0.09
	GO	51	10.6	13.6	20.3	14.0	13.8	13.8	0.11
	GR	54	10.8	13.4	16.8	13.6	13.5	13.5	0.05
Summer Chinook	BO	36	14.6	17.5	22.3	18.1	17.9	17.9	0.14
	TD	30	15.4	17.6	22.3	18.0	17.8	17.8	0.10
	JD	29	15.2	17.8	22.5	18.4	18.1	18.1	0.13
	MN	18	14.7	17.2	21.5	17.6	17.4	17.4	0.10
	IH	12	14.5	16.1	17.7	16.3	16.2	16.2	0.06
	LM	9	15.9	16.8	19.2	17.1	17.0	17.0	0.06
	GO	7	15.0	16.3	18.5	16.4	16.3	16.3	0.05
	GR	7	15.7	17.2	19.6	17.5	17.3	17.3	0.10
Fall Chinook	BO	33	13.4	19.4	22.4	20.1	19.9	19.9	0.15
	TD	27	10.8	18.8	21.6	19.7	19.5	19.5	0.19
	JD	17	12.2	19.1	21.3	19.4	19.3	19.3	0.07
	MN	7	10.1	16.4	21.7	18.5	17.8	17.7	0.45
	IH	9	12.0	18.0	21.7	18.5	18.2	18.2	0.09
	LM	7	17.3	18.3	20.5	18.9	18.7	18.6	0.15
	GO	10	10.1	16.8	20.3	17.6	17.4	17.3	0.18
	GR	6	8.8	16.1	19.0	16.6	16.4	16.4	0.12
Steelhead	BO	107	10.1	18.4	22.4	19.4	19.0	19.0	0.23
	TD	64	8.3	18.1	22.4	18.9	18.5	18.5	0.20
	JD	45	14.3	18.5	23.1	19.0	18.8	18.8	0.15
	MN	23	11.2	17.7	21.7	17.9	17.8	17.8	0.06
	IH	23	13.3	17.6	21.6	17.9	17.8	17.8	0.07
	LM	14	13.7	17.6	21.3	17.8	17.7	17.7	0.06
	GO	9	12.2	15.8	20.5	16.1	16.0	16.0	0.09
	GR	13	9.9	14.8	19.6	15.1	14.9	14.9	0.06

Appendix B Table 2. The minimum, maximum, and average temperature (°C) of RDST spring, summer, and fall Chinook salmon, and steelhead in the tailraces of the four Columbia and Snake river dams in 2002.

Species	Dam	N	Min of Min	Avg of Min	Max of Max	Avg of Max	Avg of Median	Avg of Mean	Avg of Stdev
Spring Chinook	BO	77	7.8	10.9	15.1	11.5	11.2	11.2	0.16
	TD	52	9.6	11.7	15.2	12.1	11.8	11.8	0.11
	JD	65	9.5	11.4	14.9	11.7	11.5	11.5	0.08
	MN	51	8.2	11.4	16.5	11.8	11.5	11.5	0.11
	IH	67	9.6	11.9	15.6	12.0	12.0	12.0	0.05
	LM	70	9.7	11.6	16.4	11.7	11.7	11.7	0.05
	GO	54	10.1	11.4	15.2	11.7	11.5	11.5	0.07
	GR	46	9.5	11.2	14.8	11.4	11.3	11.3	0.06
Summer Chinook	BO	31	14.2	15.9	19.6	16.2	16.1	16.1	0.08
	TD	21	14.5	16.0	19.0	16.2	16.1	16.1	0.05
	JD	26	14.1	16.1	20.3	16.5	16.2	16.2	0.11
	MN	16	13.0	16.2	20.5	16.5	16.3	16.3	0.06
	IH	23	13.5	16.0	21.6	16.1	16.1	16.1	0.04
	LM	22	13.3	16.0	21.2	16.1	16.1	16.1	0.04
	GO	16	14.7	16.2	21.4	16.7	16.5	16.5	0.11
	GR	20	13.4	15.6	20.8	15.9	15.7	15.7	0.06
Fall Chinook	BO	18	17.6	19.8	21.6	20.3	20.1	20.1	0.10
	TD	6	18.6	19.9	21.4	20.3	20.2	20.2	0.08
	JD	15	16.5	19.3	22.3	20.7	19.8	19.9	0.30
	MN	5	16.4	18.5	20.0	18.8	18.7	18.7	0.06
	IH	9	16.9	18.5	20.0	18.7	18.6	18.6	0.04
	LM	11	15.0	17.3	20.2	18.8	18.1	18.1	0.28
	GO	8	17.2	17.9	18.6	18.1	18.0	18.0	0.04
	GR	4	15.9	16.9	19.6	17.6	17.1	17.1	0.16
Steelhead	BO	147	10.0	18.7	21.9	20.0	19.5	19.4	0.35
	TD	71	14.5	19.1	21.5	19.5	19.4	19.3	0.10
	JD	81	11.3	19.2	21.9	19.5	19.4	19.4	0.08
	MN	37	12.7	18.2	21.4	18.7	18.6	18.5	0.15
	IH	60	11.4	18.3	22.0	18.5	18.4	18.4	0.05
	LM	47	11.6	17.8	21.1	18.0	17.9	17.9	0.06
	GO	30	10.7	17.2	19.7	17.5	17.4	17.4	0.09
	GR	27	8.0	16.7	19.2	17.1	16.8	16.8	0.10

Appendix B Table 3. Multiple comparisons of repeated measures ANOVA results for spring Chinook salmon temperatures in tailraces in 2000. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > *t*
Loc(dam)	Tailrace	BO	TD	0.0066
Loc(dam)	Tailrace	BO	JD	<0.0001*
Loc(dam)	Tailrace	BO	MN	<0.0001*
Loc(dam)	Tailrace	BO	IH	<0.0001*
Loc(dam)	Tailrace	BO	LM	<0.0001*
Loc(dam)	Tailrace	BO	GO	<0.0001*
Loc(dam)	Tailrace	BO	GR	<0.0001*
Loc(dam)	Tailrace	TD	JD	0.1737
Loc(dam)	Tailrace	TD	MN	0.0317
Loc(dam)	Tailrace	TD	IH	<0.0001*
Loc(dam)	Tailrace	TD	LM	<0.0001*
Loc(dam)	Tailrace	TD	GO	<0.0001*
Loc(dam)	Tailrace	TD	GR	<0.0001*
Loc(dam)	Tailrace	JD	MN	0.3915
Loc(dam)	Tailrace	JD	IH	<0.0001*
Loc(dam)	Tailrace	JD	LM	0.0002*
Loc(dam)	Tailrace	JD	GO	<0.0001*
Loc(dam)	Tailrace	JD	GR	0.0045
Loc(dam)	Tailrace	MN	IH	<0.0001*
Loc(dam)	Tailrace	MN	LM	0.0073
Loc(dam)	Tailrace	MN	GO	0.0002*
Loc(dam)	Tailrace	MN	GR	0.0576
Loc(dam)	Tailrace	IH	LM	0.1059
Loc(dam)	Tailrace	IH	GO	0.6747
Loc(dam)	Tailrace	IH	GR	0.0165
Loc(dam)	Tailrace	LM	GO	0.2543
Loc(dam)	Tailrace	LM	GR	0.4390
Loc(dam)	Tailrace	GO	GR	0.0585

Appendix B Table 4. Multiple comparisons of repeated measures ANOVA results for spring Chinook salmon temperatures in tailraces in 2002. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Tailrace	BO	TD	0.3379
Loc(dam)	Tailrace	BO	JD	0.0769
Loc(dam)	Tailrace	BO	MN	0.2789
Loc(dam)	Tailrace	BO	IH	0.0552
Loc(dam)	Tailrace	BO	LM	0.0104
Loc(dam)	Tailrace	BO	GO	0.9492
Loc(dam)	Tailrace	BO	GR	<0.0001*
Loc(dam)	Tailrace	TD	JD	0.4317
Loc(dam)	Tailrace	TD	MN	0.7970
Loc(dam)	Tailrace	TD	IH	0.2318
Loc(dam)	Tailrace	TD	LM	0.0565
Loc(dam)	Tailrace	TD	GO	0.6197
Loc(dam)	Tailrace	TD	GR	<0.0001*
Loc(dam)	Tailrace	JD	MN	0.6710
Loc(dam)	Tailrace	JD	IH	0.5513
Loc(dam)	Tailrace	JD	LM	0.1713
Loc(dam)	Tailrace	JD	GO	0.3301
Loc(dam)	Tailrace	JD	GR	<0.0001*
Loc(dam)	Tailrace	MN	IH	0.3734
Loc(dam)	Tailrace	MN	LM	0.1119
Loc(dam)	Tailrace	MN	GO	0.5228
Loc(dam)	Tailrace	MN	GR	<0.0001*
Loc(dam)	Tailrace	IH	LM	0.4638
Loc(dam)	Tailrace	IH	GO	0.1896
Loc(dam)	Tailrace	IH	GR	0.0009
Loc(dam)	Tailrace	LM	GO	0.0606
Loc(dam)	Tailrace	LM	GR	0.0129
Loc(dam)	Tailrace	GO	GR	<0.0001*

Appendix B Table 5. Multiple comparisons of repeated measures ANOVA results for summer Chinook salmon temperatures in tailraces in 2000. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Tailrace	BO	TD	0.3379
Loc(dam)	Tailrace	BO	JD	0.0769
Loc(dam)	Tailrace	BO	MN	0.2789
Loc(dam)	Tailrace	BO	IH	0.0552
Loc(dam)	Tailrace	BO	LM	0.0104
Loc(dam)	Tailrace	BO	GO	0.9492
Loc(dam)	Tailrace	BO	GR	<0.0001*
Loc(dam)	Tailrace	TD	JD	0.4317
Loc(dam)	Tailrace	TD	MN	0.7970
Loc(dam)	Tailrace	TD	IH	0.2318
Loc(dam)	Tailrace	TD	LM	0.0565
Loc(dam)	Tailrace	TD	GO	0.6197
Loc(dam)	Tailrace	TD	GR	<0.0001*
Loc(dam)	Tailrace	JD	MN	0.6710
Loc(dam)	Tailrace	JD	IH	0.5513
Loc(dam)	Tailrace	JD	LM	0.1713
Loc(dam)	Tailrace	JD	GO	0.3301
Loc(dam)	Tailrace	JD	GR	<0.0001*
Loc(dam)	Tailrace	MN	IH	0.3734
Loc(dam)	Tailrace	MN	LM	0.1119
Loc(dam)	Tailrace	MN	GO	0.5228
Loc(dam)	Tailrace	MN	GR	<0.0001*
Loc(dam)	Tailrace	IH	LM	0.4638
Loc(dam)	Tailrace	IH	GO	0.1896
Loc(dam)	Tailrace	IH	GR	0.0009
Loc(dam)	Tailrace	LM	GO	0.0606
Loc(dam)	Tailrace	LM	GR	0.0129
Loc(dam)	Tailrace	GO	GR	<0.0001*

Appendix B Table 6. Multiple comparisons of repeated measures ANOVA results for summer Chinook salmon temperatures in tailraces in 2002. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Tailrace	BO	TD	0.3621
Loc(dam)	Tailrace	BO	JD	0.1489
Loc(dam)	Tailrace	BO	MN	0.1547
Loc(dam)	Tailrace	BO	IH	0.0149
Loc(dam)	Tailrace	BO	LM	0.0108
Loc(dam)	Tailrace	BO	GO	0.0001*
Loc(dam)	Tailrace	BO	GR	0.0595
Loc(dam)	Tailrace	TD	JD	0.6688
Loc(dam)	Tailrace	TD	MN	0.5821
Loc(dam)	Tailrace	TD	IH	0.1715
Loc(dam)	Tailrace	TD	LM	0.1375
Loc(dam)	Tailrace	TD	GO	0.0058
Loc(dam)	Tailrace	TD	GR	0.3638
Loc(dam)	Tailrace	JD	MN	0.8574
Loc(dam)	Tailrace	JD	IH	0.3117
Loc(dam)	Tailrace	JD	LM	0.2542
Loc(dam)	Tailrace	JD	GO	0.0124
Loc(dam)	Tailrace	JD	GR	0.5908
Loc(dam)	Tailrace	MN	IH	0.4763
Loc(dam)	Tailrace	MN	LM	0.4064
Loc(dam)	Tailrace	MN	GO	0.0375
Loc(dam)	Tailrace	MN	GR	0.7592
Loc(dam)	Tailrace	IH	LM	0.8900
Loc(dam)	Tailrace	IH	GO	0.1179
Loc(dam)	Tailrace	IH	GR	0.6700
Loc(dam)	Tailrace	LM	GO	0.1547
Loc(dam)	Tailrace	LM	GR	0.5791
Loc(dam)	Tailrace	GO	GR	0.0576

Appendix B Table 7. Multiple comparisons of repeated measures ANOVA results for fall Chinook salmon temperatures in tailraces in 2000. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > *t*
Loc(dam)	Tailrace	BO	TD	0.1556
Loc(dam)	Tailrace	BO	JD	0.1270
Loc(dam)	Tailrace	BO	MN	<0.0001*
Loc(dam)	Tailrace	BO	IH	<0.0001*
Loc(dam)	Tailrace	BO	LM	<0.0001*
Loc(dam)	Tailrace	BO	GO	<0.0001*
Loc(dam)	Tailrace	BO	GR	<0.0001*
Loc(dam)	Tailrace	TD	JD	0.7633
Loc(dam)	Tailrace	TD	MN	0.0003*
Loc(dam)	Tailrace	TD	IH	0.0008
Loc(dam)	Tailrace	TD	LM	<0.0001*
Loc(dam)	Tailrace	TD	GO	<0.0001*
Loc(dam)	Tailrace	TD	GR	<0.0001*
Loc(dam)	Tailrace	JD	MN	0.0011
Loc(dam)	Tailrace	JD	IH	0.0033
Loc(dam)	Tailrace	JD	LM	<0.0001*
Loc(dam)	Tailrace	JD	GO	<0.0001*
Loc(dam)	Tailrace	JD	GR	<0.0001*
Loc(dam)	Tailrace	MN	IH	0.6147
Loc(dam)	Tailrace	MN	LM	0.3577
Loc(dam)	Tailrace	MN	GO	0.0052
Loc(dam)	Tailrace	MN	GR	0.0001*
Loc(dam)	Tailrace	IH	LM	0.1321
Loc(dam)	Tailrace	IH	GO	0.0003*
Loc(dam)	Tailrace	IH	GR	<0.0001*
Loc(dam)	Tailrace	LM	GO	0.0671
Loc(dam)	Tailrace	LM	GR	0.0024
Loc(dam)	Tailrace	GO	GR	0.1256

Appendix B Table 8. Multiple comparisons of repeated measures ANOVA results for fall Chinook salmon temperatures in tailraces in 2002. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Tailrace	BO	TD	0.3259
Loc(dam)	Tailrace	BO	JD	0.2279
Loc(dam)	Tailrace	BO	MN	0.0174
Loc(dam)	Tailrace	BO	IH	0.0002*
Loc(dam)	Tailrace	BO	LM	<0.0001*
Loc(dam)	Tailrace	BO	GO	<0.0001*
Loc(dam)	Tailrace	BO	GR	<0.0001*
Loc(dam)	Tailrace	TD	JD	0.0669
Loc(dam)	Tailrace	TD	MN	0.0056
Loc(dam)	Tailrace	TD	IH	0.0001*
Loc(dam)	Tailrace	TD	LM	<0.0001*
Loc(dam)	Tailrace	TD	GO	<0.0001*
Loc(dam)	Tailrace	TD	GR	<0.0001*
Loc(dam)	Tailrace	JD	MN	0.1227
Loc(dam)	Tailrace	JD	IH	0.0063
Loc(dam)	Tailrace	JD	LM	<0.0001*
Loc(dam)	Tailrace	JD	GO	<0.0001*
Loc(dam)	Tailrace	JD	GR	<0.0001*
Loc(dam)	Tailrace	MN	IH	0.5264
Loc(dam)	Tailrace	MN	LM	0.0495
Loc(dam)	Tailrace	MN	GO	0.0098
Loc(dam)	Tailrace	MN	GR	0.0042
Loc(dam)	Tailrace	IH	LM	0.1126
Loc(dam)	Tailrace	IH	GO	0.0195
Loc(dam)	Tailrace	IH	GR	0.0093
Loc(dam)	Tailrace	LM	GO	0.3584
Loc(dam)	Tailrace	LM	GR	0.1363
Loc(dam)	Tailrace	GO	GR	0.4688

Appendix B Table 9. Multiple comparisons of repeated measures ANOVA results for steelhead temperatures in tailraces in 2000. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Tailrace	BO	TD	0.0129
Loc(dam)	Tailrace	BO	JD	0.0759
Loc(dam)	Tailrace	BO	MN	0.0004
Loc(dam)	Tailrace	BO	IH	0.0009
Loc(dam)	Tailrace	BO	LM	0.0013
Loc(dam)	Tailrace	BO	GO	<0.0001*
Loc(dam)	Tailrace	BO	GR	<0.0001*
Loc(dam)	Tailrace	TD	JD	0.6911
Loc(dam)	Tailrace	TD	MN	0.0809
Loc(dam)	Tailrace	TD	IH	0.1195
Loc(dam)	Tailrace	TD	LM	0.0726
Loc(dam)	Tailrace	TD	GO	0.0002*
Loc(dam)	Tailrace	TD	GR	<0.0001*
Loc(dam)	Tailrace	JD	MN	0.0490
Loc(dam)	Tailrace	JD	IH	0.0743
Loc(dam)	Tailrace	JD	LM	0.0467
Loc(dam)	Tailrace	JD	GO	0.0001*
Loc(dam)	Tailrace	JD	GR	<0.0001*
Loc(dam)	Tailrace	MN	IH	0.8773
Loc(dam)	Tailrace	MN	LM	0.7551
Loc(dam)	Tailrace	MN	GO	0.0245
Loc(dam)	Tailrace	MN	GR	<0.0001*
Loc(dam)	Tailrace	IH	LM	0.6507
Loc(dam)	Tailrace	IH	GO	0.0171
Loc(dam)	Tailrace	IH	GR	<0.0001*
Loc(dam)	Tailrace	LM	GO	0.0651
Loc(dam)	Tailrace	LM	GR	0.0004
Loc(dam)	Tailrace	GO	GR	0.1909

Appendix B Table 10. Multiple comparisons of repeated measures ANOVA results for steelhead temperatures in tailraces in 2002. Asterisk indicates significant difference with Dunn-Sidak correction (*P*=0.0004).

Effect	Location	Dam	Dam	Prob > *t*
Loc(dam)	Tailrace	BO	TD	0.7534
Loc(dam)	Tailrace	BO	JD	0.1184
Loc(dam)	Tailrace	BO	MN	0.0002*
Loc(dam)	Tailrace	BO	IH	<0.0001*
Loc(dam)	Tailrace	BO	LM	<0.0001*
Loc(dam)	Tailrace	BO	GO	<0.0001*
Loc(dam)	Tailrace	BO	GR	<0.0001*
Loc(dam)	Tailrace	TD	JD	0.2848
Loc(dam)	Tailrace	TD	MN	0.0014
Loc(dam)	Tailrace	TD	IH	<0.0001*
Loc(dam)	Tailrace	TD	LM	<0.0001*
Loc(dam)	Tailrace	TD	GO	<0.0001*
Loc(dam)	Tailrace	TD	GR	<0.0001*
Loc(dam)	Tailrace	JD	MN	0.0150
Loc(dam)	Tailrace	JD	IH	<0.0001*
Loc(dam)	Tailrace	JD	LM	<0.0001*
Loc(dam)	Tailrace	JD	GO	<0.0001*
Loc(dam)	Tailrace	JD	GR	<0.0001*
Loc(dam)	Tailrace	MN	IH	0.2740
Loc(dam)	Tailrace	MN	LM	0.0042
Loc(dam)	Tailrace	MN	GO	0.0005
Loc(dam)	Tailrace	MN	GR	<0.0001*
Loc(dam)	Tailrace	IH	LM	0.0372
Loc(dam)	Tailrace	IH	GO	0.0045
Loc(dam)	Tailrace	IH	GR	<0.0001*
Loc(dam)	Tailrace	LM	GO	0.3189
Loc(dam)	Tailrace	LM	GR	0.0075
Loc(dam)	Tailrace	GO	GR	0.1219

Appendix B Table 11. The minimum, maximum, and average temperature (C) of RDST spring, summer, and fall Chinook salmon, and steelhead in the ladders of the four Columbia and three Snake river dams in 2000.

Species	Dam	N	Min of Min	Avg of Min	Max of Max	Avg of Max	Avg of Median	Avg of Mean	Avg of Stdev
Spring Chinook	BO	72	10.3	12.7	16.0	12.9	12.8	12.8	0.05
	TD	82	10.9	12.9	15.9	13.2	13.1	13.1	0.06
	JD	63	10.7	13.3	16.9	13.7	13.5	13.5	0.12
	MN	64	10.1	13.2	16.6	13.5	13.4	13.4	0.10
	IH	55	11.3	13.7	17.5	14.0	13.9	13.9	0.07
	LM	52	11.2	13.5	18.6	14.0	13.8	13.8	0.12
	GO	58	10.9	13.8	17.2	14.3	14.1	14.1	0.13
Summer Chinook	BO	36	15.4	17.9	22.2	18.0	18.0	18.0	0.05
	TD	34	15.4	18.0	22.1	18.2	18.1	18.1	0.05
	JD	32	15.5	18.3	22.7	18.8	18.6	18.6	0.12
	MN	35	14.8	18.1	22.9	18.7	18.4	18.4	0.16
	IH	12	15.1	16.8	20.6	17.2	17.1	17.0	0.09
	LM	10	16.0	16.8	19.3	17.5	17.2	17.2	0.18
	GO	11	15.2	16.8	20.1	17.7	17.5	17.4	0.22
Fall Chinook	BO	31	13.8	19.7	21.7	19.9	19.8	19.8	0.04
	TD	26	14.4	20.0	21.6	20.2	20.1	20.1	0.05
	JD	17	13.6	19.8	22.2	20.3	20.1	20.1	0.11
	MN	16	12.3	18.9	22.4	19.1	19.0	19.0	0.06
	IH	12	12.0	19.3	22.0	19.7	19.5	19.5	0.07
	LM	12	10.9	18.4	21.1	18.9	18.8	18.8	0.09
	GO	8	10.1	17.0	19.3	17.3	17.2	17.2	0.05
Steelhead	BO	105	13.2	19.1	22.3	19.4	19.3	19.3	0.06
	TD	46	16.4	19.7	21.6	19.9	19.8	19.8	0.04
	JD	42	13.9	18.7	22.1	18.9	18.8	18.8	0.07
	MN	43	13.4	18.1	22.8	18.4	18.3	18.3	0.08
	IH	26	14.1	17.7	21.9	18.0	17.9	17.9	0.09
	LM	18	13.2	17.2	22.5	17.6	17.5	17.5	0.09
	GO	22	12.1	17.1	21.2	17.3	17.2	17.2	0.05

Appendix B Table 12. The minimum, maximum, and average temperature (C) of RDST spring, summer, and fall Chinook salmon, and steelhead in the ladders of the four Columbia and three Snake river dams in 2002.

Species	Dam	N	Min of Min	Avg of Min	Max of Max	Avg of Max	Avg of Median	Avg of Mean	Avg of Stdev
Spring Chinook	BO	83	8.4	11.2	15.3	11.5	11.4	11.4	0.07
	TD	69	9.6	11.5	14.9	11.7	11.7	11.7	0.06
	JD	69	9.5	11.7	15.8	12.3	12.1	12.1	0.15
	MN	63	8.9	11.7	15.7	12.1	11.9	11.9	0.11
	IH	66	9.6	12.1	16.4	12.5	12.3	12.3	0.11
	LM	51	10.0	11.5	14.6	12.0	11.8	11.8	0.12
	GO	64	10.2	11.7	16.0	12.3	12.1	12.1	0.17
Summer Chinook	BO	29	14.4	16.1	19.4	16.4	16.3	16.3	0.06
	TD	28	14.5	16.2	19.2	16.4	16.3	16.3	0.05
	JD	29	14.7	16.7	21.9	17.3	17.1	17.1	0.16
	MN	26	13.4	16.7	21.6	17.1	16.9	16.9	0.10
	IH	23	13.6	16.1	22.1	16.4	16.3	16.3	0.08
	LM	18	13.3	16.1	21.6	16.6	16.4	16.4	0.13
	GO	18	15.3	16.5	21.5	17.3	17.1	17.0	0.21
Fall Chinook	BO	15	18.8	19.9	21.3	20.1	20.0	20.0	0.05
	TD	15	19.5	20.3	21.4	20.5	20.4	20.4	0.03
	JD	13	18.3	20.2	22.3	20.8	20.5	20.5	0.14
	MN	13	16.7	19.2	21.4	19.5	19.4	19.4	0.07
	IH	13	16.9	18.8	20.8	19.1	19.0	19.0	0.07
	LM	5	17.0	18.0	19.5	18.2	18.1	18.1	0.05
	GO	7	17.3	18.0	19.7	18.4	18.4	18.3	0.08
Steelhead	BO	136	14.3	19.8	21.9	20.0	19.9	19.9	0.05
	TD	99	14.5	19.8	21.9	20.0	19.9	19.9	0.04
	JD	74	14.4	19.5	22.2	19.9	19.8	19.7	0.09
	MN	69	11.0	18.7	22.8	19.0	18.8	18.8	0.09
	IH	60	12.3	18.5	22.3	18.8	18.7	18.7	0.09
	LM	38	13.1	17.7	22.1	18.1	18.0	18.0	0.09
	GO	41	15.6	17.6	21.0	17.8	17.8	17.7	0.06

Appendix B Table 13. Multiple comparisons of repeated measures ANOVA results for spring Chinook salmon temperatures in ladders in 2000. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Ladder	BO	TD	0.0028
Loc(dam)	Ladder	BO	JD	<0.0001*
Loc(dam)	Ladder	BO	MN	<0.0001*
Loc(dam)	Ladder	BO	IH	<0.0001*
Loc(dam)	Ladder	BO	LM	<0.0001*
Loc(dam)	Ladder	BO	GO	<0.0001*
Loc(dam)	Ladder	TD	JD	0.0032
Loc(dam)	Ladder	TD	MN	0.0097
Loc(dam)	Ladder	TD	IH	<0.0001*
Loc(dam)	Ladder	TD	LM	<0.0001*
Loc(dam)	Ladder	TD	GO	<0.0001*
Loc(dam)	Ladder	JD	MN	0.7234
Loc(dam)	Ladder	JD	IH	0.0003*
Loc(dam)	Ladder	JD	LM	<0.0001*
Loc(dam)	Ladder	JD	GO	<0.0001*
Loc(dam)	Ladder	MN	IH	<0.0001*
Loc(dam)	Ladder	MN	LM	<0.0001*
Loc(dam)	Ladder	MN	GO	<0.0001*
Loc(dam)	Ladder	IH	LM	0.6646
Loc(dam)	Ladder	IH	GO	0.0496
Loc(dam)	Ladder	LM	GO	0.1346

Appendix B Table 14. Multiple comparisons of repeated measures ANOVA results for spring Chinook salmon temperatures in ladders in 2002. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Ladder	BO	TD	0.0047
Loc(dam)	Ladder	BO	JD	<0.0001*
Loc(dam)	Ladder	BO	MN	0.0007
Loc(dam)	Ladder	BO	IH	<0.0001*
Loc(dam)	Ladder	BO	LM	0.0006
Loc(dam)	Ladder	BO	GO	<0.0001
Loc(dam)	Ladder	TD	JD	0.0021
Loc(dam)	Ladder	TD	MN	0.5229
Loc(dam)	Ladder	TD	IH	<0.0001*
Loc(dam)	Ladder	TD	LM	0.3998
Loc(dam)	Ladder	TD	GO	0.0008
Loc(dam)	Ladder	JD	MN	0.0179
Loc(dam)	Ladder	JD	IH	0.2830
Loc(dam)	Ladder	JD	LM	0.0467
Loc(dam)	Ladder	JD	GO	0.7369
Loc(dam)	Ladder	MN	IH	0.0007
Loc(dam)	Ladder	MN	LM	0.8139
Loc(dam)	Ladder	MN	GO	0.0079
Loc(dam)	Ladder	IH	LM	0.0031
Loc(dam)	Ladder	IH	GO	0.4700
Loc(dam)	Ladder	LM	GO	0.0230

Appendix B Table 15. Multiple comparisons of repeated measures ANOVA results for summer Chinook salmon temperatures in ladders in 2000. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > *t*
Loc(dam)	Ladder	BO	TD	0.1052
Loc(dam)	Ladder	BO	JD	<0.0001*
Loc(dam)	Ladder	BO	MN	<0.0001*
Loc(dam)	Ladder	BO	IH	0.0003*
Loc(dam)	Ladder	BO	LM	<0.0001*
Loc(dam)	Ladder	BO	GO	<0.0001*
Loc(dam)	Ladder	TD	JD	0.0015
Loc(dam)	Ladder	TD	MN	0.0021
Loc(dam)	Ladder	TD	IH	0.0119
Loc(dam)	Ladder	TD	LM	<0.0001*
Loc(dam)	Ladder	TD	GO	<0.0001*
Loc(dam)	Ladder	JD	MN	0.8625
Loc(dam)	Ladder	JD	IH	0.8263
Loc(dam)	Ladder	JD	LM	0.0487
Loc(dam)	Ladder	JD	GO	0.0002*
Loc(dam)	Ladder	MN	IH	0.7289
Loc(dam)	Ladder	MN	LM	0.0350
Loc(dam)	Ladder	MN	GO	0.0001*
Loc(dam)	Ladder	IH	LM	0.1270
Loc(dam)	Ladder	IH	GO	0.0028
Loc(dam)	Ladder	LM	GO	0.1707

Appendix B Table 16. Multiple comparisons of repeated measures ANOVA results for summer Chinook salmon temperatures in ladders in 2002. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Ladder	BO	TD	0.7537
Loc(dam)	Ladder	BO	JD	<0.0001*
Loc(dam)	Ladder	BO	MN	0.0008
Loc(dam)	Ladder	BO	IH	0.0302
Loc(dam)	Ladder	BO	LM	0.0163
Loc(dam)	Ladder	BO	GO	<0.0001*
Loc(dam)	Ladder	TD	JD	<0.0001*
Loc(dam)	Ladder	TD	MN	0.0025
Loc(dam)	Ladder	TD	IH	0.0630
Loc(dam)	Ladder	TD	LM	0.0340
Loc(dam)	Ladder	TD	GO	<0.0001*
Loc(dam)	Ladder	JD	MN	0.4399
Loc(dam)	Ladder	JD	IH	0.0693
Loc(dam)	Ladder	JD	LM	0.1949
Loc(dam)	Ladder	JD	GO	0.0088
Loc(dam)	Ladder	MN	IH	0.2946
Loc(dam)	Ladder	MN	LM	0.5525
Loc(dam)	Ladder	MN	GO	0.0012
Loc(dam)	Ladder	IH	LM	0.7078
Loc(dam)	Ladder	IH	GO	<0.0001*
Loc(dam)	Ladder	LM	GO	0.0004

Appendix B Table 17. Multiple comparisons of repeated measures ANOVA results for fall Chinook salmon temperatures in ladders in 2000. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Ladder	BO	TD	0.4885
Loc(dam)	Ladder	BO	JD	0.6331
Loc(dam)	Ladder	BO	MN	<0.0001*
Loc(dam)	Ladder	BO	IH	0.0023
Loc(dam)	Ladder	BO	LM	<0.0001*
Loc(dam)	Ladder	BO	GO	<0.0001*
Loc(dam)	Ladder	TD	JD	0.9005
Loc(dam)	Ladder	TD	MN	<0.0001*
Loc(dam)	Ladder	TD	IH	0.0129
Loc(dam)	Ladder	TD	LM	<0.0001*
Loc(dam)	Ladder	TD	GO	<0.0001*
Loc(dam)	Ladder	JD	MN	0.0001*
Loc(dam)	Ladder	JD	IH	0.0151
Loc(dam)	Ladder	JD	LM	<0.0001*
Loc(dam)	Ladder	JD	GO	<0.0001*
Loc(dam)	Ladder	MN	IH	0.2770
Loc(dam)	Ladder	MN	LM	0.2746
Loc(dam)	Ladder	MN	GO	<0.0001*
Loc(dam)	Ladder	IH	LM	0.0409
Loc(dam)	Ladder	IH	GO	<0.0001*
Loc(dam)	Ladder	LM	GO	0.0020

Appendix B Table 18. Multiple comparisons of repeated measures ANOVA results for fall Chinook salmon temperatures in ladders in 2002. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Ladder	BO	TD	0.6339
Loc(dam)	Ladder	BO	JD	0.1525
Loc(dam)	Ladder	BO	MN	0.0614
Loc(dam)	Ladder	BO	IH	0.0039
Loc(dam)	Ladder	BO	LM	0.0001*
Loc(dam)	Ladder	BO	GO	<0.0001*
Loc(dam)	Ladder	TD	JD	0.3235
Loc(dam)	Ladder	TD	MN	0.0186
Loc(dam)	Ladder	TD	IH	0.0007
Loc(dam)	Ladder	TD	LM	<0.0001*
Loc(dam)	Ladder	TD	GO	<0.0001*
Loc(dam)	Ladder	JD	MN	0.0013
Loc(dam)	Ladder	JD	IH	<0.0001*
Loc(dam)	Ladder	JD	LM	<0.0001*
Loc(dam)	Ladder	JD	GO	<0.0001*
Loc(dam)	Ladder	MN	IH	0.3118
Loc(dam)	Ladder	MN	LM	0.0114
Loc(dam)	Ladder	MN	GO	0.0122
Loc(dam)	Ladder	IH	LM	0.0735
Loc(dam)	Ladder	IH	GO	0.0931
Loc(dam)	Ladder	LM	GO	0.7867

Appendix B Table 19. Multiple comparisons of repeated measures ANOVA results for steelhead temperatures in ladders in 2000. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Ladder	BO	TD	0.0506
Loc(dam)	Ladder	BO	JD	0.0158
Loc(dam)	Ladder	BO	MN	<0.0001*
Loc(dam)	Ladder	BO	IH	0.0006
Loc(dam)	Ladder	BO	LM	0.0001*
Loc(dam)	Ladder	BO	GO	<0.0001*
Loc(dam)	Ladder	TD	JD	0.6464
Loc(dam)	Ladder	TD	MN	0.0496
Loc(dam)	Ladder	TD	IH	0.0931
Loc(dam)	Ladder	TD	LM	0.0213
Loc(dam)	Ladder	TD	GO	0.0004
Loc(dam)	Ladder	JD	MN	0.1360
Loc(dam)	Ladder	JD	IH	0.1999
Loc(dam)	Ladder	JD	LM	0.0512
Loc(dam)	Ladder	JD	GO	0.0017
Loc(dam)	Ladder	MN	IH	0.9980
Loc(dam)	Ladder	MN	LM	0.4108
Loc(dam)	Ladder	MN	GO	0.0523
Loc(dam)	Ladder	IH	LM	0.4458
Loc(dam)	Ladder	IH	GO	0.0755
Loc(dam)	Ladder	LM	GO	0.3796

Appendix B Table 20. Multiple comparisons of repeated measures ANOVA results for steelhead temperatures in ladders in 2002. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Ladder	BO	TD	0.0267
Loc(dam)	Ladder	BO	JD	0.0230
Loc(dam)	Ladder	BO	MN	<0.0001*
Loc(dam)	Ladder	BO	IH	<0.0001*
Loc(dam)	Ladder	BO	LM	<0.0001*
Loc(dam)	Ladder	BO	GO	<0.0001*
Loc(dam)	Ladder	TD	JD	0.8033
Loc(dam)	Ladder	TD	MN	<0.0001*
Loc(dam)	Ladder	TD	IH	<0.0001*
Loc(dam)	Ladder	TD	LM	<0.0001*
Loc(dam)	Ladder	TD	GO	<0.0001*
Loc(dam)	Ladder	JD	MN	0.0002*
Loc(dam)	Ladder	JD	IH	<0.0001*
Loc(dam)	Ladder	JD	LM	<0.0001*
Loc(dam)	Ladder	JD	GO	<0.0001*
Loc(dam)	Ladder	MN	IH	0.4752
Loc(dam)	Ladder	MN	LM	0.0057
Loc(dam)	Ladder	MN	GO	0.0023
Loc(dam)	Ladder	IH	LM	0.0360
Loc(dam)	Ladder	IH	GO	0.0184
Loc(dam)	Ladder	LM	GO	0.8495

Appendix B Table 21. The minimum, maximum, and average temperature (C) of RDST spring, summer, and fall Chinook salmon, and steelhead in the reservoirs of the four Columbia and three Snake river dams in 2000.

Species	Dam	N	Min of Min	Avg of Min	Max of Max	Avg of Max	Avg of Median	Avg of Mean	Avg of Stdev
Spring Chinook	BO	89	8.3	12.1	17.3	13.4	12.7	12.8	0.32
	TD	85	9.4	12.4	18.8	13.9	13.0	13.0	0.39
	JD	68	10.0	12.6	21.2	14.8	13.2	13.3	0.45
	MN	60	9.6	12.9	18.5	14.9	13.6	13.7	0.43
	IH	60	10.9	13.3	18.3	14.4	13.7	13.7	0.28
	LM	59	10.6	13.3	18.8	14.6	13.7	13.7	0.31
	GO	58	10.7	13.1	18.6	14.8	13.7	13.7	0.45
Summer Chinook	BO	38	13.7	16.8	22.4	18.3	17.7	17.7	0.31
	TD	35	15.2	17.3	22.5	18.4	17.9	17.9	0.26
	JD	33	14.6	17.7	22.9	19.3	18.3	18.3	0.35
	MN	13	14.4	15.8	21.2	17.9	16.4	16.5	0.45
	IH	13	15.1	16.3	20.6	17.5	16.9	16.9	0.28
	LM	13	14.7	16.2	20.0	17.9	16.8	16.9	0.41
	GO	11	14.4	16.0	19.9	17.6	16.6	16.6	0.39
Fall Chinook	BO	36	7.7	16.2	22.4	20.2	18.8	18.7	0.93
	TD	22	12.4	17.7	21.5	19.9	19.1	19.1	0.54
	JD	13	10.7	17.5	21.8	19.8	18.7	18.7	0.54
	MN	11	9.4	17.3	21.6	19.1	18.2	18.2	0.39
	IH	11	10.4	17.5	22.1	19.0	18.2	18.2	0.36
	LM	11	10.1	15.9	21.2	18.6	16.9	17.1	0.67
	GO	11	8.7	16.4	20.2	18.0	17.2	17.2	0.44
Steelhead	BO	112	7.0	13.2	22.4	19.7	16.1	16.2	1.34
	TD	63	10.2	16.3	22.4	19.3	18.1	18.1	0.72
	JD	41	11.3	17.3	22.4	19.1	18.2	18.2	0.39
	MN	30	12.2	16.6	22.3	18.8	17.8	17.7	0.45
	IH	26	12.8	16.9	22.1	18.2	17.5	17.5	0.29
	LM	26	11.1	14.6	21.8	17.8	16.4	16.3	0.90
	GO	24	10.2	15.2	22.1	17.3	16.1	16.2	0.51

Appendix B Table 22. The minimum, maximum, and average temperature (C) of RDST spring, summer, and fall Chinook salmon, and steelhead in the reservoirs of the four Columbia and three Snake river dams in 2002.

Species	Dam	N	Min of Min	Avg of Min	Max of Max	Avg of Max	Avg of Median	Avg of Mean	Avg of Stdev
Spring Chinook	BO	90	8.4	11.0	17.3	11.9	11.4	11.4	0.20
	TD	78	9.4	11.3	15.5	12.1	11.6	11.6	0.20
	JD	74	8.5	11.1	18.3	13.1	11.6	11.6	0.38
	MN	71	8.4	11.3	16.5	13.0	11.9	11.9	0.39
	IH	70	9.5	11.4	17.0	12.7	11.9	11.9	0.31
	LM	70	10.1	11.3	16.3	12.5	11.7	11.7	0.28
	GO	69	9.2	11.1	16.0	12.7	11.7	11.7	0.40
Summer Chinook	BO	32	13.9	15.8	19.6	16.6	16.2	16.2	0.17
	TD	31	13.8	16.0	19.5	16.6	16.2	16.3	0.15
	JD	29	13.1	16.2	21.0	17.7	16.7	16.7	0.29
	MN	29	12.9	15.9	21.9	17.6	16.5	16.5	0.43
	IH	23	13.3	15.7	22.3	16.8	16.2	16.2	0.31
	LM	23	12.7	15.7	21.7	17.0	16.4	16.3	0.32
	GO	22	12.4	15.5	21.5	17.2	16.1	16.2	0.44
Fall Chinook	BO	20	14.8	18.5	21.4	20.4	20.1	19.9	0.43
	TD	17	14.1	18.3	21.4	20.4	19.8	19.7	0.58
	JD	14	16.5	19.3	22.3	20.8	19.8	19.9	0.32
	MN	14	16.3	18.4	22.0	19.7	19.0	19.0	0.29
	IH	13	16.7	18.1	20.6	19.2	18.5	18.6	0.29
	LM	13	15.0	17.2	20.2	18.8	18.1	18.1	0.31
	GO	13	15.8	17.3	20.0	18.6	17.9	17.9	0.33
Steelhead	BO	167	6.2	13.0	22.7	20.3	16.0	16.2	1.58
	TD	118	6.6	15.9	21.9	19.9	18.2	18.1	1.05
	JD	89	10.6	17.8	22.2	19.8	18.9	18.9	0.44
	MN	75	7.2	16.9	22.8	19.3	18.2	18.2	0.50
	IH	62	10.9	17.6	23.0	18.9	18.2	18.2	0.30
	LM	59	10.5	16.3	22.3	18.6	17.6	17.6	0.55
	GO	54	8.2	16.7	22.5	18.4	17.4	17.5	0.43

Appendix B Table 23. Multiple comparisons of repeated measures ANOVA results for spring Chinook salmon temperatures in reservoirs in 2000. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Reservoir	BO	TD	0.0098
Loc(dam)	Reservoir	BO	JD	0.0002*
Loc(dam)	Reservoir	BO	MN	<0.0001*
Loc(dam)	Reservoir	BO	IH	<0.0001*
Loc(dam)	Reservoir	BO	LM	<0.0001*
Loc(dam)	Reservoir	BO	GO	<0.0001*
Loc(dam)	Reservoir	TD	JD	0.1933
Loc(dam)	Reservoir	TD	MN	0.0002*
Loc(dam)	Reservoir	TD	IH	<0.0001*
Loc(dam)	Reservoir	TD	LM	<0.0001*
Loc(dam)	Reservoir	TD	GO	<0.0001*
Loc(dam)	Reservoir	JD	MN	0.0187
Loc(dam)	Reservoir	JD	IH	0.0006
Loc(dam)	Reservoir	JD	LM	0.0009
Loc(dam)	Reservoir	JD	GO	0.0009
Loc(dam)	Reservoir	MN	IH	0.2890
Loc(dam)	Reservoir	MN	LM	0.3392
Loc(dam)	Reservoir	MN	GO	0.3258
Loc(dam)	Reservoir	IH	LM	0.9205
Loc(dam)	Reservoir	IH	GO	0.9457
Loc(dam)	Reservoir	LM	GO	0.9752

Appendix B Table 24. Multiple comparisons of repeated measures ANOVA results for spring Chinook salmon temperatures in reservoirs in 2002. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > *t*
Loc(dam)	Reservoir	BO	TD	0.2033
Loc(dam)	Reservoir	BO	JD	0.1060
Loc(dam)	Reservoir	BO	MN	<0.0001*
Loc(dam)	Reservoir	BO	IH	0.0010
Loc(dam)	Reservoir	BO	LM	0.1405
Loc(dam)	Reservoir	BO	GO	0.1134
Loc(dam)	Reservoir	TD	JD	0.7216
Loc(dam)	Reservoir	TD	MN	0.0077
Loc(dam)	Reservoir	TD	IH	0.0438
Loc(dam)	Reservoir	TD	LM	0.8119
Loc(dam)	Reservoir	TD	GO	0.7265
Loc(dam)	Reservoir	JD	MN	0.0222
Loc(dam)	Reservoir	JD	IH	0.0998
Loc(dam)	Reservoir	JD	LM	0.9115
Loc(dam)	Reservoir	JD	GO	0.9995
Loc(dam)	Reservoir	MN	IH	0.5303
Loc(dam)	Reservoir	MN	LM	0.0177
Loc(dam)	Reservoir	MN	GO	0.0244
Loc(dam)	Reservoir	IH	LM	0.0821
Loc(dam)	Reservoir	IH	GO	0.1049
Loc(dam)	Reservoir	LM	GO	0.9122

Appendix B Table 25. Multiple comparisons of repeated measures ANOVA results for summer Chinook salmon temperatures in reservoirs in 2000. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Reservoir	BO	TD	0.0637
Loc(dam)	Reservoir	BO	JD	<0.0001*
Loc(dam)	Reservoir	BO	MN	0.0181
Loc(dam)	Reservoir	BO	IH	<0.0001*
Loc(dam)	Reservoir	BO	LM	<0.0001*
Loc(dam)	Reservoir	BO	GO	<0.0001*
Loc(dam)	Reservoir	TD	JD	0.0011
Loc(dam)	Reservoir	TD	MN	0.3034
Loc(dam)	Reservoir	TD	IH	0.0009
Loc(dam)	Reservoir	TD	LM	0.0038
Loc(dam)	Reservoir	TD	GO	0.0003*
Loc(dam)	Reservoir	JD	MN	0.1727
Loc(dam)	Reservoir	JD	IH	0.3512
Loc(dam)	Reservoir	JD	LM	0.6224
Loc(dam)	Reservoir	JD	GO	0.1806
Loc(dam)	Reservoir	MN	IH	0.0501
Loc(dam)	Reservoir	MN	LM	0.1132
Loc(dam)	Reservoir	MN	GO	0.0231
Loc(dam)	Reservoir	IH	LM	0.7072
Loc(dam)	Reservoir	IH	GO	0.6880
Loc(dam)	Reservoir	LM	GO	0.4471

Appendix B Table 26. Multiple comparisons of repeated measures ANOVA results for summer Chinook salmon temperatures in reservoirs in 2002. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Reservoir	BO	TD	0.3702
Loc(dam)	Reservoir	BO	JD	0.0025
Loc(dam)	Reservoir	BO	MN	0.0437
Loc(dam)	Reservoir	BO	IH	0.0125
Loc(dam)	Reservoir	BO	LM	0.0006
Loc(dam)	Reservoir	BO	GO	0.0029
Loc(dam)	Reservoir	TD	JD	0.0327
Loc(dam)	Reservoir	TD	MN	0.2570
Loc(dam)	Reservoir	TD	IH	0.0942
Loc(dam)	Reservoir	TD	LM	0.0091
Loc(dam)	Reservoir	TD	GO	0.0306
Loc(dam)	Reservoir	JD	MN	0.3234
Loc(dam)	Reservoir	JD	IH	0.7517
Loc(dam)	Reservoir	JD	LM	0.5431
Loc(dam)	Reservoir	JD	GO	0.8463
Loc(dam)	Reservoir	MN	IH	0.5429
Loc(dam)	Reservoir	MN	LM	0.1251
Loc(dam)	Reservoir	MN	GO	0.2683
Loc(dam)	Reservoir	IH	LM	0.3780
Loc(dam)	Reservoir	IH	GO	0.6290
Loc(dam)	Reservoir	LM	GO	0.6979

Appendix B Table 27. Multiple comparisons of repeated measures ANOVA results for fall Chinook salmon temperatures in reservoirs in 2000. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Reservoir	BO	TD	0.0316
Loc(dam)	Reservoir	BO	JD	0.9049
Loc(dam)	Reservoir	BO	MN	0.0589
Loc(dam)	Reservoir	BO	IH	0.1047
Loc(dam)	Reservoir	BO	LM	<0.0001*
Loc(dam)	Reservoir	BO	GO	<0.0001*
Loc(dam)	Reservoir	TD	JD	0.1193
Loc(dam)	Reservoir	TD	MN	0.0009
Loc(dam)	Reservoir	TD	IH	0.0021
Loc(dam)	Reservoir	TD	LM	<0.0001*
Loc(dam)	Reservoir	TD	GO	<0.0001*
Loc(dam)	Reservoir	JD	MN	0.0874
Loc(dam)	Reservoir	JD	IH	0.1374
Loc(dam)	Reservoir	JD	LM	<0.0001*
Loc(dam)	Reservoir	JD	GO	<0.0001*
Loc(dam)	Reservoir	MN	IH	0.8231
Loc(dam)	Reservoir	MN	LM	<0.0001*
Loc(dam)	Reservoir	MN	GO	0.0003*
Loc(dam)	Reservoir	IH	LM	<0.0001*
Loc(dam)	Reservoir	IH	GO	0.0001*
Loc(dam)	Reservoir	LM	GO	0.5955

Appendix B Table 28. Multiple comparisons of repeated measures ANOVA results for fall Chinook salmon temperatures in reservoirs in 2002. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > t
Loc(dam)	Reservoir	BO	TD	0.3540
Loc(dam)	Reservoir	BO	JD	0.2527
Loc(dam)	Reservoir	BO	MN	0.0003*
Loc(dam)	Reservoir	BO	IH	<0.0001*
Loc(dam)	Reservoir	BO	LM	<0.0001*
Loc(dam)	Reservoir	BO	GO	<0.0001*
Loc(dam)	Reservoir	TD	JD	0.7919
Loc(dam)	Reservoir	TD	MN	0.0066
Loc(dam)	Reservoir	TD	IH	0.0001*
Loc(dam)	Reservoir	TD	LM	<0.0001*
Loc(dam)	Reservoir	TD	GO	<0.0001*
Loc(dam)	Reservoir	JD	MN	0.0191
Loc(dam)	Reservoir	JD	IH	0.0007
Loc(dam)	Reservoir	JD	LM	<0.0001*
Loc(dam)	Reservoir	JD	GO	<0.0001*
Loc(dam)	Reservoir	MN	IH	0.2574
Loc(dam)	Reservoir	MN	LM	0.0133
Loc(dam)	Reservoir	MN	GO	0.0016
Loc(dam)	Reservoir	IH	LM	0.1847
Loc(dam)	Reservoir	IH	GO	0.0451
Loc(dam)	Reservoir	LM	GO	0.4965

Appendix B Table 29. Multiple comparisons of repeated measures ANOVA results for steelhead temperatures in reservoirs in 2000. Asterisk indicates significant difference with Dunn-Sidak correction (*P*=0.0004).

Effect	Location	Dam	Dam	Prob > *t*
Loc(dam)	Reservoir	BO	TD	<0.0001*
Loc(dam)	Reservoir	BO	JD	<0.0001*
Loc(dam)	Reservoir	BO	MN	<0.0001*
Loc(dam)	Reservoir	BO	IH	<0.0001*
Loc(dam)	Reservoir	BO	LM	0.0789
Loc(dam)	Reservoir	BO	GO	0.2286
Loc(dam)	Reservoir	TD	JD	0.4375
Loc(dam)	Reservoir	TD	MN	0.7742
Loc(dam)	Reservoir	TD	IH	0.6109
Loc(dam)	Reservoir	TD	LM	0.0003*
Loc(dam)	Reservoir	TD	GO	<0.0001*
Loc(dam)	Reservoir	JD	MN	0.3604
Loc(dam)	Reservoir	JD	IH	0.2745
Loc(dam)	Reservoir	JD	LM	<0.0001*
Loc(dam)	Reservoir	JD	GO	<0.0001*
Loc(dam)	Reservoir	MN	IH	0.8347
Loc(dam)	Reservoir	MN	LM	0.0034
Loc(dam)	Reservoir	MN	GO	0.0010
Loc(dam)	Reservoir	IH	LM	0.0078
Loc(dam)	Reservoir	IH	GO	0.0026
Loc(dam)	Reservoir	LM	GO	0.6803

Appendix B Table 30. Multiple comparisons of repeated measures ANOVA results for steelhead temperatures in reservoirs in 2002. Asterisk indicates significant difference with Dunn-Sidak correction (P=0.0004).

Effect	Location	Dam	Dam	Prob > *t*
Loc(dam)	Reservoir	BO	TD	<0.0001*
Loc(dam)	Reservoir	BO	JD	<0.0001*
Loc(dam)	Reservoir	BO	MN	<0.0001*
Loc(dam)	Reservoir	BO	IH	<0.0001*
Loc(dam)	Reservoir	BO	LM	<0.0001*
Loc(dam)	Reservoir	BO	GO	<0.0001*
Loc(dam)	Reservoir	TD	JD	0.0015
Loc(dam)	Reservoir	TD	MN	0.4532
Loc(dam)	Reservoir	TD	IH	0.3698
Loc(dam)	Reservoir	TD	LM	0.0004
Loc(dam)	Reservoir	TD	GO	0.0001*
Loc(dam)	Reservoir	JD	MN	0.0003*
Loc(dam)	Reservoir	JD	IH	0.0004
Loc(dam)	Reservoir	JD	LM	<0.0001*
Loc(dam)	Reservoir	JD	GO	<0.0001*
Loc(dam)	Reservoir	MN	IH	0.8580
Loc(dam)	Reservoir	MN	LM	0.0087
Loc(dam)	Reservoir	MN	GO	0.0027
Loc(dam)	Reservoir	IH	LM	0.0186
Loc(dam)	Reservoir	IH	GO	0.0064
Loc(dam)	Reservoir	LM	GO	0.6682