Feasibility Study to Determine the Distribution of Juvenile Hatchery Spring Chinook Salmon in the Deschutes River and Their Potential Effect Upon the Aquatic Community

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Feasibility Study to Determine the Distribution of Juvenile Hatchery Spring Chinook Salmon in the Deschutes River and Their Potential Effect Upon the Aquatic Community

Annual report for 2000

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Executive Summary

In a review of National Fish Hatcheries (NFH), the U.S. Fish and Wildlife Service (USFWS) identified the need to assess the fate of hatchery-reared fish and their potential effect on the aquatic community (USFWS 1998). Additionally, in the Columbia River Biological Opinion, the National Marine Fisheries Service (NMFS) recommended monitoring and evaluating ecological interactions between hatchery and wild fish (NMFS 1999). These recommendations prompted a pilot project during 2000 to address the biological and ecological effects of fish released from the Warm Springs NFH, located on a tributary to the Deschutes River. Managers are concerned about fall releases of juvenile hatchery spring chinook salmon because hatchery fish that overwinter could displace of compete with wild fish.

In this pilot study, we used biotelemetry to examine the distribution and behavior of fall-released juvenile hatchery spring chinook salmon in the Deschutes River. Our objectives were to determine the feasibility of using radio telemetry techniques to describe the spatial distribution and extent of overwintering of juvenile hatchery chinook salmon in the Deschutes River, and to determine the feasibility of conducting underwater observations and habitat assessments to describe the potential effect of juvenile chinook salmon on the aquatic community.

From 26 October, 2000 to 4 January, 2001 we radio tagged and tracked 54 fall-released fish. Fish were surgically tagged with pulsed-coded radio transmitters using procedures described by Adams et al. (1998) and released downstream of a migrant trap on the Warm Springs River. Three telemetry fixed sites were established along the lower Deschutes River at the upper, middle, and lower sections of the study area. We calculated the travel times and travel rates of fish between detections at the fixed sites. We found that 35 % of the radio-tagged fish left the Deschutes River and 65 % remained in the Deschutes River during our study period. Median travel times, of fish that migrated downstream, from release to the middle site (Oak Springs) was 13.3 h (0.55 d), with fish reaching the mouth of the Deschutes River in a median travel time of 38.4 h (1.60 d). We found that larger fish tended to migrate faster than smaller fish and were more likely to leave the Deschutes River. Fish between 145 mm and 160 mm had a substantial overlap in their migration rates. However, fish less than 145 mm traveled less than 15 km/d, whereas fish greater than 160 mm traveled over 60 km/d. As fish migrated downstream, the relationship between fish size and travel rate became more pronounced and less

fish in the small range migrated out of the Deschutes River.

To determine the locations and spatial distribution of radio-tagged juvenile chinook salmon, we mobile tracked the lower 135 km stretch of the Deschutes River. Of the 35 fish that remained in the Deschutes River, 30 (85%) were contacted through mobile tracking. After locating a fish in a discrete location, we made an in-stream habitat assessment. Habitat assessment in areas where radio-tagged fish were holding showed that most fish chose to stay in the margin areas of the main channel, in slower moving water. Snorkeling efforts occurred on 29 November and 6 December, with limited success. Although water velocity was relatively slow, visibility was limited (1-2 m), temperature was cold (7º C), and we did not see many fish.

We measured ATPase activity as an indicator to better understand the physiological development of fish that leave the Warm Springs National Fish Hatchery during the fall volitional release. Thirty fish were sampled from each of six volitional release ponds. We also sampled 60 hatchery fish that were collected in the downstream migrant trap after they had left the hatchery, coinciding with our radio tagging. Non-lethal ATPase sampling techniques were used to determine physiological condition of migrating fish. ATPase levels of fish sampled at the migrant trap were higher than samples at the hatchery. ATPase was positively correlated to size in fish sampled at the downstream migrant trap ($R^2 = 0.4163$). The positive relation between fish size and ATPase helped to explain the faster migration rates of larger radio-tagged fish.

Our results showed that a relatively large proportion (65%) of the radio-tagged fish remained in the river. Further analysis indicated that the tendency to remain in the river may be correlated with fish size. These findings suggest that the fall-released fish have a potential to overwinter and their impact on the aquatic community could negatively effect the wild fish population.

Introduction

In a review of National Fish Hatcheries (NFH), the U.S. Fish and Wildlife Service (USFWS) identified the need to assess the fate of hatchery-reared fish and their potential effect on the aquatic community (USFWS 1998). Additionally, in the Columbia River Biological Opinion, the National Marine Fisheries Service (NMFS) recommended monitoring and evaluating ecological interactions between hatchery and wild fish (NMFS 1999). These recommendations prompted a pilot project during 2000 to address the biological and ecological effects of fish released from the Warm Springs NFH, located on a tributary to the Deschutes River.

Warm Springs NFH is a unique program in the Columbia River basin. The operation of the hatchery is considered pivotal for enhancing salmon stocks to meet tribal trust responsibilities and is also managed to preserve the genetic integrity and characteristics of hatchery and wild fish. Managers are concerned about fall releases of juvenile hatchery spring chinook salmon (hereafter referred to as juvenile chinook salmon) because hatchery fish that overwinter may interact with wild fish. However, quantifying the freshwater fate of juvenile chinook salmon, *Oncorhynchus tshawytscha,* released in the fall from Warm Springs NFH has been problematic (Olson et al. 1995). Typically, about 10% of the hatchery production volitionally exits in the fall (30,000 to 75,000 fish). In the past, this fall emigration (early October - early November) included a mixture of sizes, ranging from 70 mm to 229 mm, with the majority of fish being 140 mm or larger (USFWS 1999). Most fish released in the spring reach the Columbia River estuary within 3-4 weeks of release, whereas the destination of fish released in the fall is not clear. Cates (1992) indicates that fish from the fall release survive and contribute to adult production. Sampling in the lower Deschutes River, at Bonneville Dam, and in the Columbia River estuary indicates that fish released in the fall can exit the Deschutes River during the fall, winter, or spring periods. Recent scale analysis shows that most fall-released fish surviving to adulthood have overwintered in freshwater before migrating to the ocean in the spring (J.Fryer, Columbia River Inter-Tribal Fish Commission, personal communication). Although the fall volitional release strategy has been successful in contributing to adult returns (Olson 1998), managers are concerned that large numbers of hatchery fish rearing in the

Deschutes River may negatively affect the freshwater aquatic community. These overwintering hatchery salmon could displace or compete with wild fish in the Deschutes River.

In this pilot study, we radio tagged and tracked a sample of the fall released fish to investigate where they are distributed in the Deschutes River. Our objectives were to determine the feasibility of using radio telemetry techniques to describe the spatial distribution and extent of overwintering of juvenile hatchery chinook salmon in the Deschutes River, and to determine the feasibility of conducting underwater observations and habitat assessments to describe the potential effect of juvenile chinook salmon on the aquatic community. The results of this feasibility study, along with future studies, will help fisheries managers determine the potential impact of hatchery release strategies on the aquatic community.

Methods

Study site

Warm Springs National Fish Hatchery is operated by the U.S. Fish and Wildlife Service and is located on the Warm Springs River, within the Warm Springs Indian Reservation of Oregon. The Warm Springs River is a major tributary to the lower Deschutes River in north central Oregon. It enters the Deschutes River at river kilometer 135. The Deschutes River enters the Columbia River 330 km from the Pacific Ocean (Figure 1).

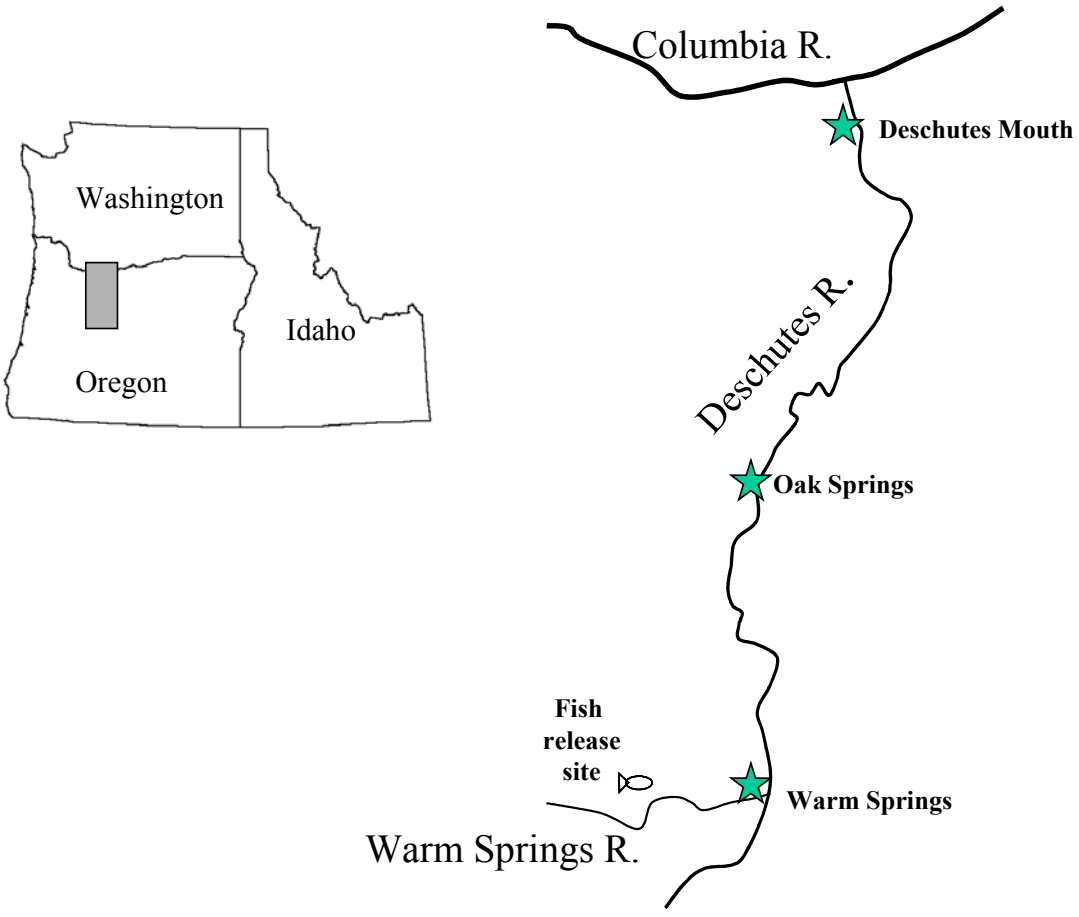


Figure 1—Map of Lower Deschutes River, Oregon, showing study area, fixed monitoring sites (stars), and release site of radio-tagged juvenile chinook salmon.

Tagging & Transmitters

Juvenile chinook salmon used in our study were collected in a downstream migrant trap in the Warm Springs River operated by the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO). The trap was located about 10 kilometers downstream from the hatchery. Fish were collected by CTWSRO personnel and held in containers (127 L) in the river for at least 24 h prior to tagging. Fish were surgically tagged with pulsed-coded radio transmitters using procedures described by Adams et al. (1998) and released downstream of the migrant trap. Biological measurements including length (fork length), weight, and overall condition were recorded for all radio-tagged fish.

We selected specific radio transmitters to address this study's objectives. Two different sizes of pulsed-coded radio transmitters were used (Advanced Telemetry System; models 384 and 393) each having a burst rate of 30 beats per minute (bpm) (Table 1). Each transmitter broadcasted on a unique frequency so that we could distinguish individual fish. Transmitter size was determined based on a maximum 6% tag weight to fish weight ratio. To achieve this criterion, larger transmitters with a 75-d operation life expectancy were used in large fish (>150 mm FL). Small tags, with a 45-d life expectancy were used in the small fish (130-149 mm FL). We did not tag fish smaller than 130 mm FL. Immediately after tagging, fish were placed in a recovery container (127 L) supplied with a constant flow of river water and bottled oxygen. After about 30 min in the recovery container, fish were transferred to holding containers and held for 24 h in the Warm Springs River before release. Releases occurred in the afternoon (between 1200 and 1600 hours). Immediately before release, transmitters were checked to ensure that they were functioning properly.

Table 1—Specifications for transmitters used in juvenile chinook salmon in the Deschutes River, 2000. Specifications supplied by manufacturer (Advanced Telemetry Systems (ATS), Isanti, Minnesota, USA).

Transmitter type	Dimensions (mm)	Weight (g)	Volume (mL)	Battery Life (days)
Small	8.8 x 20	1.7	0.6	45
Large	9 x 20	2.1	0.8	75

Fixed-Site Monitoring

Three telemetry fixed sites were established along the lower Deschutes River (Figure 1). The first site was located near the mouth of the Warm Springs River and monitored fish as they migrated out of the Warm Spring River and entered the Deschutes River (Rkm 135). The second site, located near Oak Springs Fish Hatchery (Rkm 76), served as a midway point between the Warm Springs River and the mouth of the Deschutes River. The third site, near the mouth of the Deschutes River (Rkm 2), monitored for fish as they left the Deschutes River system and entered the Columbia River. Fixed stations consisted of two four-element Yagi (aerial) antennas mounted on a 20 foot mast and connected to two Lotek SRX 400 data-logging receivers (Lotek wireless, Ontario, Canada). Each station was powered by 12 V deep-cycle batteries attached to solar powered chargers. Transmitters emitted a signal every 2 s (32 bpm). To minimize the time required to monitor all 54 frequencies, the antenna input was split between two receivers, with each receiver programmed to monitor 27 unique frequencies. To ensure sufficient time for the receiver to recognize and log the signal, each frequency was monitored for 3 s before moving to the next frequency. This resulted in an 81 s scan time for each receiver (27 frequencies for 3 s each = 81 s). Data were collected on telemetry receivers 24 h a day, 7 d a week. Sites were maintained and data recorded on the receivers were downloaded to a laptop computer on a weekly basis.

Radio Telemetry Data Management and Analysis

Data collection began on 26 October 2000 and continued until 4 January 2001 when the life expectancy of the transmitters was surpassed. Data were incorporated into SAS, statistical analysis software, (version 8.1) where it was automatically proofed. Automated proofing was followed by manual proofing to ensure the quality of all data. All fish records were scrutinized to determine fish presence at each fixed site.

We calculated the travel times and travel rates of fish between detections at the fixed sites. Travel times were calculated as the time taken to travel from the upstream site to the next downstream site. Travel rates were calculated by dividing the distance traveled by the travel time. Travel times and rates were investigated relative to fish length, weight, and condition factor. All statistical tests were conducted at the 5% probability level.

Mobile Tracking

To determine the location and spatial distribution of radio-tagged juvenile chinook salmon, as well as to verify data from fixed sites, we mobile tracked the lower 135 km stretch of the Deschutes River on a weekly basis. CTWSRO personnel mobile tracked using vehicles and boats equipped with a telemetry antenna and receiver between 0800 and 1600 hours. When a radio-tagged fish was located, a GPS unit was used to georeference the position. Fish locations were also marked on a map, along with the time and a written description of the general area. Most fish were contacted every week. Once a fish was found repeatedly in a discrete location for more than two weeks, we considered that the fish was holding. We then pinpointed its precise location and described the physical habitat. All fish locations were incorporated into a GIS database.

Habitat Assessment

Most efforts in addressing the second objective of this pilot study focused on evaluating potential habitat sampling methods in the Deschutes River for radio-tagged fish, which was especially important given the high flows, velocities, and turbidities typically encountered during winter months. After locating a fish at a discrete location, we made an in-stream habitat assessment. Snorkeling at sites with radio-tagged fish would allow us to observe and collect data on fish species assemblages and size classes. Snorkel assessment followed methods described in Thurow (1994). Habitat measurements were taken at locations where radio-tagged fish were holding. We classified holding areas as: side channel, margin habitat, back eddy, margin habitat along a straight reach, margin habitat along the inside or outside of a bend, habitat associated with submerged or exposed point bars. We collected microhabitat data at fish locations, such as substrate, velocity, cover, and depth. Daily stream flow data was obtained from USGS gaging stations along the lower Deschutes River, at Moody (Rkm 2.5), and on the Warm Springs River, at Kahneeta (Rkm 10). Temperature data was also available, from PGE thermagraphs, on the lower Deschutes River at Rattlesnake Rapids (Rkm 4) and Kaskela (Rkm 127).

ATPase Sampling and Analysis

Gill Na^+,K^+-ATPase, hereafter referred to as ATPase, activity has commonly been used as an indicator of physiological development of anadromous salmonids during the parr-smolt transformation (Ewing 1984) and for smolt condition assessment (Beckman et al. 1999; Dickhoff 1995; Folmar 1980). Elevated levels of ATPase are typically correlated with seaward migration of chinook salmon (Hart et al. 1981). We measured ATPase activity as an indicator to better understand the physiological development of fish that leave the Warm Springs National Fish Hatchery during the fall volitional release. Fish size is usually positively correlated with ATPase activities (Folmar 1981). Because the sizes of fish leaving the hatchery during the fall volitional release are substantially larger than the fish remaining at the hatchery (B. C. Cates, U.S. Fish and Wildlife,unpublished data), we hypothesized that fish that leave volitionally should have higher ATPase levels than those smaller fish that remain in the hatchery. ATPase samples were taken from fish from the Warm Springs National Fish Hatchery on two separate occasions; Pre-release at the hatchery, on 26 September, and at the migrant trap during migration of the fall volitional release on 27 October and 2 November.

Pre-release sampling was conducted during the annual fish health screening at Warm Springs National Fish Hatchery. Personnel from the U.S. Fish and Wildlife Service collected data on fish length, weight, and tag retention, along with gill biopsies and blood samples. We sampled from volitional release ponds in conjunction with the fish health screenings. ATPase analysis was conducted using procedures described by Schrock et al. (1994). We sampled 30 fish from each of six volitional release ponds: Ponds 26, 27, 28 (Erythromycin treated) and ponds 14, 15, and 16 (control), for a total of 180 samples.

We also sampled 60 hatchery fish that were collected in the downstream migrant trap. ATPase samples were collected on 27 October and 2 November, and coincided with our radio tagging of juvenile chinook salmon. Non-lethal ATPase sampling techniques were used to determine physiological condition of migrating fish. These fish were not radio tagged but were of similar size to those implanted with transmitters. Condition factor was also calculated. Gill Na+, K+ -ATPase activity was determined and compared to fork length.

Results

Tagging

During fall 2000 (26 October-3 November), we radio tagged and released 54 juvenile chinook salmon (Table 2; Appendix 1). One fish died (1.8% mortality rate) after the first tagging session and before release into the Warm Springs River. This fish may have had bacterial kidney disease as evidenced by a "swollen belly" at the time of tagging. During the first release, all fish were implanted with the smaller (1.7 g) transmitter. Once we found that all fish responded favorably to the tag, we began using the larger (2.1 g) transmitter on the larger fish (Table 3).

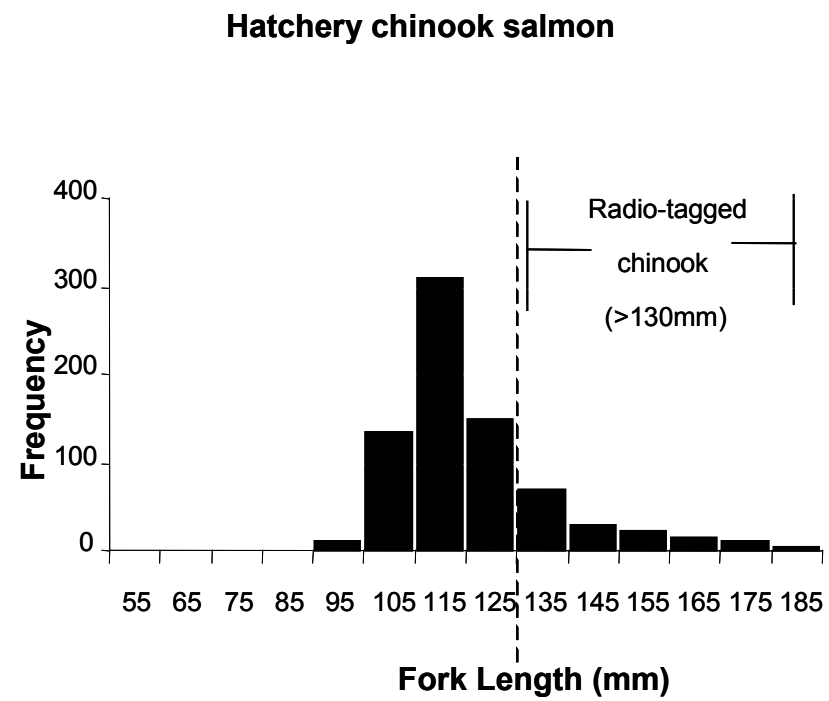
Hatchery fish collected at the Warm Springs downstream migrant trap between 3 October and 2 November were larger than their wild counterparts (Figure 2). The mean size of hatchery juvenile chinook salmon was 122 mm and ranged from 86 to 186 mm. In comparison, the mean size of wild juvenile chinook salmon was 96 mm and ranged from 52 to 135 mm. Hatchery fish that met the minimum size criterion for radio tagging represented the upper 22% of the hatchery fish distribution collected at the trap.

Table 2—Release summary of radio-tagged juvenile chinook salmon in the Warm Springs River, Oregon, 2000.

Release Number	Release Date	Release Time Range	Number Released	Mean Length (mm)	Mean Weight (g)
1	10/26/00	12:05-12:12	5	145	36.6
2	10/27/00	15:04-15:14	7	141	30.7
3	10/28/00	15:37-16:16	15	161	51.2
4	11/02/00	12:51-14:45	14	153	47.0
5	11/03/00	13:02-15:15	13	144	39.0

Table 3—Release summary of radio-tagged juvenile chinook salmon in the Warm Springs River, Oregon, 2000. Radio-tagged fish were surgically implanted with small (1.7 g) or large (2.1 g) transmitter.

Release Number	Release Date	Tag Size	Number Released	Fork Length (mm)		Weight (g)	
				Mean	(Range)	Mean	(Range)
1	10/26/00	Small	5	145	(130-165)	36.6	(26.7-54.6)
2	10/27/00	Small	6	138	(131-147)	29.2	(25.5-33.2)
		Large	1	159	-	39.7	-
3	10/28/00	Small	3	138	(137-140)	31.6	(29.9-33.6)
		Large	12	168	(150-188)	56.1	(42.5-75.7)
4	11/02/00	Small	6	140	(133-147)	36.2	(29.7-41.6)
		Large	8	163	(149-173)	55.1	(38.9-73.1)
5	11/03/00	Small	7	138	(132-144)	34.7	(31.0-39.3)
		Large	6	152	(148-155)	44.1	(38.5-51.5)



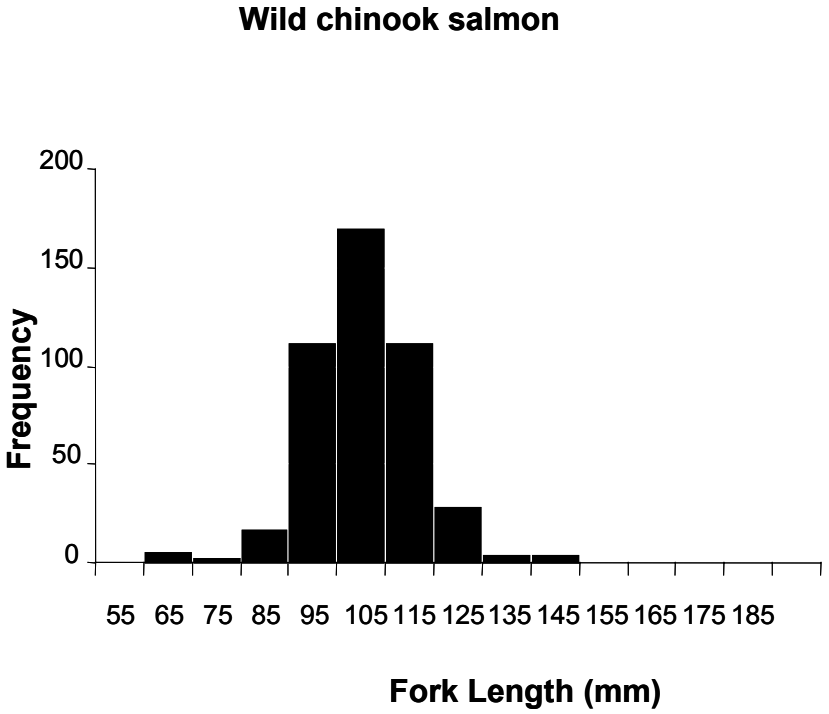


Figure 2—Size distribution of hatchery and wild juvenile chinook salmon captured at the downstream migrant trap between 26 September and 2 November, 2000.

Migration Behavior, Travel Time, and Travel Rate

By the end of the study period, we found that 35 % of the radio-tagged fish left the Deschutes River and 65 % remained in the Deschutes River. Larger fish tended to migrate farther downstream and leave the system. At the end of the study, 16 fish still remained upstream of the Oak Springs site, 19 fish had distributed downstream of Oak Springs, and 19 fish had exited the Deschutes River entirely (Table 4). Fish that left the Deschutes River system were larger (mean = 162 mm) than fish that remained (mean = 145 mm). Fish that remained upstream of the Oak Springs site had a mean fork length of 140 mm, and fish downstream of Oak Springs River system had a mean fork length of 150 mm.

Radio-tagged fish migrated out of the Warm Springs River quickly after release (median = 0.9 h; Table 5). Of the 54 fish that were radio tagged and released, all 54 were detected at the first fixed site station as they entered the Deschutes River. Once fish entered the Deschutes River, many moved quickly downriver. Travel time and travel rates were based only on fish that migrated downstream. Median travel time from release to the Oak Springs fixed site was 13.3 h (0.55 d), with fish reaching the mouth of the Deschutes River in a median travel time of 38.4 h (1.60 d). Travel times varied widely, with times to Oak Springs ranging from 9.6 h (0.04 d) to 726.6 h (30.27 d) and times to the mouth of the Deschutes River ranging from 33.0 h (1.38 d) to 1394.1 h (58.09 d). The median travel rate of fish migrating past Oak Springs was 117.4 km/d, whereas fish traveling through the lower portion of the study area from Oak Springs to the mouth of the Deschutes River had a slower median travel time of 70.3 km/d (Table 6).

We found that large fish tended to migrate faster than small fish. Fish between 145 mm and 160 mm had a substantial overlap in their migration rates (Figure 3A). However, fish less than 145 mm traveled less than 15 km/d, whereas fish greater than 160 mm traveled over 60 km/d. As fish migrated downstream, the relationship between fish size and travel rate became more pronounced and less fish in the small range migrated out of the Deschutes River (Figure 3B).

Table 4—Mean fork lengths (mm) and weights (g), including standard deviation, and range of radio-tagged juvenile chinook salmon in three location categories on the Deschutes River, 2000

Fish location	N	Fork Length (mm)			Weight (g)		
		Mean	STD	Range	Mean	STD	Range
Did not pass Oak Springs	16	139.50	8.45	131-161	34.12	6.74	25.5-52.8
Did not pass Deschutes mouth	19	150.05	11.00	130-170	41.76	9.16	26.2-61.4
Exited Deschutes R.	19	161.95	15.64	134-188	52.19	15.23	29.7-75.7

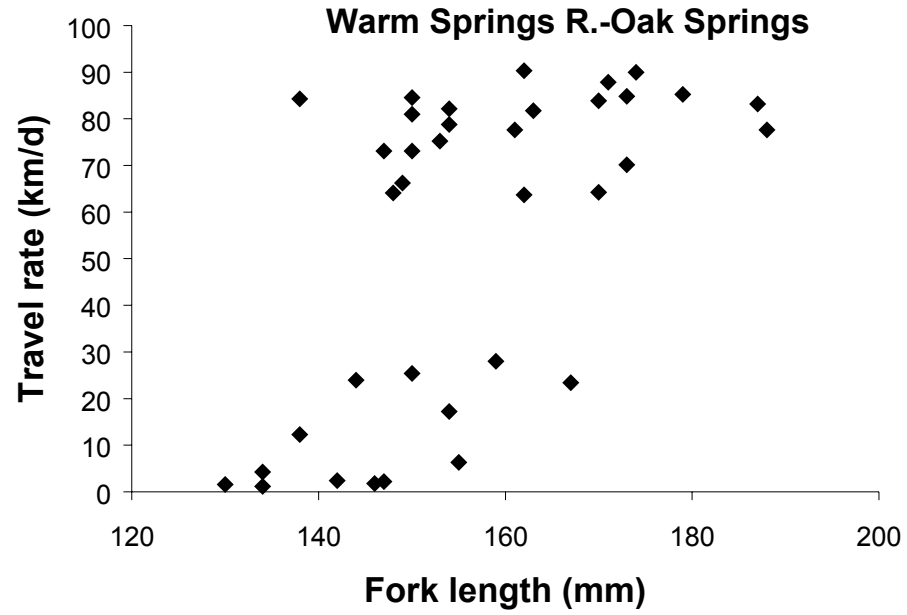
Table 5—Travel times, in hours (and days), from release to fixed site stations on the Deschutes River for radio-tagged juvenile chinook salmon. Travel times in days are presented within parentheses.

Travel Reach	N	Median	Mean	Minimum	Maximum
Release-Warm Springs R.	54	0.9 (0.04)	2.1 (0.09)	0.0 (0.00)	25.2 (1.05)
Release-Oak Springs	36	13.3 (0.55)	94.7 (3.95)	9.6 (0.40)	726.6 (30.27)
Release -mouth Deschutes R.	19	38.4 (1.60)	298.5 (12.44)	33.0 (1.38)	1394.1 (58.09)

Table 6—Travel rates (km/d) of radio-tagged juvenile chinook salmon from release to detection at fixed site stations on the Deschutes River.

Travel Reach	N	Median	Mean	Minimum	Maximum
Warm Springs –Oak Springs	36	117.4	88.9	1.9	148.0
Oak Springs- mouth Deschutes R.	17	70.3	50.4	1.6	81.3
Warm Springs- mouth Deschutes R.	19	87.4	60.1	2.3	98.5

Travel Rates



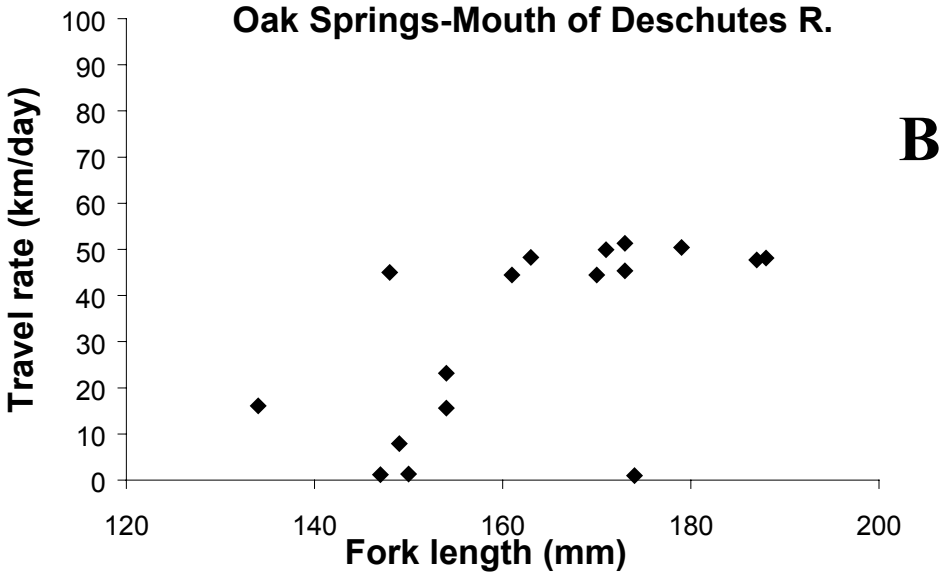


Figure 3-Travel rates of radio-tagged juvenile chinook salmon between fixed sites on the Deschutes River versus fork length, 2000. Travel rates were determined between the Warm Springs River and Oak Springs (A) and Oak Springs and the mouth of the Deschutes River (B).

Mobile Tracking and Habitat Assessment

From 10 November 2000 through 20 December 2001, CTWSRO personnel radio-tracked juvenile chinook salmon in the Deschutes River. Tracking was conducted primarily by vehicle when roads paralleled the river. A boat was used to track sections of the river that were inaccessible by road. The GPS could not be used in some areas due to interference caused by the steep canyon. Of the 54 radio-tagged fish that were released, 19 left the system entirely. Of the remaining 35 fish remained in the Deschutes River and 30 (85%) of these were contacted through mobile tracking. Five fish were never contacted after the initial detection at the Warm Springs fixed site station. Mobile tracking allowed ground-truthing of fixed site data and determining when fish were holding in an area for more than two weeks. After a couple of weeks, trackers began contacting fish in the same general area repeatedly. Mobile tracking by boat enabled us to collect fine-scale positions on fish. In all cases, fish were located in slower moving water near the river's edge. This allowed tracking personnel to wade into the river and determine the location of the fish with an accuracy of about 3 m. Once a fish stopped migrating downstream and found a suitable habitat, it remained in that general location, with some small-scale downstream migration, throughout the length of the study.

Habitat assessment in areas where radio-tagged fish were holding showed that most fish chose to stay in the margin areas of the main channel, along the inside or outside of a bend. Some fish stayed in distinct eddies along the inside of bends. The substrate in these areas was typically a combination of sand and cobble, with a grass and shrub riparian area. Cover consisted of grasses and shrubs, with occasional woody debris. Water depth was variable, ranging from 0.5 to 2 m.

Snorkeling efforts occurred on 29 November and 6 December. Although water velocity was relatively slow, visibility was limited (1-2 m) and we did not see many fish. In most cases, fish reacted to the presence of the diver and quickly left the range of visibility.

The Deschutes River is known to be a relatively stable river (Deschutes River Subbasin Summary, 2001), primarily because the Pelton/Round Butte complex regulates daily outflow. Mean daily discharge remained relatively stable throughout the length of the study, ranging from 4,990 to 6,410 cfs (Figure 4). Temperatures on the Deschutes decreased from 14 ^{o}C in early October to 6 ^{o}C in January (Figure 5).

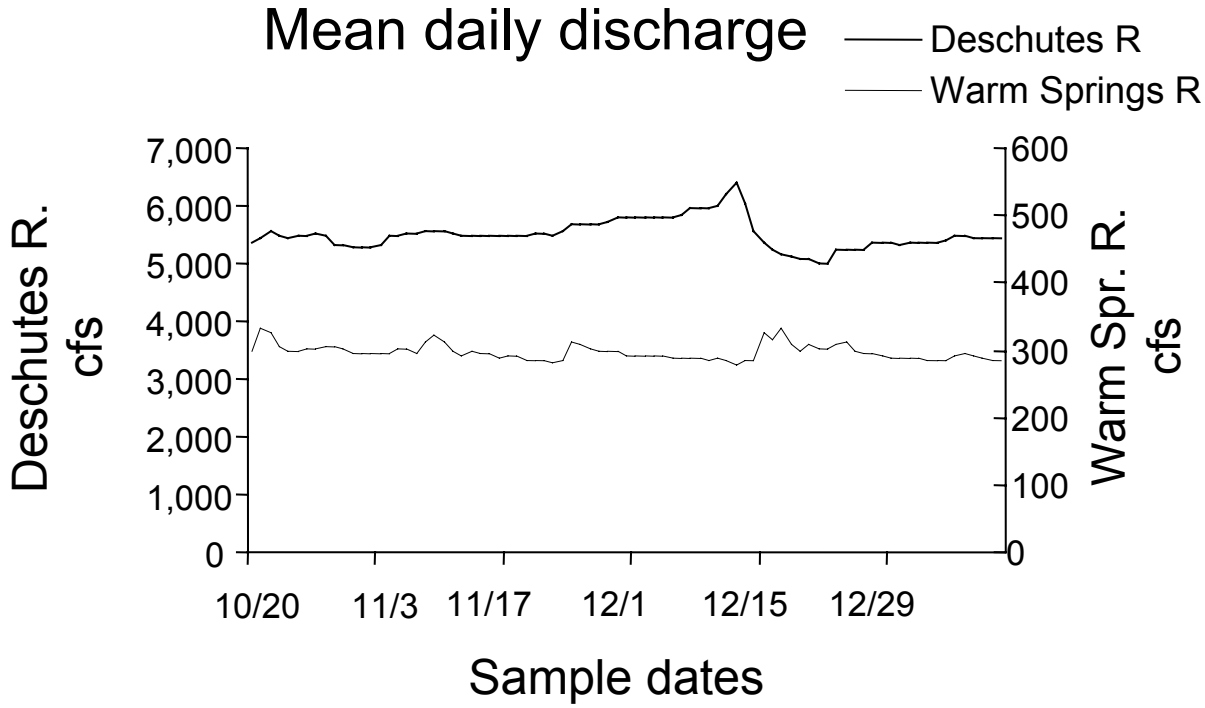


Figure 4-Mean daily discharge (cfs) from 20 October , 2000 through 20 January, 2001 on theDeschutes River (rkm 2.5) and Warm Springs River (rkm 10), Oregon.

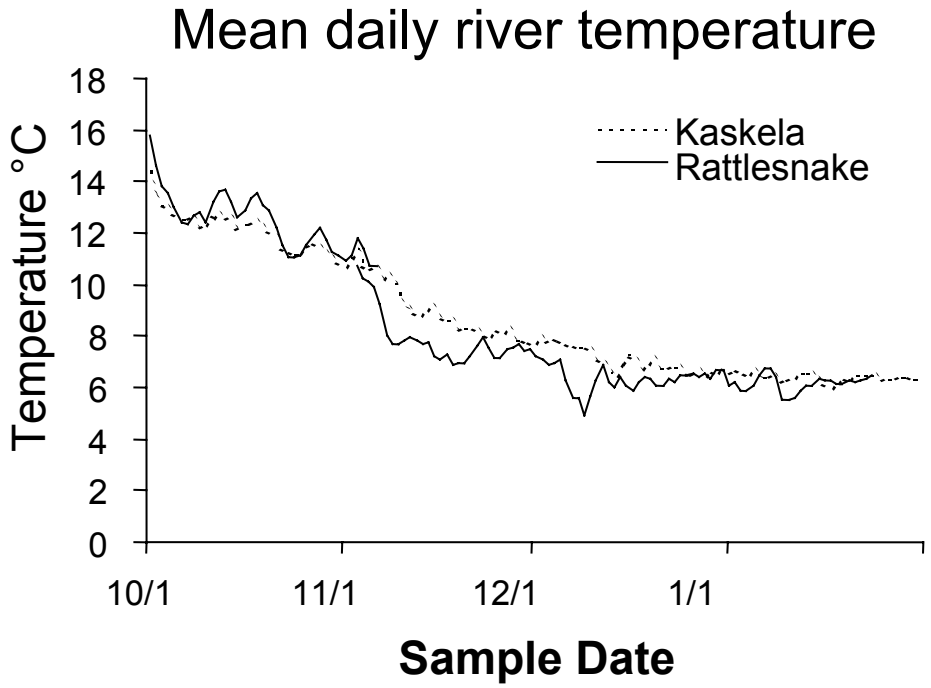


Figure 5-Mean daily river temperature (°C) of the Lower Deschutes River between 1 October, 2000 and 31 January, 2001. Sample locations were at Kaskela (rkm 127) and Rattlesnake rapids (rkm 4).

ATPase

Mean ATPase activity of fish sampled at Warm Springs National Fish Hatchery was 4.4 μmoles ATP hydrolyzed/mg protein per hour (Table 7). Fish size varied and fork lengths ranged from 75 mm to 165 mm, with a mean of 110 mm. Mean weight was 17.6 g and the condition factor was 1.256. The ATPase, condition factor, fork length, and weight were not different between ponds ($P>0.05$). Therefore ATPase data at the hatchery were pooled.

ATPase levels of fish sampled at the migrant trap were higher than samples at the hatchery (Table 8). Fish sampled at the trap had an overall mean ATPase activity of 7.4 μmoles ATP hydrolyzed/mg protein per hour. However, ATPase levels varied, depending on sample date and size class. Mean ATPase in small fish (130-149 mm) was 6.3 μmoles (27 October) and 5.9 μmoles (2 November). Mean ATPase in large fish (>150 mm) was 10.0 μmoles (27 October) and 11.6 μmoles (2 November). The overall condition factor was 1.275, similar to at the hatchery. Fish sampled at the trap ranged in size from 130 mm to 176 mm, the mean fork length was 145.7 mm, and weight was 40.5 g.

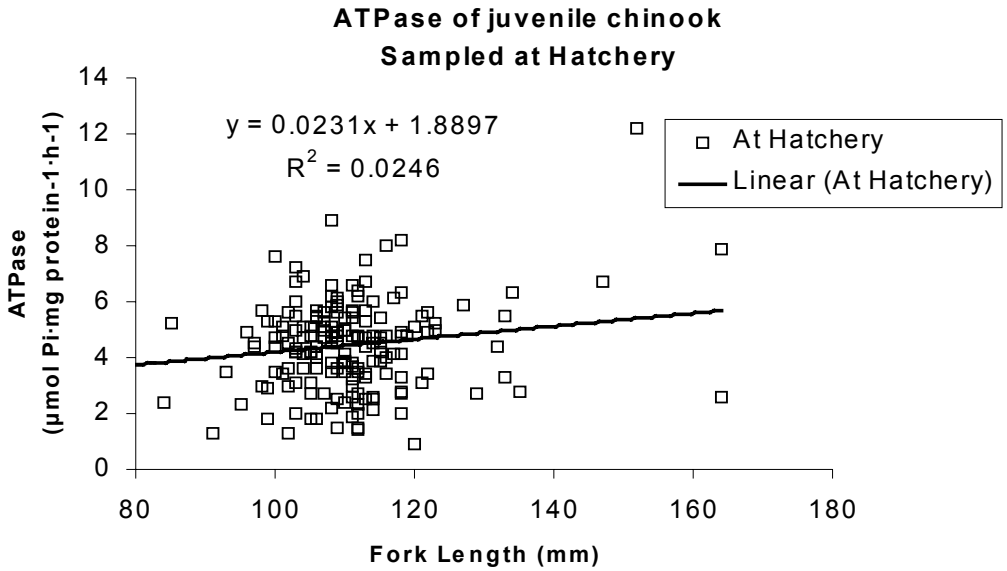
ATPase levels were not correlated to size in fish collected at the hatchery ($R^2 = 0.0246$), (Figure 6). However, ATPase was positively correlated to size in fish sampled at the downstream migrant trap ($R^2 = 0.4163$). At the downstream migrant trap, smaller fish had lower levels of ATPase activity while larger fish appear to have developed higher levels of ATPase activity. However, it is unknown if this difference in ATPase levels developed at the hatchery or during the outmigration.

Table 7. Na^+, K^+-stimulated ATPase activities (μmol P_i·mg protein^{-1}·h^{-1}) of juvenile chinook salmon sampled at the Warm Springs National Fish Hatchery on 26 September, 2000, along with condition factor, fork length, and weight.

Pond	N	ATPase		Condition factor		Fork Length (mm)		Weight (g)	
		Mean	STD	Mean	STD	Mean	STD	Mean	STD
14	30	4.0	1.4	1.233	0.048	110.2	10.3	16.9	5.6
15	29	4.8	1.5	1.272	0.065	109.9	8.8	17.2	4.1
16	30	4.3	1.9	1.250	0.090	109.9	9.2	16.9	4.7
26	28	4.7	2.1	1.254	0.064	114.3	15.5	19.7	10.0
27	27	4.7	1.3	1.278	0.075	112.6	12.2	19.0	8.3
28	29	4.1	1.5	1.252	0.074	107.0	9.6	15.7	4.1
Overall	173	4.4	1.6	1.256	0.071	110.6	11.19	17.6	6.5

Table 8. Na^+, K^+-stimulated ATPase activities (μmol P_i·mg protein^{-1}·h^{-1}) of juvenile chinook salmon sampled at the downstream migrant trap on the Warm Springs River on 27 October and 2 November, 2000, along with condition factor, fork length, and weight.Chinook between 130-149 mm are designated "small", chinook greater than 150 mm are designated as "large."

Sample Date	Size (at trap)	N	ATPase		Condition factor		Fork Length (mm)		Weight (g)	
			Mean	STD	Mean	STD	Mean	STD	Mean	STD
10/27/00	Small	15	6.3	2.0	1.300	0.120	136.7	6.7	33.2	5.5
	Large	13	10.0	3.2	1.277	0.083	163.1	9.6	56.0	9.8
11/02/00	Small	15	5.9	1.4	1.260	0.091	137.8	5.4	33.2	4.7
	Large	1	11.6	-	1.100	-	172.0	-	56.4	-
Overall:		44	7.4	2.9	1.275	0.101	145.7	14.4	40.5	12.6



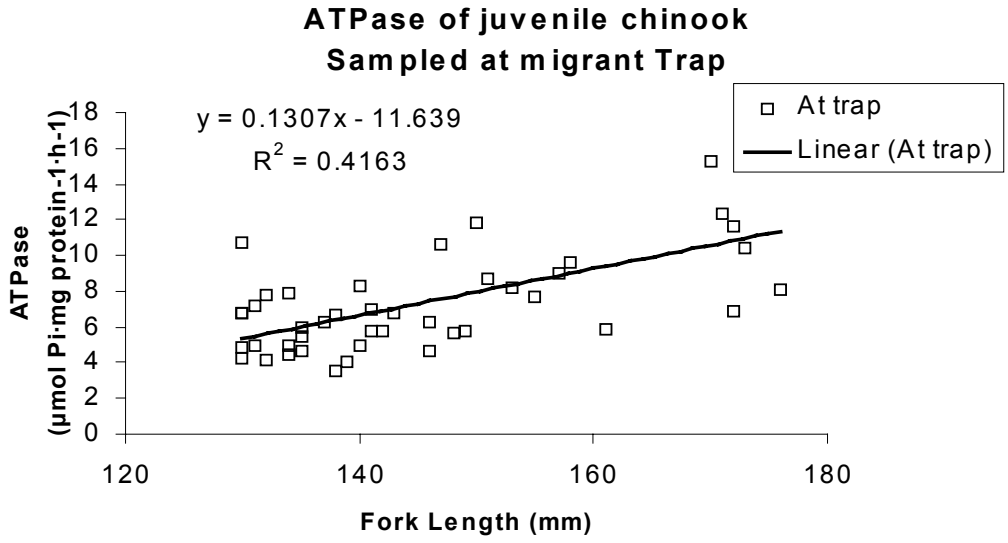


Figure 6-ATPase of juvenile chinook salmon collected at the Warm Springs NFH, 26 September, and the downstream migrant trap, 27 October and 2 November.

Discussion

Migration Behavior and ATPase

Our data not only supports previous findings, but also determined that fish size was a factor in migration behavior. Larger fish (mean = 165 mm) tended to leave the Deschutes River and smaller fish (mean = 145 mm) remained in the river. Size-dependent migration behavior is consistent with the findings of Beckman et al. (1998), who found that larger hatchery fish had a greater disposition to migrate. We found variable migration behaviors in radio-tagged juvenile chinook salmon once they left the Warm Springs River, which also supports and explains previous findings. Of the 54 radio-tagged fish released, 35% (19) migrated through the Deschutes River and entered the Columbia River. The remaining 65% (35 fish) distributed in the Deschutes River until the end of the study period in January. Past sampling in the lower Deschutes River, at Bonneville Dam, and in the Columbia River estuary indicate that fish volitionally released in the fall can exit the Deschutes River during the fall, winter, and spring periods (Lindsay et al. 1989).

Although our sample size was small, we were able to characterize the migration behavior of fall-released fish. However, due to size constraints related to tag and body-weight ratios, we tagged only the larger fish in the fall release. Due to size-selective tagging, our results apply only to the larger fish that represent the upper 22% of the hatchery fish size distribution. If we assume that smaller fish tend to stay in the Deschutes River, and large fish exit the system, we may have underestimated the number of fish that stay in the river. Had we tagged a representative group of fish from the remaining 78% of the population, the proportion of fish staying in the system would likely have been much higher than 65%.

We compared migration behaviors of hatchery juvenile chinook salmon to their wild counterpart. Wild juvenile chinook salmon that migrate from the Warm Springs River in the fall at age 0 overwinter in the Deschutes or Columbia rivers until spring of the following year before migrating seaward (Lindsay et al. 1989). Based on scale analyses, only 1 % of the returning adults had migrated to the ocean at age 0. In addition, wild chinook salmon marked in the fall as age 0 migrants from the Warm Springs River were recaptured in the Deschutes River in the spring as yearlings. Fall migrants were also recaptured at the Dalles Dam the following spring as

yearling smolts. Although there appears to be a higher proportion of wild fish overwintering compared to our study, many of our fish share the same life history pattern. The Warm Springs National Fish hatchery incorporates about 10% wild stock into their hatchery each year (Olson 1998). If hatchery fish follow a similar life history as wild, it would follow that hatchery fish overwinter in the Deschutes River. Our estimates of fish remaining in the river during the winter were low compared to wild estimates. This may be in part due to our tagging of only the larger fish or the fact that we did not track our fish beyond the mouth of the Deschutes River. Monitoring further downstream in the Columbia River may prove important in this assessment.

The positive relation between fish size and ATPase helps to explain the faster migration rates of large fish. Several studies have shown that physiological smolt development and development of downstream migratory tendencies are correlated (Beckman 1998). Hart et al. (1981) found hatchery chinook salmon with higher Na^+,K^+-ATPase activities migrated out of rearing channels sooner than fish with lower ATPase activities. Beckman (1998) suggested that physiological change and migration behavior are temporally linked. We observed a physiological change in the relation between size and ATPase at the hatchery and the downstream migrant trap. ATPase activity of hatchery fish sampled at the downstream migrant trap (mean = 7.4 μmol P_i·mg protein^{-1}·h^{-1}) was higher compared to fish sampled at the hatchery during earlier health screenings (mean = 4.4 μmol P_i·mg protein^{-1}·h^{-1}) one month earlier. The ATPase activity in fish at the time they left the hatchery is unknown. Once fish emigrated from the hatchery, they were exposed to a natural river flow and temperature. This change in conditions may have caused an increase in ATPase activity, therefore prompting the fish to begin their migration downstream to the migrant trap. Sampling at the hatchery during the fall volitional release would provide us further insight.

ATPase samples taken at the hatchery were not correlated (R^2 =0.0246) with fish size. However, there was a strong correlation (R^2 = 0.4163) between size and ATPase level in fish sampled at the downstream migrant trap. We do not know the ATPase levels of fish as they left the hatchery, so it is hard to determine if the elevated ATPase caused fish to leave the hatchery, or if once leaving the hatchery, their ATPase levels changed due to river conditions. Beckman (1998) showed that there was a strong relation between fish size and growth rate and advanced

state of smoltification. This may result in a greater propensity of larger fish to move downstream when released into a natural system.

Habitat Assessment and Snorkeling

Although fish distributed throughout the entire lower Deschutes River, radio-tagged fish were found in similar microhabitats. During this feasibility study, we were able to characterize the microhabitat in general terms. Microhabitat sites contained similar physical characteristics; slow moving water, sand, and cobble substrate and depths ranging from 0.5 to 2 m. Once a fish stopped migrating downstream and found a suitable habitat, it appeared that it remained in that location, with only limited downstream migration. The Deschutes River is known to be a relatively stable river (Deschutes River Subbasin Summary 2001), because Pelton/Round Butte dams regulate the daily outflow. This consistent flow is confirmed by data collected at the USGS gaging stations. Therefore, once a fish found a suitable habitat, the characteristic of that habitat would be relatively consistent throughout most of the winter.

Snorkeling on the lower Deschutes River did not allow us to determine fish assemblage or distribution. Thurow (1994) states that underwater observation using snorkeling gear is a valuable tool for studying fish populations and assessing how fish use habitats in flowing waters. However, several factors, including the behavior of the target fish species and attributes of the physical habitat (stream size, water clarity, temperature, and cover) can bias results. Thurow (1994) developed minimum criteria (water depth, temperature, visibility) to determine if this method can be successfully applied to study fish behavior in streams. One of these criteria is that water temperature should be above 9º. Water temperature during our study was below 9º. Thurow (1994) also indicated a positive correlation between visibility and the numbers of fish observed. He recommended minimum visibilities ranging from 1.5 to 4 m. Visibility during snorkeling efforts conducted for this study was estimated at 0.5 to 2 m. Zimmerman (1999) was successful in conducting snorkel assessments in the lower Deschutes River, however his snorkel efforts were done in specifically selected sections that met minimum criteria and they were conducted during the summer months when water temperatures and clarity were more suitable.

Conclusions

Concerns regarding the fall releases of juvenile chinook salmon from the Warms Springs NFH will need to be addressed further. Prior to this pilot study, it was unknown how many hatchery fish remained in the Deschutes River over the winter. We found that radio telemetry was an effective tool in assessing juvenile chinook salmon migration behavior and determining their distribution throughout the lower Deschutes River. Given that we found many of the fall released fish remaining in the Deschutes River from 26 October to 3 January, and presumably until spring, there may be interactions between hatchery and wild fish, as well as other species. Interactions of particular concern include the wild juvenile spring chinook salmon, fall chinook salmon, listed bull trout, and listed steelhead. Downstream migrant trap data showed that juvenile hatchery fish were larger than wild fish at the time of migration out of the Warm Springs River. The size of juveniles at time of migration from the Warm Springs River may influence the outcome of competitive interactions with larger fish dominating. Hatchery fish that have a size advantage would have a theoretical advantage in obtaining optimum habitat (Zimmerman 1999). Although there is considerable evidence relating the size of the fish at migration to elevated ATPase levels, disposition to migrate, and potential negative interactions, we should use caution in basing management decisions on fish size alone. Past reports have shown that relatively large fish generally have higher smolt-to-adult returns, and Beckman (1998) has indicated that growth rate prior to release may play a larger part in migration than size alone.

Based on our findings that 65% of fish tagged remained in the Deschutes River and that the fall release was estimated to be 30,000 to 75,000 fish, we estimate that 19,500-48,750 fish distributed throughout the lower Deschutes River in fall 2000. However, our sample size was small and included a limited size range. Additional studies are needed to further examine annual variability, migration, fish distribution, and examine potential interactions that may occur in the Deschutes River.

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Appendix 1. Summary of individual radio-tagged fish in feasibility study, 2000. Summary includes transmitter frequency, fish length, weight, and K factor, size of tag implanted, release date, last contact information, and travel time (in days) in the Upper (Warm Springs to Oak Springs), Lower (Oak Springs to Mouth of Deschutes), and Total study area. Last contact is shown as either the last fixed site contact (Warm Springs, Oak Springs, or Exit) or kilometer where the fish was last detected while mobile tracking.

						Last Contact		Travel Time (d)		
Frequency	Fork Length (mm)	Weight (g)	K Factor	Tag Size	Release Date	Location	Date	Upper	Lower	Total
149.013	159	39.7	0.99	LARGE	10/27/00	38 km	12/19	1.28	-	-
149.021	179	64.9	1.13	LARGE	10/28/00	EXIT	10/30	0.42	0.95	1.37
149.032	165	54.6	1.22	SMALL	10/26/00	EXIT	10/27	-	-	1.38
149.043	134	31.7	1.32	SMALL	11/02/00	124 km	11/16	-	-	-
149.053	162	45.9	1.08	LARGE	10/28/00	32 km	12/28	0.4	-	-
149.064	188	75.7	1.14	LARGE	10/28/00	EXIT	10/30	0.46	1.00	1.46
149.073	142	33.2	1.16	SMALL	10/27/00	58 km	12/19	15.19	-	-
149.085	146	41.6	1.34	SMALL	11/02/00	40 km	01/10	19.98	-	-
149.093	163	45.3	1.05	LARGE	10/28/00	EXIT	10/30	0.44	0.99	1.43
149.112	139	29.6	1.10	SMALL	10/26/00	Warm Spr	10/26	-	-	-
149.134	187	75.4	1.15	LARGE	10/28/00	EXIT	10/30	0.43	1.01	1.44
149.152	154	42.0	1.15	SMALL	10/26/00	111 km	12/12	-	-	-
149.170	170	55.5	1.13	LARGE	10/28/00	EXIT	10/30	0.43	1.08	1.51
149.193	130	26.7	1.22	SMALL	10/26/00	63 km	01/04	22.3	-	-
149.214	162	46.0	1.08	LARGE	10/28/00	Oak Spr	10/29	0.57	-	-
149.233	135	30.1	1.22	SMALL	10/26/00	Warm Spr	10/26	-	-	-
149.253	174	68.9	1.31	LARGE	10/28/00	EXIT	12/17	0.4	48.92	49.32
149.273	147	31.6	0.99	SMALL	10/27/00	EXIT	12/24	16.36	41.65	58.01
149.290	154	47.3	1.30	LARGE	10/28/00	43 km	01/10	0.46	-	-
149.312	143	30.8	1.05	SMALL	10/27/00	98 km	12/05	-	-	-
149.333	150	42.5	1.26	LARGE	10/28/00	27 km	12/28	0.44	-	-
149.351	134	26.2	1.09	SMALL	10/27/00	105 km	11/13	30.2	-	-
149.373	153	45.9	1.28	LARGE	10/28/00	74 km	01/04	0.48	-	-
149.392	133	27.9	1.19	SMALL	10/27/00	98 km	11/27	-	-	-
149.412	154	40.6	1.11	LARGE	11/3/00	EXIT	11/09	2.09	3.08	5.17
149.432	131	25.5	1.13	SMALL	10/27/00	81 km	12/12	-	-	-
149.455	171	59.9	1.20	LARGE	10/28/00	EXIT	10/30	0.41	0.96	1.37
149.473	138	31.3	1.19	SMALL	10/28/00	127 km	11/16	-	-	-
149.494	150	38.9	1.15	LARGE	11/02/00	50 km	11/28	0.49	-	-
149.514	137	29.9	1.16	SMALL	10/28/00	EXIT	12/17	-	-	49.90
149.533	173	73.1	1.41	LARGE	11/02/00	EXIT	11/04	0.42	1.06	1.48
149.552	140	33.6	1.22	SMALL	10/28/00	108 km	12/12	-	-	-
149.574	170	61.4	1.25	LARGE	11/02/00	Oak Spr	11/03	0.56	-	-
149.594	133	32.9	1.40	SMALL	11/02/00	Warm Spr	11/02	-	-	-
149.611	161	53.6	1.28	LARGE	11/02/00	EXIT	11/04	0.46	1.08	1.54
149.632	147	41.2	1.30	SMALL	11/02/00	129 km	11/16	-	-	-
149.654	161	52.8	1.27	LARGE	11/02/00	126 km	11/16	-	-	-
149.672	134	29.7	1.23	SMALL	11/02/00	EXIT	11/14	8.45	2.98	11.44
149.693	173	61.0	1.18	LARGE	11/02/00	EXIT	11/04	0.51	0.94	1.45
149.713	149	41.2	1.25	LARGE	11/02/00	EXIT	11/09	0.54	6.05	6.59
149.731	167	58.9	1.26	LARGE	11/02/00	64 km	11/28	1.54	-	-
149.752	147	40.0	1.26	SMALL	11/02/00	27 km	12/28	0.49	-	-
149.772	150	38.5	1.14	LARGE	11/03/00	EXIT	12/10	0.43	35.93	36.36
149.790	138	32.9	1.25	SMALL	11/03/00	Oak Spr	11/06	2.94	-	-
149.812	154	51.5	1.41	LARGE	11/03/00	EXIT	11/06	0.44	2.08	2.51
149.832	138	34.8	1.32	SMALL	11/03/00	Warm Spr	11/04	-	-	-
149.851	148	40.7	1.26	LARGE	11/03/00	EXIT	11/05	0.56	1.07	1.63
149.872	132	31.0	1.35	SMALL	11/03/00	92 km	12/12	-	-	-
149.892	144	37.6	1.26	SMALL	11/03/00	54 km	01/10	1.50	-	
149.910	132	31.4	1.37	SMALL	11/03/00	89 km	12/12	-	-	-
149.932	150	44.6	1.32	LARGE	11/03/200	39 km	01/10	1.42	-	-
149.951	142	39.3	1.37	SMALL	11/03/00	Warm Spr	11/03	-	-	-
149.970	155	48.6	1.31	LARGE	11/03/00	74 km	12/12	5.69	-	-
149.992	138	35.6	1.35	SMALL	11/03/00	Oak Spr	11/04	0.43	-	-