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Early Life History Attributes and Run Composition of PIT-tagged Wild Subyearling Chinook Salmon Recaptured after Migrating Downstream Past Lower Granite Dam

Abstract

Seaward migration timing of Snake River fall chinook salmon (*Oncorhynchus tshawytscha*) smolts is indexed using subyearling chinook salmon passage data collected at Lower Granite Dam. However, not all of the subyearlings are fall chinook salmon. For six years, we recaptured wild subyearling chinook salmon smolts, which had been previously PIT tagged in the Snake River, to genetically determine if the fish were offspring of spring and summer (hereafter, spring/summer), or fall chinook salmon. Springfall chinook salmon comprised over 10% of the samples of recaptured smolts in five of six years. For these five years, we used discriminant analysis to determine run membership of PIT-tagged smolts that were not recaptured (i.e., not sampled for genetic identification). Accuracy of the discriminant analysis models, based on genetically identified smolts, varied between 75 and 85%. After using discriminant analysis to classify run membership for each PIT-tagged smolt that was not genetically identified, we compared early life history attributes between fall and spring/summer chinook salmon and calculated annual run composition. The life history attributes we studied overlapped, but spring/summer chinook salmon reared along the shoreline of the free-flowing Snake River earlier, were larger, and began seaward migration earlier than fall chinook salmon. Spring/summer chinook salmon made up from 15.1 to 44.4% of the tagged subyearling smolts that were detected passing Lower Granite Dam. As a result, the presence of spring/summer chinook salmon makes migration timing for the fall chinook salmon seem earlier and more protracted than is the case. If wild subyearling spring/summer chinook salmon smolts are not considered, fall chinook salmon abundance at Lower Granite Dam will be overestimated.

Introduction

Chinook salmon (*Oncorhynchus tshawytscha*) are indigenous to streams throughout the Snake River basin. Wild Snake River spring and summer (hereafter, spring/summer) chinook salmon typically have a "stream-type" (Healey 1991) early life history. Adult spring/summer chinook salmon spawn mainly in small tributaries of the Imnaha, Salmon, Grande Ronde, and Clearwater rivers (Figure 1) from August through early September (Howell et al. 1984). Fry emerge from the gravel primarily from late January through early May (Howell et al. 1984). Many parr rear in natal tributaries through spring, summer, and winter (R. Kiefer, Idaho Department of Fish and Game, personal communication), while others migrate downstream and overwinter in mainstem tributaries of the Snake River (Chapman and Bjornn 1969, Bjornn 1971). Wild Snake River spring/summer chinook salmon typically smolt and migrate seaward in the spring as yearlings (e.g., Achord et al. 1996).

In contrast to spring/summer-run stocks, wild Snake River fall chinook salmon spawn primarily in the mainstem Snake and lower Clearwater rivers (Figure 1) from late October through early December (Groves and Chandler 1999). Fall chinook salmon typically have an "ocean-type" (Healey 1991) early life history. Fry emerge from the gravel primarily from April to June, parr rear along the shoreline of the Snake River from April to July, and smolts typically migrate seaward during summer as subyearlings (W. P. Connor, U. S. Fish and Wildlife Service, unpublished data).

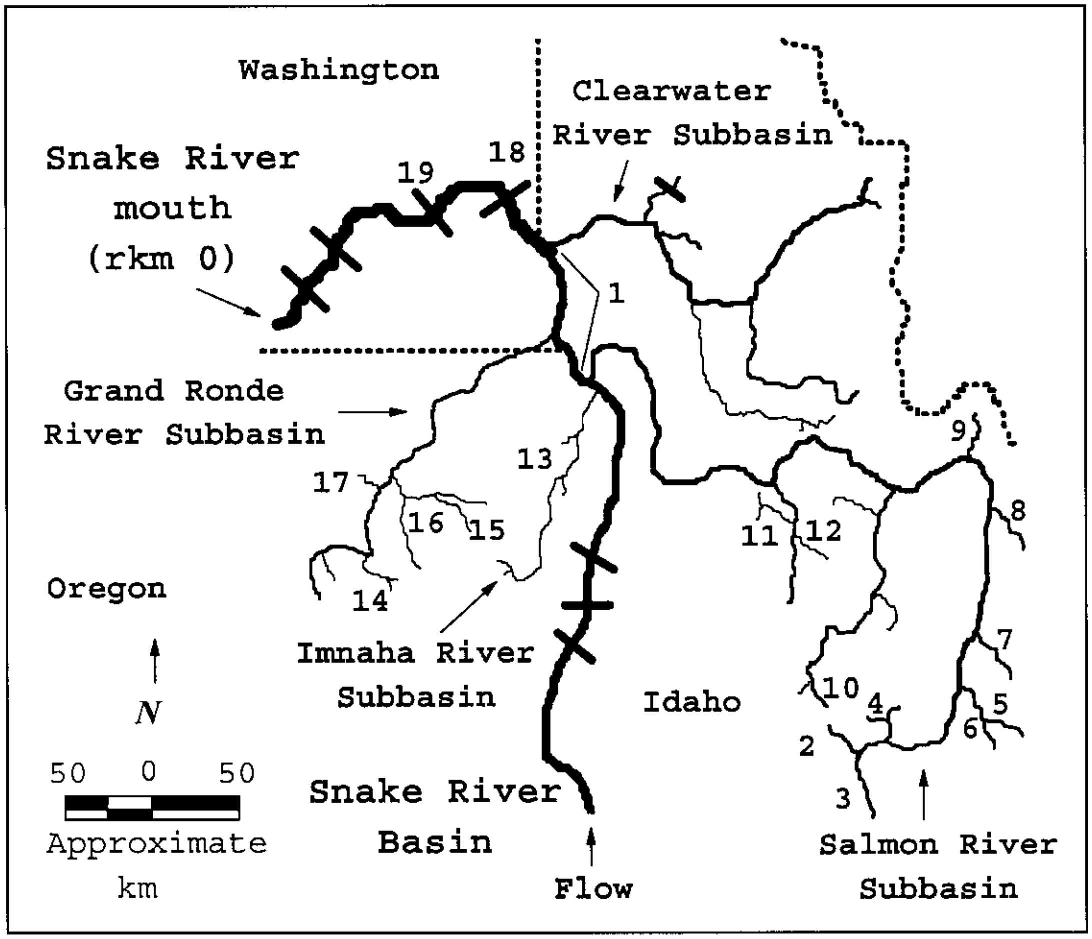

Figure 1. The Snake River basin including several of the subbasin tributaries where wild spring and summer* chinook salmon spawn, the beach seining area, and Lower Granite and Little Goose dams where PIT-tagged smolts were recaptured.

1. Seining area
2. Valley Creek
3. Upper Salmon River
4. West Fork Yankee Fork Creek
5. Herd Creek
6. East Fork Salmon River
7. Pahsimeroi River
8. Lemhi River
9. North Fork Salmon River
10. Marsh Creek
11. Secesh River*
12. Johnson Creek*
13. Imnaha River
14. Catherine Creek
15. Lostine River
16. Minam River
17. Lookingglass Creek
18. Lower Granite Dam
19. Little Goose Dam

Seaward migration timing of wild subyearling Snake River fall chinook salmon is indexed annually at Lower Granite Dam (Figure 1), which is the first dam smolts encounter en route to the Pacific Ocean. However, not all of the subyearling smolts are fall chinook salmon. Some wild Snake River spring/summer chinook salmon also migrate seaward as subyearlings. Marshall et al. (2000) found that from 5 to 63% of the subyearlings they sampled at Lower Granite Dam were spring/summer chinook salmon. Tiffan et al. (2000) attempted to separate wild subyearling chinook salmon at Lower Granite Dam into fall-run and spring/summer-run groups by using discriminant analysis models fit from body morphology traits. Tiffan et al. (2000) found that spring/summer and fall chinook salmon were morphologically similar, thus their discriminant analysis models mis-classified run membership of wild subyearling chinook salmon an average of 74% of the time.

In this paper, we expand on the findings of Marshall et al. (2000) and Tiffan et al. (2000) by comparing several early life history attributes of wild subyearling fall and spring/summer chinook salmon that were tagged in the Snake River including seaward migration timing measured as passage date at Lower Granite Dam. We also provide estimates of the proportions subyearling fall and spring/summer chinook salmon in annual tag groups that passed Lower Granite Dam (i.e., run composition) from 1993 to 1998.

Methods

We sampled wild subyearling chinook salmon parr in the free-flowing Snake River upstream of Lower Granite Reservoir between rkm 224 and rkm 291 (Figure 1) by beach seining as described by Connor et al. (1998) from 1993 to 1998. We began beach seining in April and continued into June or July until water temperatures exceeded 20°C and the catch was near zero. We tagged parr $\geq$ 60-mm fork length with Passive Integrated Transponders (PIT tags)(Prentice et al. 1990). For details of parr handling and tagging, see Connor et al. (1998). Tagged parr were released where they were captured to resume rearing and seaward migration.

A percentage of the PIT-tagged parr that survived rearing and early seaward migration were subsequently detected as smolts passing Lower Granite Dam in the fish bypass system (Connor et al. 2000). We recaptured a subsample of the detected smolts after they passed Lower Granite Dam by using a diversion device (Marsh et al. 1999) located in the fish bypass system of Lower Granite Dam (1993 to 1995) and Little Goose Dam (1996 to 1998)(Figure 1). From 1993 to 1997, we sampled scales, body muscle, heart, liver, and eye tissues (Marshall et al. 2000) from each recaptured smolt. In 1998, we sampled scales and pelvic fin clips.

We used scale pattern analysis (Koo 1967) to confirm that each recaptured wild chinook salmon smolt was a subyearling. The genetic lineage (i.e., fall or spring/summer run) of each recaptured smolt was identified using allozyme multilocus genotypes with accuracy near 100% (Marshall et al. 2000) from 1993 to 1997. In 1998, the genetic lineage of each recaptured smolt was identified non-lethally using the dual primer product of a nuclear DNA marker (R. Rodriguez, U. S. Geological Survey, unpublished method). Run identification using the DNA marker is almost 100% reliable and provided nearly identical results when compared to identifications from allozyme genotypes (A. Marshall, Washington Department of Fish and Wildlife and C. Rasmussen, U. S. Geological Survey, unpublished data).

We recaptured PIT-tagged smolts in diel samples from approximately May through September. Continuous daily sampling during these months was not possible because of logistical constraints and Endangered Species Act restrictions. We compared detection dates of all tagged smolts to the detection dates of the recaptured tagged smolts. We found that early and late migrating smolts were sometimes under-sampled. Therefore, we developed discriminant analysis models to classify run membership for tagged smolts that passed Lower Granite Dam, but were not recaptured and genetically identified.

We fit separate discriminant analysis models for every year (except 1995 for reasons described in Results) using four variables from life history attribute data collected on genetically identified smolts. Variables included initial capture date (expressed as day of year), fork length at initial capture, rkm of initial capture, and passage date at Lower Granite Dam (expressed as day of year). We fit test models using every combination of these variables, and by pooling and not pooling the covariance matrices (Johnson 1998).

For each year, we calculated both within-run (fall and spring/summer, separately) and across-run (fall and spring/summer, combined) classification accuracy for each test model using the cross-validation method (a.k.a., jack knifing)(Johnson 1998). Within-run classification accuracy was the number of correct classifications divided by the number of recaptured fall or spring/summer chinook salmon for each year. Across-run classification accuracy was calculated as the weighted average of the within-run classification accuracy estimates for each year.

We selected the final discriminant analysis models for each year based on across-run classification accuracy. We ran the final models to predict run membership for every PIT-tagged subyearling chinook salmon detected at Lower Granite dam that was not recaptured for genetic analysis. We combined fish of classified run membership (i.e., by discriminant analysis) with those genetically identified to obtain a data set of smolts detected at Lower Granite Dam throughout the sampling period. These groups provided better early life history comparisons and run composition estimates than could be made using genetically identified fish alone.

Results

We inserted PIT tags in 6,789 parr during the six years studied (Table 1). Detections of tagged smolts at Lower Granite Dam ranged from 97 to 379 (Table 1). We recaptured from 18.5 (1998) to 59.6% (1994) of the tagged smolts after they were detected passing Lower Granite Dam (Table 1). The numbers of spring/summer and fall chinook salmon that were genetically identified in each annual sample of recaptured smolts varied among years. Genetically identified spring/summer chinook salmon varied between 67 (1993) and 4 (1995) (Table 2). Fall chinook salmon ranged from a high of 92 (1994) to a low of 14 (1997)(Table 2).

We did not fit a discriminant analysis model to the 1995 data because the proportion of spring/summer chinook salmon was too small (4/46; 0.087) (Table 2). When using the life history

TABLE 1. The number of wild subyearling chinook salmon that were captured along the Snake River and PIT tagged, the number of PIT-tagged fish that were detected passing Lower Granite Dam, and the number and percentage detected fish that were recaptured after passing Lower Granite Dam, 1993 to 1998.

	Number of fish			
Year	Tagged	Detected	Recaptured	Recaptured (%)
1993	1,252	234	116	49.6
1994	2,337	193	115	59.6
1995	802	236	46	19.5
1996	413	126	26	20.6
1997	553	97	25	25.8
1998	1,432	379	70	18.5
Total	6,789	1,265	398	31.5

TABLE 2. Classification of run membership using discriminant analysis models fit with genetically identified (actual) wild subyearling spring/summer (abbreviated as spring) and fall chinook salmon smolts that were recaptured after being detected at Lower Granite Dam, 1993 to 1998. Within- and across-run cross-validation classification accuracies (%) are given by year, except in 1995 when the proportion of spring chinook salmon was too small for model fitting.

			Number classified into each run		Classification accuracy (%)	
Year	Actual run	*n*	Fall	Spring	Within-run	Across-run
1993	Spring	67	14	53	79.1	77.6
	Fall	49	37	12	75.5	
1994	Spring	23	7	16	69.6	78.3
	Fall	92	74	18	80.4	
1995	Spring	4	—	—	N/A	N/A
	Fall	42	—	—	N/A	
1996	Spring	4	1	3	75.0	84.6
	Fall	22	19	3	86.4	
1997	Spring	11	2	9	81.8	76.0
	Fall	14	10	4	71.4	
1998	Spring	32	8	24	75.0	75.7
	Fall	38	29	9	76.3	

attributes of the genetically identified smolts to fit the discriminant analysis models for the other five years, we found that across-run classification accuracy averaged 78.4% and ranged from 75.7 to 84.6% (Table 2). Initial capture date, fork length at initial capture, and date of passage at Lower Granite Dam were used in the 1993 and 1994 models to classify the smolts. For the 1996 model, classification was based on fork length at initial capture, and passage date at Lower Granite Dam. Passage date at Lower Granite Dam was used in the 1997 model to classify smolts. In the 1998 model, classification was based on rkm of initial capture, and passage date at Lower Granite Dam.

After combining the smolts of classified-run origin with those genetically identified, the total number of smolts available for comparing early life history attributes and estimating run composition was 1,029 (Table 3). Early life history, based on the attributes we measured, proceeded on a slightly earlier time schedule for spring/summer chinook salmon than for fall chinook salmon (Figure 2). Spring/summer chinook salmon were captured earlier (*N* = 5; Grand median = day 155) than fall chinook salmon (*N* = 5; Grand median = day 160). Spring/summer chinook salmon were consistently larger (*N* = 5; Grand median = 85 mm) when captured than fall chinook salmon (*N* = 5; Grand median = 73 mm). There was no consistent pattern among years for rkm of capture. Spring/summer chinook salmon passed Lower Granite Dam earlier (*N* = 5; Grand median = day 187) than fall chinook salmon (*N* = 5; Grand median = day 202).

TABLE 3. The percentages of PIT-tagged wild subyearling spring/summer (abbreviated as spring) and fall chinook salmon (i.e., run composition) detected passing Lower Granite Dam, 1993, 1994, 1996—1998. Detected smolts combine fish of classified run membership (i.e., using discriminant analysis) and those that were genetically identified.

Year	Number of smolts detected	Run composition (%)	
		Spring	Fall
1993	234	44.4	55.6
1994	193	23.8	76.2
1996	126	15.1	84.9
1997	97	33.0	67.0
1998	379	17.9	82.1
Total	1,029	26.1	73.9

Of the 1,029 smolts available for estimating run composition, 269 (26.1%) were spring/summer chinook salmon and 760 (73.9%) were fall chinook salmon (Table 3). Annual run composition ranged from 15.1 to 44.4% spring/summer chinook salmon, and 55.6 to 84.9% fall chinook salmon (Table 3).

Discussion

We were able to use genetic identification methods on samples of wild subyearling chinook salmon smolts to provide data for fitting discriminant analysis models. The models classified subyearling chinook salmon run membership from combinations of capture date, fork length at capture, rkm of capture, and passage date at Lower Granite Dam with an accuracy ranging from 75.7 to 84.6%. These levels of correct classification show that there are detectable differences in timing of shoreline rearing, parr fork length, rearing location, and early seaward migration timing between wild Snake River subyearling fall and spring/summer chinook salmon.

After our smolt sampling and analyses, we found that wild spring/summer chinook salmon parr were captured earlier, and were larger than wild fall chinook salmon parr. A possible explanation for these differences may be that spring/summer chinook salmon spawn 2 to 3 months earlier than fall chinook salmon, hence spring/summer chinook salmon fry emerge earlier than fall chinook salmon fry and then grow while dispersing downstream or rearing in the Snake River. Spring/summer chinook salmon smolts were also detected passing Lower Granite Dam earlier than fall chinook salmon smolts, perhaps because spring/summer chinook salmon parr reached a threshold size for seaward migration (Folmar and Dickhoff 1980, Wedemeyer et al. 1980) earlier than fall chinook salmon parr. Other studies of juvenile anadromous salmonids have documented differences in early life history attributes that resulted from time of fry emergence (Lister and Genoe 1970, Everest and Chapman 1972).

The early life history findings in the present paper are important to future studies of the Snake River fall chinook salmon population, which was listed for protection under the Endangered Species Act in 1992 (NMFS 1992). Fishery biologists need to be aware that some spring/summer chinook salmon deviate from the typical stream-type early life history. Some spring/summer

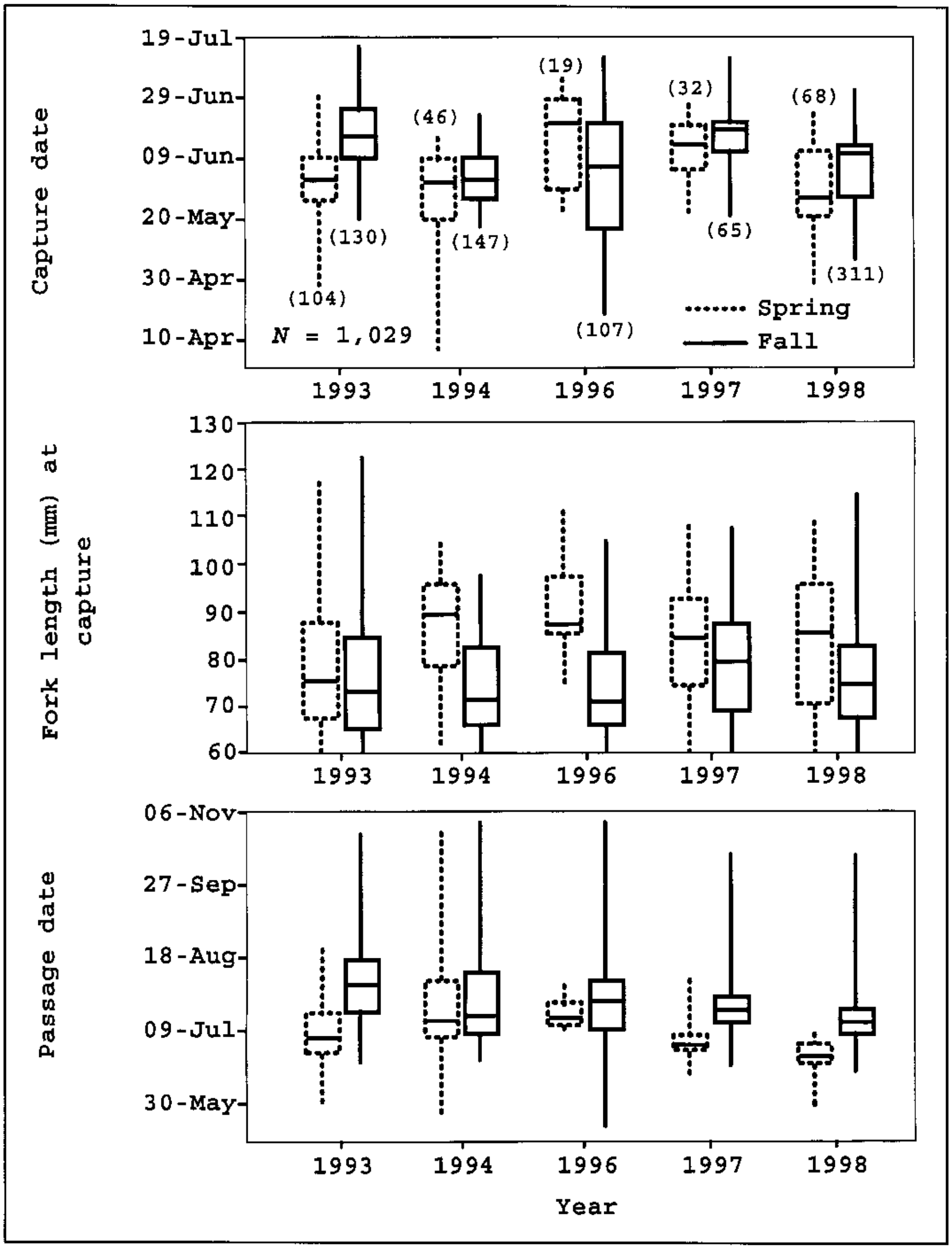

Figure 2. Capture date (Top), fork length at initial capture and tagging (Middle), and passage date at Lower Granite Dam (Bottom) for PIT-tagged wild subyearling spring/summer (dashed box plots) and fall (solid box plots) chinook salmon (*N* is given in parentheses at top), 1993, 1994, 1996–1998. The range is shown by the vertical lines, the top of each box is the 75th percentile, the horizontal line in the box is the median, and the bottom of each box is the 25th percentile.

chinook salmon rear in mainstem rivers rather than tributaries, and begin seaward migration as subyearlings rather than yearlings. The presence of unnoticed subyearling spring/summer chinook salmon would make fall chinook salmon early life history and smolt passage at Lower Granite Dam appear to be earlier and more protracted than is the case.

Although the proportion of Snake River spring/summer chinook salmon that migrate to the sea as subyearlings is a small fraction of the total number of spring/summer chinook salmon, we estimated that they can compose up to 44% of the subyearling out-migration from the Snake River. Fishery managers monitoring the recovery of Snake River fall chinook salmon need to know that the wild subyearling chinook salmon run passing Lower Granite Dam during early seaward migration includes both fall and spring/summer chinook salmon smolts. Fall chinook salmon smolt abundance can only be assessed using passage data collected at Lower Granite Dam if genetic samples are collected from the run at large to account wild subyearling spring/summer chinook salmon.

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