

Salmon use in the Lower Willamette River

CHINOOK SALMON (*ONCHORYNCHUS TSHAWYTSCHA*)

The Lower Columbia and Upper Willamette chinook lie near the center of the species' North American distribution (Myers 2003). The Willamette River basin encompasses 29,800 km² (11,500 mi²) (Myers 2003).

Willamette Basin spring chinook are an early-run population and are believed to be relatively isolated from other Columbia Basin spring chinook salmon. Major spring-run bearing streams include the Clackamas, Molalla, Calapooia, Santiam, McKenzie, and Middle Fork Willamette Rivers – all drain the Cascade Range from the east (Mattson 1948; Myers 2003; Nicholas 1995; ODFW (b)). Adult spring chinook return to the Willamette River during the spring, when flows are high and passage above natural falls, such as Willamette Falls is optimal. In contrast, fall chinook return during low flow conditions in early autumn. Fall run Chinook did not historically ascend Willamette Falls; rather most if not all spawned and reared in reaches and tributaries of the lower Willamette basin, most notably the lower Clackamas River and Scappoose drainage (Hutchinson and Aney, 1964). Today, because of managed flows in the upper and middle basin, along with fish passage improvements at Willamette Falls (beginning in the 1880's), fall run chinook ascend the Willamette Falls and spawn and rear in middle reaches of the Willamette subbasin; the McKenzie River is believed to be the only basin above the Falls to sustain significant natural production (Myers 2003).

The decline of chinook productivity in recent past has caused NOAA Fisheries to list two Willamette basin populations (or Evolutionarily Significant Units): Lower Columbia River chinook (threatened) and Upper Willamette River chinook (threatened). However, the lower Willamette River continues to provide critical spawning and rearing habitat for native Willamette Basin Chinook. In addition, recent fish monitoring data by Ducks Unlimited suggest that Columbia River basin Chinook (Upper Columbia River spring-run (endangered); Snake River spring / summer – run (threatened); and Snake River fall-run (threatened)) may be using the lower Columbia Slough (and Smith and Bybee Lakes) for rearing and refuge.

A description of general life history characteristics along with specific information relevant to Willamette basin spring and fall chinook is described below.

Early Life History Rearing

It is appropriate to consider freshwater rearing and growth respective to the different age, size and physiological conditions of “juvenile chinook”: fry, subyearling and yearling life stage. Fry are young-of-the-year fish. Subyearling fish are those that remain in freshwater thru the first fall (and are approximately six to nine months old) - these fish may or may not emigrate seaward at this age. Those that do not, and overwinter in freshwater comprise the yearling age class of the cohort population. *Note, fry, subyearling and yearling chinook may rear and reside available habitats in the lower Willamette River; hence, habitat quantity and quality (or environmental condition) prominently affects potential growth, survival, and ultimately potential population productivity.*

Egg Incubation, Alevin Development and Fry Emergence

The locations of nesting beds are synonymous with spawning areas, or redds, for adults. Eggs incubate (in the nesting gravels) from 90 to 150 days after fertilization. Significant mortality can occur during incubation if the redd is disturbed by overspawning, fluctuating flows, dewatering, freezing, isolation, suffocation, or microbial infestation (Beauchamp et al. 1983). “Alevins”, or newly hatched young with yolk sac intact, hatch in late fall thru early winter. They characteristically have an undeveloped body form and are just a few millimeters in size. Alevins remain in the substrate for four to six weeks until the yolk sac is absorbed (Beauchamp et al. 1983), after which they emerge as free-swimming “fry” that actively feed. Scales analysis from spring Chinook adults returning to Willamette Falls from 1946 to 1951, indicate that most fry emerge from spawning gravels from February through March – although some emerge well into June, yielding a prolonged emergence period of four to five months (Mattson (1962 and 1963). Fall chinook emerge from gravels beginning in late December, with peak emergence in mid-January. Chinook fry spend one to 18 months in freshwater – some migrate downstream, within weeks of emergence, soon after yolk sac resorption at 30 to 45 mm (Lister et al. 1971 and Healey 1991), while some remain in their natal stream for a year or more.

Juvenile Emigration

Life history expression of juvenile chinook is complex and dynamic – they begin their downstream migrations (or emigration) at various ages, size and physiological condition. For example, some chinook begin emigration within weeks of emerging from their nesting gravels, whereas others (from the same cohort population) may continue to rear in their natal stream for a year or more. For these reasons, it is appropriate to consider juvenile emigration respective to each age class and life stage comprising the “juvenile chinook” classification.

Spring Chinook. Three distinct emigration periods have been described for Willamette basin chinook. The first downstream migration of fry occurred during the first spring and summer following fry emergence. Although fry were noted as early as January and as late as August, peak movement occurred in April. This group was frequently the largest in numbers and constituted up to 55 percent of the year class. These early emigrants ranged in size from 37 to 100 millimeters (mm) (Mattson 1962 and 1963). Craig and Townsend (1946) reported that juveniles (or fry) began emigrating out of the North Santiam River in March, soon after emergence. They further noted that emigration continued through the summer, fall and winter; and concluded that juveniles emigrated as subyearling, and did not overwinter in the North Santiam. Rather, they left their natal stream to rear and grow in mainstem habitats and off-channel areas of the Willamette River. Scale analysis (collected from adults in the North Santiam and McKenzie River) showed that most juveniles (90% in the North Santiam and 87% in the McKenzie) entered the ocean as yearlings, suggesting that juvenile chinook overwintered in the mainstem Willamette or Columbia Rivers. Craig and Townsend (1946) observed similar life history characteristics in spring chinook from the South Santiam River, but noted that chinook left the McKenzie River basin as early as February. Dimick and Merryfield (1945) noted similar use of the mainstem Willamette River by young-of-the-year fry in the early 1940's. In the early 1940s, large numbers of fry were found from Harrisburg to Independence in February, March, and April; and in 1945, fry were collected from Corvallis to the Sellwood Bridge in Portland.

The second period of peak emigration occurred in late fall and early winter (October and November) and coincided with high stream flows and reduced stream temperature. This group was the second largest in numbers and constituted up to 50 percent of the year class. These fingerling emigrants ranged in size from 100 to 130 mm (Mattson 1962 and 1963). The third and final peak movement occurred the following spring (March through May) and constituted the smallest of the year class, with an upper magnitude of 35 percent. These yearling emigrants were the largest of the emigrating year class, averaging 100 to 140 mm (Mattson 1962 and 1963).

In addition to these three peak migrations, Mattson reported presence of juvenile chinook salmon in every month of the year near Lake Oswego, indicating year-round movement into the lower river. In 1952, the Oregon State Game Commission (1952) collected 1,400 salmon from Sauvie Island from July 1 through September 4. Most salmon were of yearling size, and were collected as part of the State's fish salvage activities.

Recent observations and studies thru the lower, middle and upper Willamette Basin show that juvenile chinook continue to express these life history traits and migration timing (Baker and Miranda 2003; Cramer 1996; ODFW 2005; Schroeder 2003). In 2003, staff biologists from ODFW (Schroeder 2003) identified three life history traits in McKenzie River spring chinook: 1) age-0 fry that migrate in late winter through early spring, 2) age-0 subyearlings that migrate in late winter through early spring, and 3) yearling smolts that migrate in early spring. These documented life history traits are the same as those that characterized Willamette basin chinook in the 1950's and 1960's. Schroeder (2003) also documented subyearling chinook extensively using the lower McKenzie River, upper and lower Willamette River and the lower Santiam Rivers from late May through July. Schroeder (2003) likewise documented an early summer migration of subyearling chinook over Willamette Falls; and studies through the lower Willamette River confirm the presence of a large number of subyearling Chinook salmon throughout a greater portion of the year. Four consecutive years of fish monitoring and research in the lower Willamette River (below Willamette Falls) found subyearling chinook present in every month sampled from May 2000 to July 2003 (ODFW 2005), with highest catches from autumn thru early summer (November thru June/July) of the following year.

Migration rates and residence times of yearling chinook (> 100 mm) was also studied. Data showed that yearling chinook travel quickly through the lower river (median migration rate = 12.4 km/day and residence time = 2.4 days); migration rate was positively correlated with increasing river flows and increasing forklength. Baker and Miranda (2003) have likewise monitored subyearling chinook entering Multnomah Channel and the lower Columbia Slough from January thru June, with peaks in February, and PGE staff observe chinook fry and juveniles passing the Willamette Falls (Sullivan Plan) during high flow events (Reed 2004).

Fall Chinook. Most juvenile fall chinook emigrate seaward in late winter (February) thru early summer (July) (Beamer et al. 2000) and enter the lower Willamette at 60 to 120 days of age, or in late summer / early autumn of their first year. Recent scale analysis of adult returns show that a small proportion (<10%) of the naturally spawning fall chinook do not emigrate until their second spring, as yearlings (Myers 2003).

Habitat and Ecology

A suite of environmental conditions and habitat characteristics affect the quantity and quality of the freshwater environment respective to feeding and growth. For example, gravel quality (size and embeddedness), stream flow and silt load affect egg incubation, alevin development, and the age, size, and condition of emerging fry. Redds, or nesting beds are generally located in areas 0.15 to 0.30-m deep (Everest and Chapman 1972) and in areas with enough current to ventilate the eggs during incubation and prevent desiccation as waters recede (Naiman et al 1992); and young-of-the-year fry select areas with low stream velocity (less than 0.10 m/s) to avoid being displaced downstream (Bjornn and Reiser, 1991). Generally, egg to fry survival is higher in areas with instream structure. Large wood structure diversifies flows, reduces stream energy and stabilizes bedload and streambanks (Naiman et al, 1992). High sediment loads can fill substrate interstices, reducing intragravel flow; and (if sever enough) can be a physical barrier to emerging fry. Other water quality constituents that can significantly affect freshwater rearing, growth and physiological development include stream temperature and dissolved oxygen. Below is a brief summary of findings.

During their first summer, juveniles (considered subyearling at this time) hold in areas with moderate velocities: boulders, wood jams, and undercut banks. These areas provide the greatest opportunities to maximize food intake, while expending the least amount of energy. In addition, instream structure such as wood, boulders, undercut banks and overhanging vegetation provide important cover from predators, refuge habitat during high flows and areas to feed and rest during migrations (Everest et al 1985). In summer juveniles select habitats with enough summer flow to prevent the streams from becoming excessively warm or drying-up; and through the winter, they select shallow water, low velocity habitats (backwaters, side-channels and off-channel areas) along unconstrained reaches in alluvial floodplain reaches (Sedell and Luchessa, 1982) to feed, rest and grow. Notably, preferences for different types of habitats change throughout the year as environmental conditions fluctuate and as chinook grow.

	Dissolved Oxygen (mg/L)	Temperature (°C)
Egg Incubation	Leitritz and Lewis reported a lower limit of 0.5 mg/L	Embryos exhibit 50% mortality at temperatures <u>below</u> 2.5°C and 3.0°C, and <u>above</u> 16.0°C (Beacham and Murray, 1990).
Freshwater Rearing	Whitmore (1960) documented preferred dissolved oxygen concentrations at or above 4.5 mg/L. Alabaster (1979) noted that growth rate and food conversion efficiency becomes limited at concentrations below 5.0 mg/L. Davis (1963) noted that maximum sustained swimming performance drops off at concentrations below 8.0 to 9.0 mg/L.	Bjornn and Reiser (1991) documented optimal stream temperatures ranging from 12.0°C to 14.0°C, with lower and upper lethal limits of 0.8°C and 26.2°C respectively. Morrow (2000) documented optimal stream temperatures of 11.7°C to 15.5°C for all freshwater rearing.

Juvenile Chinook overwinter in larger river reaches. They prefer large, deep (> 0.5-m) pools with small substrate and are associated with complex habitat forms such as large boulders and woody debris that provides cover and refuge. During freshwater rearing, juveniles generally prefer bank edges that enable opportunistic feeding (e.g., they are characterized as drift, benthic feeders that feed primarily on insects). Yearling chinook experience an accelerated growth rate in early spring, smolt in April and May, then emigrate to lower river estuarine areas. Notably, flow, seasonal flood cycles, turbidity and water temperature are positively correlated with periods of juvenile migrations seaward. Specifically, juvenile chinook begin their migrations immediately following spring, summer and fall freshets, which are often associated with higher turbidity and warmer stream temperatures in the Willamette Valley.

Feeding and Growth

Salmonid diet studies in large, low gradient rivers, such as the lower Willamette River are scarce. In the early 1960's, Mattson analyzed scales of returning adult Chinook salmon to evaluate relative growth patterns during freshwater rearing. Mattson (1962) concluded that growth rates of fry and subyearling chinook that reared in the lower Willamette River (near Lake Oswego) exceeded freshwater growth rates of yearling migrants that remained in the upper Willamette tributaries such as the McKenzie, Middle Fork Willamette and Santiam rivers. Mattson (1962) further concluded that the small number of yearling spring migrants experienced superior freshwater growth in the lower Willamette River. Howell et al. (1985) found similar results, noting that juveniles rearing in the lower mainstem Willamette had an accelerated growth pattern and emigrated seaward up to two months earlier than juveniles emigrating from upper Willamette Basin tributaries.

Recent studies completed by ODFW suggest similar findings. From 2000 thru 2004, ODFW (2005) analyzed the diet and growth rate of juvenile chinook in the lower Willamette River, specifically from Willamette Falls to the confluence with the Columbia River. They found that migrating yearling Chinook extensively utilize available food resources in the lower Willamette River as they move seaward towards the Columbia River. Median fork lengths and weights of juvenile chinook salmon were significantly greater from upstream sample sites to downstream sampling sites during winter and spring, suggesting feeding and growth. Forklength of marked hatchery fish increased an average of 14-mm, and ODFW estimated that unmarked juvenile salmon grew 0.9 – 2.3 mm from upper to lower sites, suggesting significant growth and confirming what Mattson (1963), Howell (1988) and others concluded nearly 50 years before – the lower Willamette River is valuable rearing habitat.

In addition to evaluating changes in size, state biologists evaluated the stomach contents in yearling chinook salmon (defined as those >99-mm forklength). Diet analysis show that daphnia are a dominant food item (comprising 91% of the food items in the samples collected) and comprise a significant proportion of dietary intake (43% of the weight) throughout most of the year. The high numbers and large size of daphnia in the lower Willamette River make them a favorable food item to yearling Chinook. The mean number of daphnia consumed by juvenile Chinook salmon varied greatly among different nearshore habitat types. Notably, from Ross Island Bridge downstream to the mouth of the Willamette, the number of daphnia consumed by juvenile, yearling Chinook was highest in alcove areas. From Willamette Falls downstream to the mouth, percent daphnia consumption was equal among all shoreline habitats sampled. In general, percent daphnia composition was highest at mixed habitats (rip rap on beaches) in winter and spring, and was lowest at riprap sites compared to alcove and beach habitats in the fall.

Interestingly, juvenile chinook exhibited specialized, selective feeding behavior and consumed larger amounts of the daphnia for most of the year, compared to chironomids, another major food item in the lower Willamette River. *Corophium* (spp.) was the second most abundant food item (4%) and were present in 51% of the stomach samples examined. Notably, corophium was a more dominant food item in the fall, as the proportional amount of daphnia consumed declined; and corophium were slightly more abundant in the stomach contents of larger fish (>141-mm). Similarly, Craddock et al. (1976) found that juvenile Chinook salmon fed selectively on daphnia in the nearby lower Columbia River.

Based on patterns of feeding and growth rates, ODFW (2005) concluded that the lower Willamette River is clearly more than a simple migration corridor, but provides value as rearing habitat: "Juvenile Chinook salmon feed and apparently grow during their outmigration". Sub-yearling chinook are also present in substantial numbers, and their survival is undoubtedly related to available food resources (ODFW 2005). Baker and Miranda (2003) have likewise documented subyearling growth during residence in the lower Columbia Slough, Smith and Bybee Lakes and in several locations of Multnomah Channel from January thru June. Based on the compilation of recent and historic studies throughout the lower Willamette Region, specifically from Willamette Falls downstream to the confluence with the Columbia River, it is reasonable to presume that juvenile chinook historically and presently continue to feed and grow throughout the lower Willamette area.

Estuarine and Ocean Rearing

Juvenile chinook, again defined as fry, subyearling and yearling, enter estuarine environments during periods of high river discharge and turbidity, which often coincides with higher river flows in spring and summer; however, they will continue to enter lower river reaches and estuaries well into the fall. Juvenile chinook range from 35-mm to 160-mm upon entering the estuary (Beauchamp et al. 1983). Estuarine residence times varies from several days

to several months – residence time is believed to be influenced by river and tidal flows, fish densities, and environmental characteristics of the estuary. In 1980, Miyamoto documented a preference for soft, packed substrate and Healey (1980) found chinook salmon in water a few centimeters to over a meter deep over gravel, sand and mud substrates. Smaller chinook have been associated with shoreline areas (or surface waters), while larger fish occupy deeper waters (Meyer et al. 1980).

Spring Chinook. After entering the ocean, spring chinook of the Pacific Northwest travel in a northwesterly direction in the ocean. Migration is relatively slow while they feed and grow. Spring chinook are often found far from the coastal region. They remain in the marine environment between one and six years, but more commonly between two and four years (Rich 1920, Beauchamp et al. 1983), until reaching sexual maturity.

In 1941, Craig and Townsend reported that chinook entered saltwater no earlier than the autumn of their first year, and a recent study shows that Willamette River spring chinook salmon have a physiological smoltification window during their first autumn. Willamette River subyearling spring chinook were positively identified through genetic mixed-stocks analysis rearing in the Columbia River plume (Myers 2003). The above suggests that the large numbers of fry emigrating out of the upper Willamette basin from early spring through summer do not immediately enter the estuary; rather they likely rear in the lower Willamette and / or lower Columbia River.

Fall Chinook. Fall chinook travel in a northwesterly direction in the ocean. Migration is relatively slow while they feed and grow. Whereas spring chinook tend to migrate farther from the coastal area, fall chinook tend to migrate along the coast. They remain in the marine environment between one and six years, but more commonly between two and four years (Rich 1920, Beauchamp et al. 1983).

Adult Return

Note, adult spring chinook enter the lower Willamette in the spring, and must pass through the lower River reach to access spawning areas in the Clackamas and middle and upper reaches of the Willamette basin. Because the adults have no alternative route to reach their spawning beds, habitat quantity and quality (and environmental condition) in the lower Willamette River prominently affect adult survival, spawning success and ultimately a population productivity.

Run Size

Annual run size of adult Chinook returning to the Willamette River has oscillated widely since the mid 1900's – mean annual run size has ranged from 25,000 and 97,000 fish. In 1946, 55,000-spring chinook were counted passing over Willamette Falls thru April, May, and June. Over the next six years, from 1946 thru 1951, annual chinook runs (composed of mainstem Willamette River sport catch, escapement above Willamette Falls, and escapement to the Clackamas River) averaged 55,600 salmon and ranged from 25,100 to 96,800 chinook (Mattson 1963). Comparatively, during this same period, 97,543-spring chinook passed over Bonneville Dam (Fish Commission of Oregon 1948). In 1950, Parkhurst estimated the carrying capacity for the McKenzie River basin and North Santiam River to be 80,000 and 30,000 adult spring chinook respectively.

Mean annual run size oscillated between 25,000 and 45,000 fish between 1962 and 1986, and averaged 34,759 over 25 years. During this period, a low run of 19,079 chinook were recorded in 1975 and a peak run of 47,501 chinook were recorded in 1978 (Firman 2004). From 1987 to 1991, the mean annual run size averaged 64,000; through the 1990's and early 2000's the number of adult Chinook returning to the Willamette River basin has steadily increased, reaching a high of 96,725-spring chinook in 2004 (Firman 2004).

Age Structure

Spring Chinook. Spring chinook of the PNW generally reenter freshwater at age three to five from April-June. Freshwater entry is usually associated with spring freshets and warming temperatures. The majority of Willamette River spring chinook historically matured in their fourth and fifth year, with five year olds comprising the largest portion of the run. Mattson reported the following observations in 1963:

- 3-year age fish: 4 percent
- 4-year age fish: 24 percent;
- 5-year age fish: 62 percent
- 6-year age fish: 10 percent

In the mid 1920's Rich and Holmes (1929) similarly observed "5-year old adults predominated, 6-year old salmon returned in larger numbers than 4's, and only a few 3-year olds were recovered." Notably, by the early 1950's, six-year age adults had declined, such that four-year age adults comprised the second largest portion of the adult return. Six-year age adults comprised the second most significant age class of the annual run in the early 1920's; and were comprised of proportionally more yearling-age emigrants than younger age cohorts (Mattson 1963). The number of yearling migrants proportionally increased with increasing adult return age, while the number of fry and fingerling emigrants accounted for a higher proportion of three-year age adults (Mattson 1963); suggesting that older-age adults reared in fresh water (either in their natal streams or in the lower Willamette River) a full year before emigrating seaward, while the younger aged adults emigrated from their natal stream during their first year.

Recent scale analysis of known wild spring chinook adults show that subyearling ocean migrants continue to contribute to adult returns, in some areas such as the North and South Santiam they make significant contributions. Below is a brief summation of these research results - reported during the [Subyearling Chinook Data Sharing Workshop in 2004](#) (Reed 2004).

Willamette Basin	Adult Return Year	Proportion of the run comprised of subyearling Ocean-migrants (age 0)
McKenzie River	2001	4 %
	2002	26 %
	2003	17 %
North Santiam	2001	55 %
	2002	52 %
South Santiam	2002	82 %
Clackamas River (above North Fork Dam)	2002	27 %
Middle Fork Willamette	2002	6 %
Sandy River (above Marmot Dam)	2002	7%

In comparison, Mattson reported the following in 1963.

Willamette Basin	Adult Return Year	Proportion of the run comprised of subyearling Ocean migrants (age 0)
Lower Willamette River (below Willamette Falls)	1946	14 %
	1947	22 %
	1948	13 %
	1951	13 %

Age analysis from naturally spawning spring chinook from the Kalama and Lewis Rivers likewise indicate a significant contribution to escapement by subyearling ocean migrants (Myers 2003).

Fall Chinook. Fall chinook enter freshwater at an advanced stage of maturity, at two to four years of age from late summer through fall. They swim rapidly upstream to lower mainstem river reaches with the higher autumn flows, and spawn within days or weeks of freshwater entry. Note, early run tule fall chinook mature and return to freshwater as 3 and 4 year age adults, while late run fall chinook (e.g., those originating from the Sandy and Lewis Rivers) mature at an older age (Myers 2003).

Recent genetic analysis (microsatellite DNA) of tissue samples collected from chinook salmon of known stock origin in different parts of the Willamette River basin show that all juvenile chinook salmon sampled above the Santiam River are of spring chinook origin, whereas those collected below the Santiam Rivers are a mix of both spring and fall chinook: 94% spring chinook origin and 6% fall chinook origin (Schroeder 2003) (Reed 2004). Juveniles collected from the lower reaches of the Santiam River had the highest assemblage of fall chinook with 44% of the cohorts being of fall chinook origin. Samples were collected in late June and late July. Interestingly, proportions of juvenile fall chinook were similar in all mixed schools (captured in and below the lower Santiam River) suggesting that juvenile fall chinook rear in mainstem and tributary reaches of the upper Willamette well into summer, which is generally believed to be past the peak of their normal migration into lower river reaches (Reed 2004). Data suggests that the Santiam River is the upstream extent of fall chinook migration and spawning.

Notably, the later fall chinook releases were confined to the North Santiam River (at Stayton Pond, about 16.5 miles from upstream from the mouth of the North Santiam) (Reed 2004).

Migration and Spawning

Spring Chinook. Adult spring chinook migrate slowly upstream, holding in deep pools (0.10-m to 10-m) through the summer (Chapman, 1943; and Briggs, 1953), then spawn in mid- to upper river reaches in late summer and fall (between August and November). Upstream migrations are often associated with fall freshets, or higher river flows that allow passage over barriers such as waterfalls, cascades, or debris jams. Chinook generally live two to four weeks after spawning. Following is brief synopsis of average redd size, egg depth and fecundity, or number of eggs produced per female annually.

Life Stage	Description
Average Redd Size	43 – 162 sq ft.
Egg Depth	7 ½ inches
Fecundity	3,000 and 6,000 eggs. Fecundity is related to body size, age, migration-distance and stock origin.

Spring chinook historically and currently spawn in prominent east-side subbasins of the Willamette River. These include the McKenzie River, North and Santiam River and the middle Fork Willamette River. As early as 1903, Oregon state fish biologists noted that Willamette River salmon were an early-run fish that entered the Columbia River basin early in the season in order to navigate above Willamette Falls and get up into remote areas of the upper Willamette River (and its tributaries) (Department of Fisheries 1905). Adult migrations generally coincided with periods of high rainfall or snowmelt and with warmer temperatures. Higher river flows over Willamette Falls allowed spring chinook to ascend the falls in the spring. This relationship between flow and run-timing of Willamette Basin chinook has long been recognized by fishery biologists: “Another peculiarity in connection with the habits of this species of salmon is that they will not enter any stream which is not fed by snow water...” (ODF 1900). Adult spring chinook enter the lower Columbia and Willamette Rivers beginning in February and ascended Willamette Falls in April and May (with peak migrations from mid to late May) (Myers 2003; Wilkes 1845). Depending on weather patterns and the river state, migration timing may vary. In recent past, spring chinook have ascended the falls beginning in March, with peak passage in May, and the majority of adults passing in April and May, and tailing-off in June thru August (Firman et al. 2005).

Spawning generally begins in late August / early September (but sometimes as early as late July in the Clackamas and Molalla Rivers (Dimick and Merryfield 1945)) and continues through mid-October, with peak spawning in September. Dimick and Merryfield (1945), and Mattson (1963) observed that spawning generally coincided with a slight drop in water temperature following the first few cool nights. Today, Willamette River spring chinook (above the falls) continue to spawn from late August thru October, with peak spawning in September (Schroeder et.al. 2003) (Olsen et.al. 1992).

Although a large portion of the spring run passed and occupied reaches above the falls, historic records show that a run of spring chinook entered the Clackamas subbasin in March, prior to the upper Willamette fish run. The upper Clackamas basin was historically very productive for spring chinook salmon. Important areas included the upper mainstem river and the Collawash River, particularly the Big Bottom area. The Clackamas River run historically entered the river in March and April, and sometimes as early as February (Barin 1886). The peak of the run generally occurred in April (Abernethy 1886). ODF (1903) reported that, “the Clackamas River is, as has always been conceded, the greatest salmon breeding stream of the water that our state affords...” Dimick and Merryfield (1945) reported spawning activity in the upper Clackamas and Molalla Rivers as early as July. Records show that hatchery staff began taking eggs from spring chinook in the Upper Clackamas basin (Oak Grove Fork) in July and continued through early September, with peak spawning in early to mid August (Myers 2003; ODF 1903). Today, adults enter the upper Clackamas basin from May thru July, with peak spawning in October.

Fisherman of the lower Willamette claimed that before 1927, a run of large salmon passed through the lower river each June, which they referred to as the “June hogs”. Mattson (1963) likewise acknowledged the existence of a late run spring chinook salmon that ascended Willamette Falls in June. Adults averaged 25 to 30 pounds in weight and were believed to be mostly six-year age fish. Notably, six-year age adults comprised the second most significant age class of the annual run in the early 1920’s. Likely only the larger, summer run fish would have been able to ascend Willamette falls in June. As with Columbia River basin spring and summer chinook, Willamette basin early

and late run spring chinook are believed to occupy similar spawning and rearing grounds. However, some spatial segregation may have occurred. Spring-run chinook are more abundant in upper mainstem reaches (and tributaries), while summer-chinook generally occupy middle and lower mainstem reaches (Fulton 1968). Notably, the last sizeable run of these June migrants passed Willamette Falls in 1934, which notably coincided with the loss of the Clackamas River fall-run chinook (Mattson 1963).

Both spring and fall run chinook historically and presently spawn and rear areas below Willamette Falls, most prominently the Clackamas River, Johnson Creek (and Crystal Springs Creek), Milton Creek, and Scappoose Creek (Hutchinson et al. 1964) (Willis et al. 1960); and juvenile chinook of both races continue to rear and reside in lower mainstem habitats throughout a greater portion of the year.

Fall Chinook. Most, if not all fall chinook native to the Willamette Basin populated reaches below Willamette Falls, most notably the lower Clackamas River and Scappoose drainage (Hutchinson and Aney 1964). The Clackamas River, a principal tributary to the lower Willamette River supported a tule fall chinook run until that 1930's. The Clackamas River fall chinook run was believed to use the lower 18 kilometers of stream. Willis (1960) reported that fall run chinook spawned throughout the Clackamas River basin and in nearly all-accessible large tributaries. In addition to the Clackamas, Myers (2003) recently concluded that fall chinook likely spawned in the other lower Willamette River tributaries such as Johnson Creek and Abernathy Creek.

In addition, fall chinook formerly spawned in the mainstem Willamette River below the mouth of the Clackamas River (Fulton 1968). Today, a late-run population of Chinook salmon continues to spawn and rear in the lower Clackamas River; however, it is unknown whether these fish are of fall chinook origin or are the later part of the spring-run.

From 1952 to 1981, lower Columbia River hatchery stocks of fall chinook were released into the Clackamas basin, with the hopes of reestablishing the run. In 1964, fisheries managers introduced an early spawning (tule) and a late spawning (Cowlitz) fall chinook stock into streams above Willamette Falls. Large numbers of hatchery reared fall chinook were released each year above and below the Santiam River until 1996 when the Willamette Basin fall chinook hatchery program was discontinued. Today, fall chinook continue to spawn and rear in the mainstem Willamette River and lower reaches of eastside tributaries, at least up to the lower Santiam River (ODFW 2000a; Schroeder 2003), and prominently near sites where hatchery releases occurred.

Fall chinook generally enter freshwater at an advanced stage of maturity and spawn shortly after reaching their spawning grounds, from mid-September through early October. Both Stone (1878) and Barin (1886) observed chinook salmon returning to the lower Clackamas River (just upstream of Clear Creek) beginning in early September, with "ripe" spawning salmon observed just two weeks later in mid-September. Hatchery records from the late 1880's likewise show that fish were spawned from mid-September thru the first week of November.

Habitat and Ecology

A suite of environmental conditions and habitat characteristics affect spawning behavior, specifically adult migration, holding and spawning. Adult spring chinook seek mainstem river reaches where enough flow is available to sustain deep, cool pools (Beauchamp et al. 1983), yet not scour the spawning beds. They typically spawn in coarse gravel and cobble substrates (up to 14.0 cm diameter) (Briggs, 1952; Groot and Margolis; Wydoski and Whitney and Reiser and Bjornn, 1979) and in pools at least 0.24 meters deep (Reiser and Bjornn 1979; Hutchison and Aney 1964). Adults select pool-riffle channel morphology versus plane bed or step pool channels (Montgomery et al. 1999). Notably, wood, boulders and other instream structure provides important cover from predators, refuge habitat during high flows and areas to feed and rest during migrations (Everest et al. 1985). Nest building (or redd building) commences earlier in upper river reaches, and progresses sequentially downstream as river temperatures drop (Beauchamp et al. 1983).

Much research has been conducted to evaluate optimal stream temperatures, and lower and upper lethal temperature limits for adult spring chinook. In the 1940's Mattson (1948) and Hodges and Gharrett (1949) documented an upper lethal limit of 23.0°C; in 1991, Bjornn and Reiser (1991) documented an optimal range between 4.0°C and 14.0°C; in 1986, Bell documented an optimal range between 5.6°C and 13.9°C; and recently Morrow (2000) documented an optimal range from 11.7°C to 15.5°C. In addition to temperature, stream turbidity and dissolved oxygen concentrations can affect habitat quality and ultimately whether or not adult spring chinook successfully spawn.

Notably, migrating salmon will avoid waters where dissolved oxygen concentrations fall below 4.5 mg/L (Hallock et al, 1970) – hence, areas in which this occurs can effectively become a barrier to migration, thus reducing potential productivity of the population. In addition, high concentrations (> 4000 mg/L) of suspended sediment (measured as Total Suspended Solids (TSS) - a surrogate for turbidity) may delay or divert spawning and can cause avoidance to spawn (Bell 1986).

STEELHEAD (*ONCHORYNCHUS MYKISS*)

Two life-history phases of steelhead are native to the Willamette Basin: anadromous steelhead and resident rainbow trout. Both life histories inhabit eastside and westside tributaries of the Willamette River Basin (Dimick and Merryfield 1945). Upstream of Willamette Falls, winter steelhead prominently populate eastside tributaries and the Tualatin River to the west (ODFW 2000a; Fulton 1970). In the Lower Willamette, anadromous steelhead and resident rainbow trout spawn and rear both east and west side tributaries, notably, the Clackamas River, Johnson Creek and Tryon Creek. Populations below Willamette Falls are part of the larger Lower Columbia River Evolutionarily Significant Unit (ESU), listed as “threatened” on the federal ESA in March 1998 and reaffirmed in January 2006. Critical spawning and rearing habitat was described and adopted by NOAA Fisheries in January 2006; and includes all streams and tributaries in the lower Willamette River, below Willamette Falls. Tualatin River steelhead are part of the larger Upper Willamette River ESU, which were listed in March 1998 and reaffirmed in January 2006. Critical habitat for these populations were adopted in January 2006; and includes all the Willamette River, Oregon, and its tributaries upstream from Willamette Falls to the Calapooia River, inclusive.

The life history of lower Willamette River populations (most prominently the Clackamas River) are generally a late returning population, taking advantage of high river flows (and cool stream temperatures) to move upstream and navigate natural falls, and high gradient stream reaches. The lower Willamette populations return to spawn during their fifth and sixth year. Native, late-run winter steelhead enter the Willamette River from October through May (Dimmick and Merryfield 1945). Spawning begins as early as March; however, peak spawning is believed to be greatest in April in westside tributaries and May in eastside tributaries. Steelhead spawn in cool, clear, and well-oxygenated streams with small to large gravel (1.3 to 11.4 cm) and suitable flow (0.76 meters/second) (USFWS 1983). These conditions are found in riffle-type habitats and are typical of habitat found in the upper tributary reaches. Most steelhead die after spawning, however, some will re-enter the ocean, returning to their natal stream for a second time to spawn again. Adults exhibiting this life history characteristics are characterized as “kelts”.

Eggs hatch and fry emerge in winter or early spring, depending on habitat, water temperature, and spawning season. After emergence, fry continue to rear in riffle-type habitats through the summer, then move into pools in the winter. Steelhead generally become inactive in winter months, often burrowing into stream-bottom substrates and other available instream cover. Steelhead, like Chinook, rely on an abundance of instream structure for cover during overwintering months.

Juvenile steelhead generally spend two years in freshwater before smolting, with peak juvenile emigration beginning early April and extending through early June, and larger steelhead emigrating earlier than smaller ones (ODFW 2000a). Smoltification is initiated by a combination of environmental factors including photoperiod, water temperature, and water chemistry. Larger steelhead generally emigrate sooner than their smaller cohorts (ODFW 2000a). Marine survival is correlated with smolt size, with the critical minimum size ranging from 14 to 16 cm upon saltwater entry. Steelhead rear in the ocean for one to four years before returning to their natal streams.

COHO (*ONCHORYNCHUS KISUTCH*)

Historically, the lower Willamette River basin provided the third most important spawning grounds for coho salmon, throughout the entire Columbia River basin (Fulton 1970). Coho are believed to be native only to subbasins below Willamette Falls, notably the Clackamas River, Johnson Creek (Fulton 1970), Tyron Creek; and tributaries of Multnomah Channel (Willis 1960). This population, now classified as the Lower Columbia River coho population (or Evolutionarily Significant Unit) are listed “endangered” on the state ESA (July 1999) and were recently listed “threatened” on the federal ESA (June 2005). Critical habitat has not yet been identified by NOAA Fisheries, however, based on historic and present fish use, the lower Willamette River (and its tributaries) up to Willamette Falls includes critical spawning and rearing habitat for this ESU.

Life history of this population is based upon native populations in the Lower Willamette River, most notably the early-run Clackamas River population. Native lower Willamette basin coho return as three-year age adults and two-year age jacks. They are an early run population, reaching Willamette Falls from late August through early November, with peak migrations occur from middle to late September, following periods of considerable rainfall.

Peak spawning generally occurs soon afterwards from September through December. Coho commonly use tributaries to lower river reaches, and spawn in small, low-gradient areas; however, they will spawn in mainstem reaches. Generally, they prefer fast-flowing waters with small to large gravel substrates (1.3 to 10.2 cm). After fertilization, eggs incubate for 80-150 days, depending on stream temperatures. Fry emerge from mid-January through April, yielding a four-month emergence period. During this period they seek shallow water areas, before dispersing downstream into deeper habitats. While a small proportion of fry emigrate during the first year, most fingerling smolts emigrate during the second spring, beginning in March and extending through mid-July. Those that remain in their natal streams will migrate upstream or downstream, seeking slack water habitats often found in side channels, backwater pools, and beaver ponds. These habitats are especially important during overwintering months because they harbor insects and provide a continual source of food for coho. Yearling juvenile coho emigrate seaward in early spring, with peak migrations in April/May. Generally, coho will rear for two additional years in the ocean and return to their natal streams as three- and four-year age adults in the fall.

CUTTHROAT (*ONCHORYNCHUS CLARKI*)

Coastal cutthroat had the greatest overall distribution of any of the salmonids in the Willamette River Basin, and were known to populate most streams in the basin (Hutchinson and Aney 1964). Dimick and Merryfield (1945) reported that “few tributaries of the Willamette system is without cutthroat trout unless blocked by natural barriers. Two life-history phases of cutthroat trout resided in Portland area streams: migratory and non-migratory. Non-migratory, or resident, cutthroat historically did not migrate far from upper tributary reaches (Hutchinson and Aney 1964), remaining in fresh water for their entire lifespan. Migratory, or sea-run, cutthroat were believed to drop down into the mainstem Willamette River in the spring, rear throughout the summer, then migrate to the ocean in the fall or early winter. Notably, they did not use the mainstem reaches for spawning; rather, they used them for spring, summer, fall, and early winter rearing. Sea-run cutthroat were noted to reside predominantly near tributary confluence regions of mainstem Willamette River. The USFWS previously considered Southwest Washington/Columbia River coastal cutthroat trout a “candidate” species for federal ESA listing. However, in June 2002, they determined that the population did not warrant protection under the ESA, based on trends in population abundance and recently enacted fish and habitat protections (that included protections by the City of Portland).

In 1945, Dimick and Merryfield noted that no morphological differences between resident and sea-run cutthroat, except for differences in the size of adults. One distinct difference they did note was related to spawn timing; sea-run cutthroat spawned in January, February, and March (much like native winter steelhead), while resident cutthroat spawned in May, June, and July. Notably, in Oregon and Washington, sea-run cutthroat return to their natal stream anytime from mid-summer thru spring of the following year, with peak movement occurring from September thru October. Generally, they migrate to upper mainstem and tributary stream reaches (above favorable coho and steelhead spawning habitat), but will spawn and rear along-side other resident fish (notably, resident cutthroat and rainbow trout). Selection of these upper reaches spatially segregates them from other co-occurring salmonids and avoids competition for rearing and spawning areas. Cutthroat spawn in small- to moderate-size gravel, often in pool tail-outs. They are repeat spawners; if they survive post-spawning, they overwinter in fresh water and emigrate downstream the following spring. Adult migrations generally precede emigration of juvenile cutthroat heading seaward. Note, some female cutthroat do not spawn in the first winter after returning to freshwater (Johnston 1982). Rather, they overwinter in freshwater, then return to the ocean the following spring.

Eggs incubate for four to six weeks in the gravel. Upon emergence, fry seek shallow stream margins, with low-velocity flows. During early life history rearing cutthroat are opportunistic feeders, feeding predominately on aquatic invertebrates suspended in the water column. If other salmonids are present, fry can be easily displaced; their distribution and habitat use is therefore highly dependent on interspecific competition with other native fishes. Notably, juvenile (and adult) cutthroat generally prefer deep pools and low-velocity instream habitats, but will move either upstream and downstream to seek food, avoid competition and find better rearing habitats. Cutthroat smolt from age one to four (and sometimes later), but generally at age three or four, when they reach a size of 200 to 250 mm (fork length). Downstream migrations generally occur from March to June, peaking in mid-May. A unique characteristic that cutthroat exhibit (different from other salmonids) is that they form schools before salt-water entry and remain schooled throughout their saltwater migrations and rearing. In the ocean, cutthroat remain close to the Pacific shoreline, rearing in shallow waters. Although salt-water residence time varies among populations, cutthroat tend to re-enter freshwater in the same year they migrated to sea; hence return to their natal stream during the subsequent fall season.

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