Summary of Juvenile Skagit Chinook Salmon Life History Diversity and Distribution
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Brief history of research on Skagit Chinook salmon life history diversity

Researchers have observed variations of life history types and strategies among Skagit Chinook salmon. Stream (yearling or older) and ocean type (subyearling) Chinook salmon have been known to comprise the Skagit Chinook salmon outmigrating populations since the 1960s, when scales were used to identify the juvenile smolt ages of returning adults. Hayman et al. (1996) was the first to identify three different juvenile life history strategies for wild Skagit ocean type Chinook salmon. These were based purely on juvenile fish timing and size patterns observed in freshwater and estuarine habitats throughout the Skagit River and its estuary. Beamer et al. (2000) later confirmed the presence of these same juvenile life history strategies based on otolith microstructure observations. Beamer et al. (2005a & 2005b) summarized existing information on Skagit Chinook salmon life history diversity to develop analytical tools used in the Skagit Chinook Recovery Plan (Skagit River System Cooperative and Washington Department of Fish and Wildlife 2005). Subsequent to Skagit Chinook Plan development, research on juvenile Chinook life history diversity has continued, especially in the areas of habitat use by juveniles in the Salish Sea environment (Beamer et al. 2006; Beamer and Fresh 2012; Beamer et al. 2013) and juvenile Chinook population dynamics, a significant cause of variability in life history diversity within each brood year of the Skagit's outmigrating population (Zimmerman et al. accepted; Beamer et al. reviewed).

In this paper, I summarize the existing research into a description of five life history strategies and explain briefly the population dynamics that contribute to their expression, and report the distribution of juvenile Skagit Chinook in shoreline habitats of the Salish Sea.

The Skagit Chinook life history types

The distinct juvenile life history types of Skagit Chinook salmon occur based on branching patterns (i.e., does the fish remain or migrate?) from observations of juvenile Chinook within three main ecological zones (freshwater, natal estuary, and marine nearshore). Branching occurs in each zone, resulting in five distinct juvenile life history types (Figure 1). The ecological zones correspond to distinct geographic areas: 1) freshwater = Skagit River and its tributaries; 2) natal estuary = Skagit tidal delta; and 3) marine nearshore = Whidbey Basin. Simply explained (and diagramed below in Figure 1), each year cohorts of Chinook salmon fry emerge from their gravel egg pockets in the Skagit River and its tributaries during the winter and early spring months. Some fry migrate downstream without doing any appreciable rearing in the freshwater environment. Fry remaining in freshwater branch into two main life history types after an extended freshwater residence period. Some fish remain in freshwater for a few months and migrate downstream as parr, while others remain in the freshwater environment for over a year and migrate the following spring as yearlings. Of the fry that migrate downstream, some establish residence in the Skagit's natal estuary for a period of time while others migrate into the more marine waters of Skagit Bay, part of the Whidbey Basin. Of the fry that end up in the Whidbey Basin, some establish residence in nearshore refuge habitats while others do not.

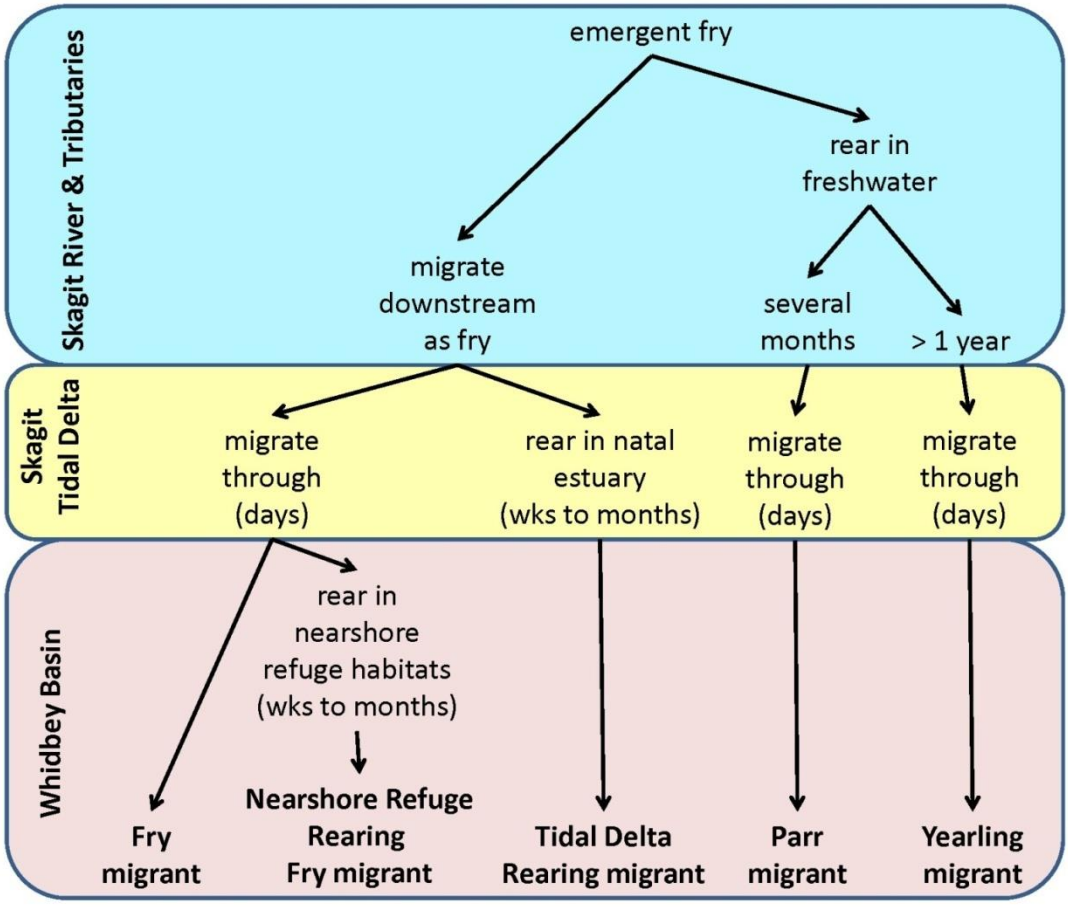

Figure 1. Phenotypic branching of juvenile Skagit Chinook salmon by major ecological zones, resulting in five distinct juvenile life history types.

Description of each juvenile Chinook salmon life history type

In recent years (brood years 1993 – 2008), one million to over seven million wild juvenile Chinook salmon have migrated from the Skagit River each year (Zimmerman et al. accepted). Out of each migration, we observe all juvenile life history types present. Each life history type is described in more detail below.

Fry Migrants – These fry emerge from egg pockets and migrate quickly downstream to Skagit Bay. Fry migrants do not rear extensively in tidal delta habitat, so no tidal delta rearing structure is observed on their otolith. They enter Skagit Bay usually in February and March, at an average fork length of 39 mm (observed range from otoliths is 30-46 mm fork length). Some fry migrants take up residence in "nearshore refuge habitats". Nearshore refuge habitats include pocket estuaries (Beamer et al. 2003; Beamer et al. 2006) and small independent streams that drain directly into the Whidbey Basin nearshore (Beamer et al. 2013). These areas provide fry migrants with a survival or growth advantage over the more exposed and marine-like nearshore habitats. While fry migrants are present in the Skagit's outmigration population each year, their abundance is a phenotypic response to density dependence occurring first in freshwater (Zimmerman et al. accepted) and then later in estuarine habitat of the Skagit River system (Beamer et al. reviewed). Depending on the total outmigration population size, all fry migrants (those that use and do not use nearshore refuge habitats) make up approximately 5% to over 40% of the juvenile Chinook salmon in Skagit Bay each year (Beamer et al. reviewed).

Tidal Delta Rearing Migrants – Tidal delta rearing migrants emerge as fry from egg pockets and migrate downstream at the same time as fry migrants. Instead of directly entering Skagit Bay, they reside in tidal delta habitat for a period ranging from several weeks to several months, reaching an average size of 74 mm fork length (observed range from otoliths is 49-126 mm fork length). The average tidal delta residence period for tidal delta rearing Chinook salmon in 1995 and 1996 (combined) was 34.2 days (Beamer et al. 2000). Following the tidal delta rearing period, these fish migrate to Skagit Bay, usually starting in late May or June. We observe a tidal delta rearing region on their otolith. Beamer and Larsen (2004) further defined several life history sub-strategies for tidal delta rearing Chinook salmon based on movement patterns and overall residence period within the tidal delta. The number of tidal delta rearing migrants each year is a function of the river's outmigration population size of fry and density dependence occurring in estuary habitat (Beamer et al. reviewed). As tidal delta habitat fills up with migrating fry from upstream, the excess fry respond by moving downstream into the Skagit Bay. Beamer et al. (2005b) estimated tidal delta rearing capacity at 2.25 million juvenile Chinook per year.

Parr Migrants – Parr migrants emerge as fry from egg pockets and rear for a couple of months in freshwater to achieve a size similar to their tidal delta rearing cohorts over the same time period. Following freshwater residence, parr migrants move through the tidal delta and into Skagit Bay, usually starting in late May or June at an average size of 75 mm fork length (observed range from mainstem trapping is 57-92 mm fork length). Parr migrants do not reside in tidal delta habitats. We observe an extended freshwater rearing region and no tidal delta rearing region on their otolith (Beamer et al. 2000). Some of these fish reside in off channel habitat within the large river floodplain areas of the Skagit River (Hayman et al. 1996). Depending on the total

outmigration population size, parr migrants make up approximately 15% to over 60% of the subyearling outmigration each year (Zimmerman et al. accepted). Parr migrant abundance has averaged approximately 1.2 million per year and is a result of density dependence occurring in the freshwater rearing environment (Zimmerman et al. accepted).

Yearlings – These fry emerge from egg pockets and rear in freshwater for a period over one year. Yearlings migrate to the estuary generally from late March through May at an average size of 120 mm fork length (observed range is 92-154 mm fork length). Yearlings do not reside in tidal delta habitats for an extended period of time like tidal delta rearing migrants do. Yearlings seem to pass through tidal delta habitats (possibly lingering briefly) and on to nearshore areas. Yearlings are rarely found in shallow intertidal environments, but are most commonly detected in deeper subtidal or offshore habitats. Yearling abundance has ranged from 6,000 to 97,000 in recent years (Zimmerman et al. accepted).

Fry migrant use of "refuge" nearshore habitats (pocket estuaries and small streams)

The juvenile Chinook salmon found in the pocket estuaries and small coastal streams of the Whidbey Basin are a result of non-natal processes. The fish originate from the three Whidbey Basin Chinook salmon bearing rivers: Skagit, Snohomish, and Stillaguamish. The Whidbey Basin pocket estuary and small streams studies (Beamer et al. 2003; Beamer et al. 2006; Beamer et al. 2013) show that juvenile Chinook salmon are not just present in pocket estuaries and small streams, but are actively rearing and growing. Most juvenile Chinook salmon use pocket estuaries and small streams in the months of January through May each year (Figure 2). While in pocket estuaries and small streams of the Whidbey Basin, individual juvenile Chinook salmon reared from weeks to months and grew up to 1 mm/day (Figure 3). In short, fry migrants appear to be using pocket estuaries and small streams as an alternative nursery habitat, much like the Skagit's natal estuary (Skagit tidal delta) is used by juvenile Chinook salmon.

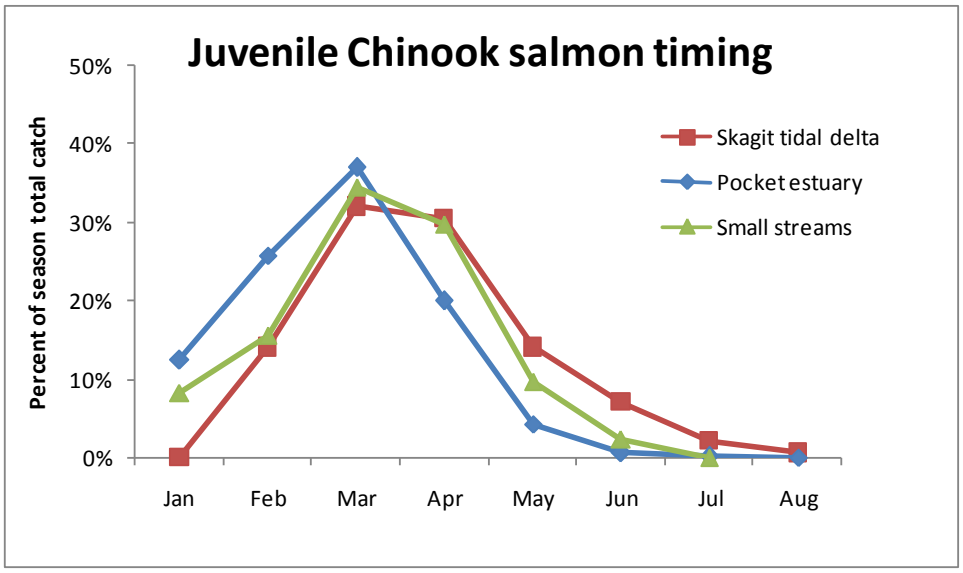

Figure 2. Standardized timing of juvenile Chinook salmon in natal estuary (Skagit River tidal delta), pocket estuary and small streams within the Whidbey Basin (from Beamer et al. 2013).

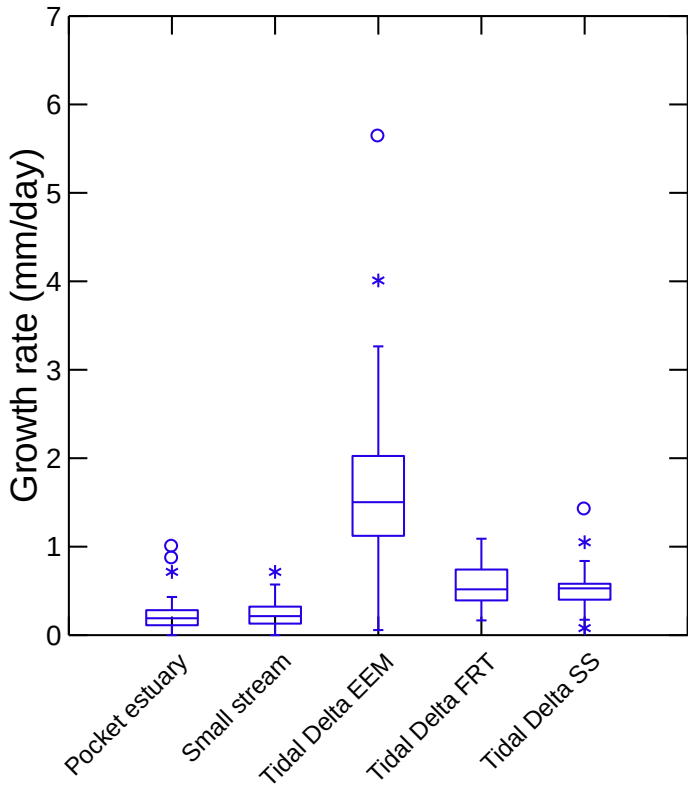

Figure 3. Boxplot of growth rates of juvenile Chinook salmon in Whidbey Basin pocket estuaries and small streams as well as three wetland zones of the Skagit River tidal delta: EEM (estuarine emergent marsh), FRT (forested riverine tidal), and SS (scrub shrub). Boxes show median, 25th and 75th percentiles. Whiskers show 5th and 95th percentiles. Circles are outliers (from Beamer et al. 2013).

Genetic basis for life history type expression

Limited samples of juveniles with a known juvenile life history type were genetically analyzed to determine whether there is a pattern of life history type expression by any of the six Skagit Chinook salmon populations (Heeg et al. 2004). The study found fry migrants and tidal delta rearing migrants in all six populations (Figure 4). The Lower Skagit Falls sample did not detect a yearling migrant component and the Lower Sauk Summers sample did not detect a parr migrant component. However, the number of samples available in the Heeg et al. study was limited and it is likely that each of the six Skagit Chinook salmon populations can produce all juvenile life history strategies as progeny. Juvenile life history expression of Skagit Chinook salmon is likely caused by phenotypic pressures such as habitat opportunity, environmental disturbances (e.g., timing of freshets), and density dependence (Beamer et al. reviewed; Zimmerman et al. accepted).

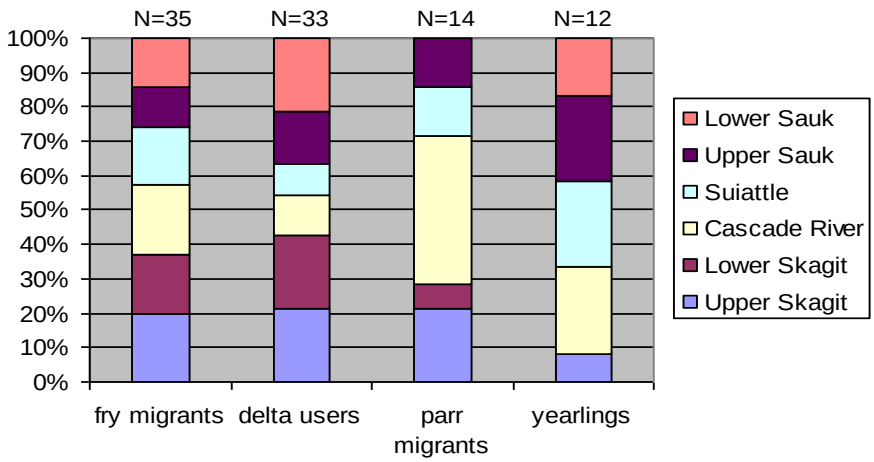

Figure 4. Life history types of Skagit Chinook salmon stocks. Percentage assignment of life history typed to the DNA baseline for each of the six Skagit Chinook stocks. The numbers of individuals of each life history strategy are noted above the corresponding column (from Heeg et al. 2004).

Distribution of wild juvenile Skagit Chinook salmon in selected marine nearshore areas of the Salish Sea

Use of Salish Sea ecosystems by juvenile Chinook salmon likely varies among populations or regional groups of populations due to such attributes as fish size at entry into the Salish Sea, origination point (what river they come from), and timing (when they enter the nearshore ecosystem). With respect to Skagit Chinook salmon, two studies were completed in 2011 that examined spatial patterns of wild juvenile Skagit Chinook salmon within a subset of Salish Sea nearshore habitat. One study each was completed for WRIA 2 (San Juan County) and WRIA 6 (Island County). The WRIA 6 study (SRSC 2011a) conducted genetic analysis using DNA from over 1,700 individual unmarked juvenile Chinook salmon collected in 2008 in the Whidbey Basin and Admiralty Inlet (west side of Whidbey Island) to determine their river of origin (or population grouping) by area as well as by habitat type: small coastal streams, pocket estuaries, shorelines, offshore. The WRIA 2 study (SRSC 2011b) conducted genetic analysis using DNA from over 1000 individual unmarked juvenile Chinook salmon collected in 2008 and 2009 in the San Juan Islands, Rosario Straits, and Bellingham/Samish Bays to determine their river of origin (or population grouping) by area as well as by habitat type: shorelines and offshore.

Overall, about 30% of the juvenile Chinook caught throughout the San Juan Islands were from Puget Sound Chinook populations. In contrast, over 90% of the juvenile Chinook caught within the Whidbey Basin were from Puget Sound Chinook populations. In Admiralty Inlet and Bellingham/Samish Bays, approximately 60% and 85% of the juvenile Chinook salmon caught were from Puget Sound populations, respectively.

Of the Puget Sound origin Chinook salmon caught in the San Juan Ialands, approximately 60% were from Whidbey Basin rivers. However, the origin of Chinook within the San Juans was not spatially uniform. Juvenile Chinook salmon caught along shorelines of the southern sides of San Juan and Lopez Islands, the eastern and western shorelines of Rosario Strait, and the interior of the San Juan Islands were dominated by fish originating from the Whidbey Basin. Of the Puget

Sound origin Chinook salmon caught in Admiralty Inlet and Bellingham/Samish Bays, approximately 60% and 30% were from Whidbey Basin rivers, respectively. The majority of wild juvenile Chinook originating from the Whidbey Basin are from the Skagit River.

Of the Puget Sound origin Chinook salmon caught in Whidbey Basin, nearly 90% were from Whidbey Basin Chinook populations. Skagit origin fish were the most common Chinook salmon in shoreline habitat of the Whidbey Basin (40%-70%) regardless of geographic area. The result was more pronounced in pocket estuary and small stream habitat within the Whidbey Basin. Skagit origin fish were approximately 80% of the juvenile Chinook salmon in pocket estuaries & small streams associated with Skagit Bay, 60% in Port Susan, and 40% in Possession Sound.

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