THE IMPORTANCE OF SKAGIT DELTA HABITAT ON THE GROWTH OF WILD OCEAN-TYPE CHINOOK IN SKAGIT BAY: IMPLICATIONS FOR DELTA RESTORATION

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Eric M. Beamer
Skagit River System Cooperative
Research Program
P.O. Box 368
LaConner WA 98257
ebeamer@skagitcoop.org

and

Kim Larsen
United States Geological Survey
Biological Resource Division
Western Fisheries Research Center
6505 NE 65th Street
Seattle, Washington 98115
Kim_Larsen@usgs.gov

Ongoing research conducted by the Skagit River System Cooperative[1] observes a density dependent relationship occurring within the Skagit delta on wild ocean type Chinook. The finding provides a solid basis for advocating delta restoration, especially considering the history of approximately 80% habitat loss within the delta (Collins and others 2001).

In addition to our density dependence research, we have been studying juvenile Chinook otolith microstructure[2] in order to identify the juvenile life history type of individual fish and estimate their growth and residence by habitat type. We recently completed analyses that show the relationship of delta residence on later performance (measured as growth rate in Skagit Bay) by wild ocean type Chinook originating from within the Skagit River.

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[1] Skagit River System Cooperative is the fisheries management agency for the Swinomish Tribal Community and the Sauk-Suiattle Indian Tribe.

[2] Otolith microstructure analysis is a common tool for estimating timing, resident period, and growth rates of individual fish in specific habitat types.

Juvenile wild Skagit Chinook: Density Dependence in the Delta

The density dependence study results indicate that the relationship between freshwater wild juvenile Chinook population size and wild juvenile Chinook abundance in estuarine river delta habitat is density dependent (asymptotic) (Figure 1). This result supports the idea that present day Skagit delta habitat capacity is inadequate for outmigrating delta-rearing Chinook. Conversely, the proportion of the total wild juvenile Chinook population in Skagit Bay that bypasses rearing in delta habitats and migrates directly into Skagit Bay (we define this life history type as *fry migrant*) increases with wild smolt outmigration levels above 2,500,000 (Figure 2). This finding indicates that at least some of the density dependence occurring in the delta results in the displacement of juvenile Chinook out of delta rearing habitats and into Skagit Bay early in the year (usually in February or March) at a very small size (~40 mm fork length). The findings provide a solid biological basis for advocating restoration to delta capacity for rearing ocean-type Chinook.

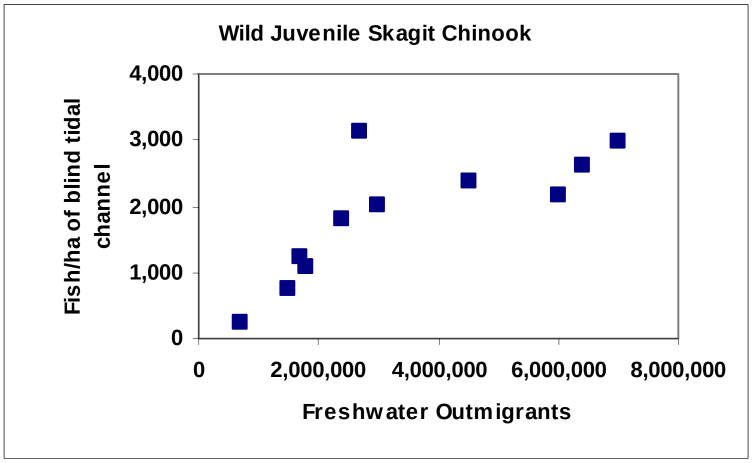

Figure 1. The relationship between freshwater wild Chinook smolt population size and density of juvenile wild Skagit Chinook in Skagit River delta habitat, 1992-2002. The number of Chinook per unit area within the delta levels-off as the total number of outmigrants increases, indicating density dependent use of the delta. Freshwater Chinook smolt population estimates are from D. Seiler, WDFW, Olympia, WA. Juvenile Chinook density estimates in delta habitat are seasonal averages derived from 8 index sites using fyke trapping methods.

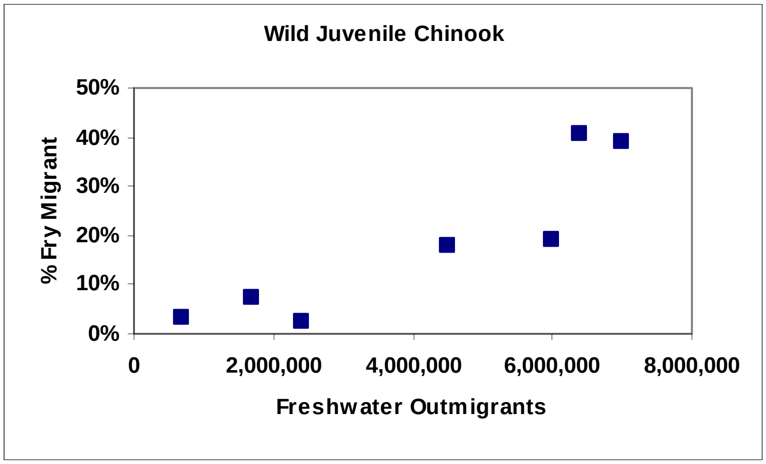

Figure 2. The relationship between freshwater wild Chinook smolt population size and the proportion of wild juvenile Chinook population with a fry migrant life history type, derived from Skagit Bay index beach seine sites, 1996-2002. The number of fry migrant Chinook (those migrating directly to Skagit Bay without residing in the delta) increases as the outmigrating population increases, indicating that some fish are displaced from the delta and tend to become fry migrants. Freshwater Chinook smolt population estimates are from D. Seiler, WDFW, Olympia, WA.

IMPORTANCE OF DELTA HABITAT ON THE GROWTH OF JUVENILE CHINOOK IN SKAGIT BAY

Considering the delta density dependent relationship exhibited by wild Chinook (Figure 1) and the fry migrant displacement response (Figure 2), we examined some potential relationships between delta and bay residence and growth using juvenile Chinook otolith microstructure. For these analyses we used only juvenile life history types that would be potentially affected by delta density dependence. These include all delta rearing life history types and fry migrants. The specific life history types are defined as:

Delta Rearing Type 1– These fish rear in delta habitat on average for 28.1 days and show a progression of habitat occupation on their otolith typical of "textbook" ocean-type Chinook: a freshwater residence period followed by a delta residence period followed by bay residence.

Delta Rearing Type 2– These fish rear in delta habitat on average for 45.2 days and show a progression of habitat occupation on the otolith similar to Delta Rearing Type 1 fish, (a freshwater residence period followed by a delta residence period followed by bay residence). However, within the delta residence period there is a fast growth period followed by a slow growth period before bay residence occurs.

Delta Rearing Type 3– These fish rear in delta habitat on average for 51.0 days and show a progression of habitat occupation on the otolith similar to Delta Rearing Type 1 fish, (a freshwater residence period followed by a delta residence period followed by bay residence). However, within the delta residence period there is a fast growth period followed by a slow growth period, and then followed by another period of fast growth before bay residence occurs.

Fry Migrants – These fish do not rear for an extended period in delta habitat. They do not exhibit a delta region on their otolith. Migration to bay habitat is early in the year (usually February through April). On fry migrant otoliths we observe a freshwater residence period followed directly by bay residence.

Our results indicate that the longer wild sub-yearling Chinook spend in the delta, the better they grow in the bay (Figure 3). Two distinct life history types illustrate the two extremes in growth. Delta Rearing Type 3 fish reside the longest in the delta and exhibit high rates of growth in the bay. Fry migrants (those individuals that spend no time in the delta) grow poorly in the bay. Also, fish size at bay entrance positively infuenced growth rate in the bay (Figure 4) and the later in the season fish entered bay habitat, the better they grew in bay habitat (Figure 5). There are life history type differences within both overall relationship with fry migrants and Delta Rearing Type 3 fish appearing as the extremes. It is also true that fish expressing life history types of longer delta residence, enter the bay later in the year.

We also find the longer wild sub yearling Chinook spend in the bay, the better their growth rate in the bay (Figure 6). This is possibly evidence of adjustment to change in food habitats (moving from delta to bay) and/or adaptation to higher salinities experienced in the bay (delta salinities range from 0.0 – 10.0 ppt whereas bay salinities are up to 30.0 ppt). This relationship appears to be true and unique by all delta rearing life history types, but not for fry migrants (however our dataset is small for fry migrants). Delta Rearing Type 3 individuals (those that spend longest time in the delta – an average of 51 days) are best able to take advantage of conditions in the bay for accelerated growth while fry migrants (on the other extreme – those individuals that spend no time in the delta) grow poorly in the Bay. It should be noted that we have not observed any fry migrants to reside in Skagit Bay habitat for longer than 20 days (using limited data from 1996, 1997, and 1998). Either fry migrants are migrating through Skagit Bay more quickly than other life history types or surviving at a much lower rate that other life history types. It is most likely that fry migrants that stay in bay habitat survive very poorly once they reach Skagit Bay. This conclusion is based on their low bay growth rate, their size at entrance to the bay, and the early time of year they appear in the bay – all factors pointing to poor growth and a high risk of predation compared to other life history types.

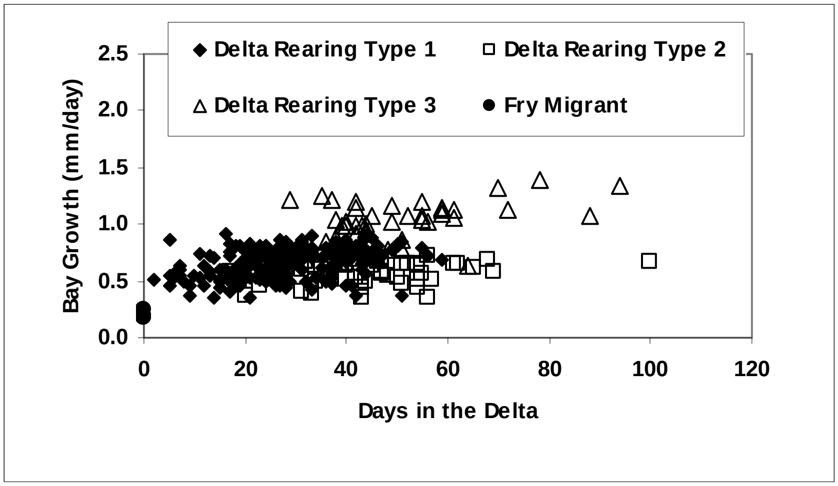

Figure 3. Relationship between residence in the delta and growth rate in the bay for wild ocean type Chinook, 1995 and 1996 samples collected in Skagit Bay. The overall relationship is positive and highly significant (r^2=0.22, p=9.27 x 10^{-19}, n = 317). Life history type differences are evident.

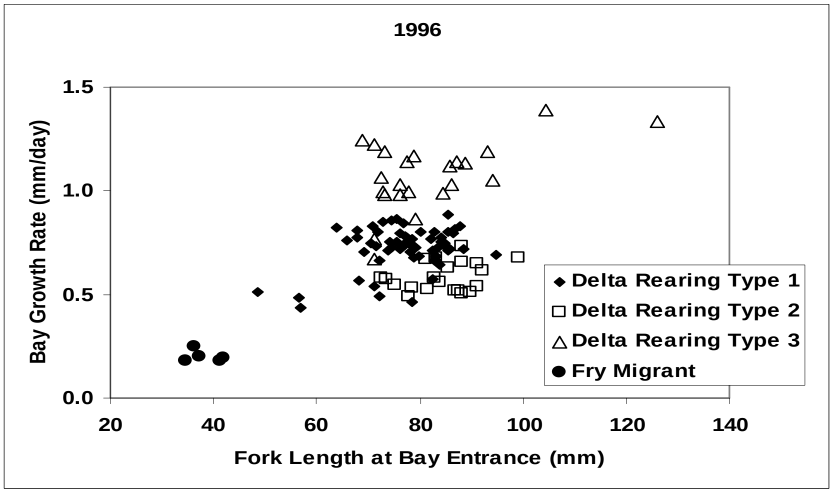

Figure 4. Relationship between size of fish entering the bay and growth rate in the bay for wild ocean type Chinook, 1996 samples collected in Skagit Bay. Samples collected in 1995 are not shown because no fry migrants were caught that year. The overall relationship is positive and highly significant (r^2=0.26, p=1.59 x 10^{-8}, n = 110). Life history type differences are evident.

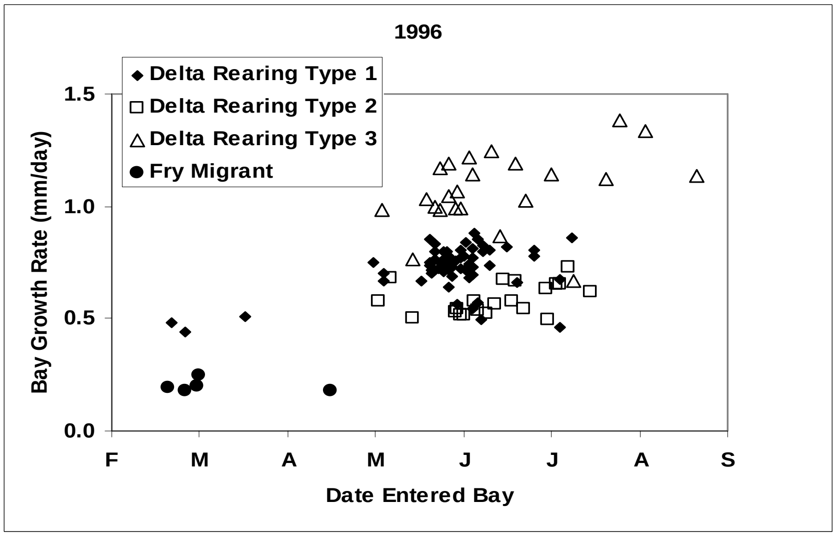

Figure 5. Relationship between the date fish entered the bay and growth rate in the bay for wild ocean type Chinook, 1996 samples collected in Skagit Bay. Samples collected in 1995 are not shown because no fry migrants were caught that year. The overall relationship is positive and highly significant (r^2=0.27, p=5.43 x 10^{-9}, n = 110). Life history type differences are evident.

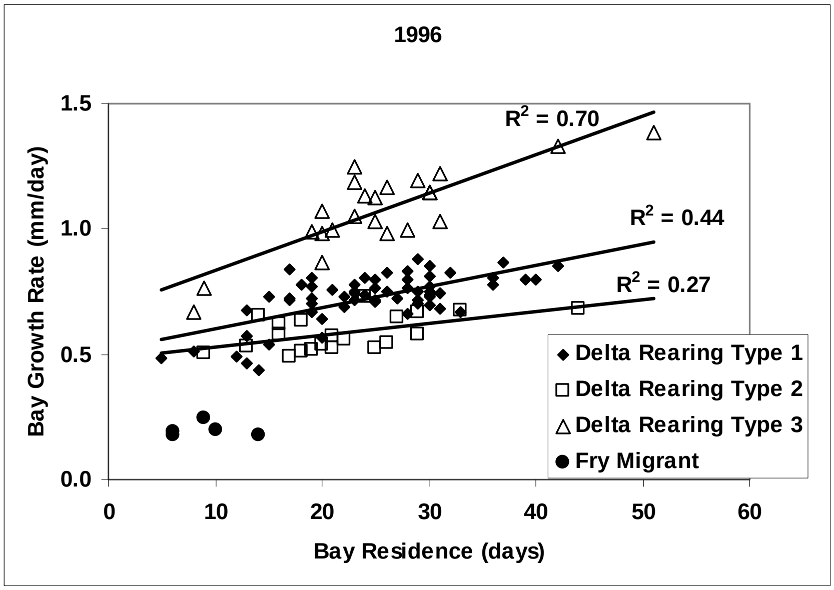

Figure 6. Relationship between bay residence period and growth rate in the bay for wild ocean type Chinook, 1996 samples collected in Skagit Bay. Samples collected in 1995 are not shown because no fry migrants were caught that year. Significantly different and positive relationships exist for all delta rearing types.

IMPLICATIONS FOR DELTA RETORATION

The otolith results independently support what the density dependence study asserts – that delta restoration is needed for wild Skagit Chinook recovery. All relationships presented here support the idea that a delta rearing period improves growth of wild juvenile Chinook after they reach Skagit Bay. Skagit Bay residence is the beginning of the more marine rearing phase of the Chinook life cycle. If faster growth is important to later survival and we know that there is some form of density dependence occurring in the delta (e.g., our field study results shown in Figures 1 and 2), then it would make good restoration sense to increase delta habitat capacity (and quality) in order to increase fish residence in the delta habitat. Increased time of residence equates to a larger size before entering bay habitat. The current constraining delta conditions “export” some juvenile Chinook salmon prematurely to the bay where they are not well suited to survive. A nuance to this idea is pocket estuary rearing by “exported” fish. If “exported” fish find pocket estuary habitat within Skagit Bay, they may be able to mitigate to some degree the effects of delta density dependence. However, Beamer and others (2003) showed that pocket estuary habitat is in short supply around Skagit Bay and its restoration potential is not sufficient to solve the effects of delta density dependence.

Juvenile salmon growth is not the same as survival, however higher growth rates have been linked to higher survival for both yearling and sub yearling salmon. Studies in yearling spring Chinook salmon have demonstrated that faster growth prior to seawater entry in the spring improves smolt physiology (seawater adaptability) and smolt-to-adult survival (Wagner and others 1969; Beckman and others 1999). Bilton (1984) found that larger sub yearling Chinook salmon survived to adulthood at a much higher rate than smaller fish. Clark and Shelbourne (1985) showed that larger sub yearling Chinook salmon have greater seawater tolerance than smaller fish. Parker (1971) showed that smaller fish in juvenile salmon populations were eaten at a higher rate than larger fish. Together, these studies strongly support the idea that faster growing and larger juvenile Chinook have a survival advantage over smaller individuals.

This study helps us understand how the delta residence period of ocean type Chinook influences performance at a later life stage. This means that the consequences of poor habitat conditions in an earlier life stage (e.g., a limitation in delta capacity for delta rearing juvenile Chinook) may be observed later in the Chinook salmon's life cycle. Our otolith results support the hypothesis that mortality in Skagit Bay is linked with growth in the Skagit delta. A modeling study by Greene and others (2003) found that conditions in Skagit Bay are a strong determinant of overall mortality across the life cycle of wild Skagit Chinook. Together, both studies provide strong evidence that delta restoration will have a large benefit for the Skagit Chinook population by alleviating capacity constraints in the delta and also improving growth (and therefore survival) of fish after they reach Skagit Bay.

We also present some evidence refuting the idea that there is little that can be done in terms of habitat restoration for salmon recovery since recent studies have shown that salmon mortality in the marine environment is high and variable. Higher or more dynamic mortality rates than expected in marine environments may be caused or exacerbated by poor or limiting habitat conditions occurring earlier in the salmon life cycle.

ACKNOWLEDGEMENTS

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