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A Late Ocean Entry Life History Strategy Improves the Marine Survival of Chinook Salmon in the Strait of Georgia

by

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Abstract

The productivity of juvenile chinook salmon that enter the Strait of Georgia has generally declined over the past two decades. One aggregate of 15 populations from the South Thompson drainage of the Fraser River drainage, however, has increased. The increased productivity appears to be related to a life history strategy that results in juveniles entering the ocean in July, much later than most other chinook salmon populations. Juveniles from the South Thompson drainage are generally not common in the Strait of Georgia early in July, but they are abundant in September. They appear to leave the Strait of Georgia by November, probably through Juan de Fuca Strait. Late ocean entry, sea-type, Harrison River sockeye salmon are also surviving better in recent years than the majority of sockeye salmon that are entering the ocean earlier. Because pink and chum salmon that enter the ocean early are at high levels of abundance, it is possible that very early and very late ocean entry times are life history strategies that match the current state of the Strait of Georgia ecosystem.

Introduction

Systematic surveys of juvenile Pacific salmon in the Strait of Georgia have been completed each July and September since 1998, except for July 2003 (Beamish et al. 2000; Sweeting et al. 2003). Juvenile chinook salmon were moderately abundant in the surveys, with the catches in September being similar or only slightly smaller than the catches in July. Furthermore, the average length of the chinook salmon in the September surveys was similar or only slightly larger than the average length of the chinook salmon captured in July. An analysis of Coded Wire Tags (CWT) identified anomalies in the expected catches of the various populations (Beamish et al. 2007), but it was not until we identified the specific populations using DNA that we were able to explain the reasons for the generally small sizes of chinook salmon in September. In this paper we show that there is a large change in the stock composition of populations between July and September. Most of the populations that were present in July are no longer present in September and a new group of populations appears. We report the catch data and genetic stock identification that show that a late ocean entry life history is currently beneficial for chinook salmon populations that rear as juveniles in the Strait of Georgia.

South Thompson chinook salmon

There are 14 populations of chinook salmon (summer chinook) that make up the South Thompson summer chinook salmon DNA baseline (Table 1). Juvenile chinook salmon from these populations have a life history that is similar to the ocean-type, except that they remain in fresh water longer (about six months) in the spring than most other chinook salmon. Adults return to spawn in the summer.

In general, South Thompson summer chinook salmon stocks have been very productive in recent years as indicated by the increasing escapements since the mid-1990s (Figure 1). Six stocks (Lower Adams, Little River, Lower Shuswap/Upper Adams, Lower Shuswap, Middle Shuswap and South Thompson River) have been particularly productive (PSC 2009). This contrasts with the general escapement trends of almost all of the 133 populations (DFO 2009) that return to the Fraser River (PSC 2009).

Methods

The catch and escapement data for all chinook salmon from the Fraser River were from the Pacific Salmon Commission. Juvenile chinook salmon in the Strait of Georgia were captured as part of a study of the early marine biology of juvenile Pacific salmon in the Strait of Georgia. The survey dates, the standardized track line and the description of the trawl were reported in other reports (Beamish et al. 2000, 2010a, 2010b). Juvenile chinook salmon are caught at deeper depths than other juvenile Pacific salmon. Thus, our catches include depth strata from 0-15 m, 16-30 m, 31-45 m and 46-60 m. Catches were reported as numbers in a standard 30 minute set or adjusted to a catch per unit effort (CPUE) of one hour. An average catch was the sum of the CPUE for each set, divided by the number of sets. Fork lengths were measured from either a total catch or from randomly collected samples. Abundance estimates were calculated by dividing the volume of water filtered for each stratum into the volume of water in that stratum and multiplying by the catch according to the procedures in Beamish et al (2000). In this report, we include only the results from the 2007, 2008 and 2009 surveys as DNA stock identifications are available for these surveys. DNA stock identifications were determined using the procedures similar to Beacham et al. (2010) and Tucker at al. (In review) and by the Molecular Genetics Laboratory at the Pacific Biological Station.

Results

The CPUE in the July surveys in 2007, 2008 and 2009 was 59.7, 40.9 and 49.7 juvenile chinook salmon, respectively. In the September surveys, the CPUE in 2007, 2008 and 2009 was 32.7, 47.8 and 38.5 fish, respectively. In all surveys, catches were distributed throughout the Strait of Georgia (Figure 2A,B), although there was a tendency for larger catches in the southern Strait of Georgia in September (Figure 2B). The mean lengths of all juvenile chinook salmon varied among years (Table 2). In 2008, the average lengths in the July and September samples were identical and similar in 2009 (Table 2).

We examined the DNA of about 4,000 juvenile chinook salmon collected in the Strait of Georgia in 2007, 2008 and 2009 (Figure 3). These analyses show that juvenile chinook salmon from the South Thompson group increase in abundance in the Strait of Georgia after most other juvenile chinook salmon have entered the strait. By September between 63% and 77% of the juvenile chinook salmon in our catches and sampled for DNA originated from the South Thompson group (Figure 3). The percentages of the six major DNA groupings of all chinook salmon that enter the Strait of Georgia show that in July 2008 and 2009 the percentage of South Thompson populations (Figure 3, Table 3) is less than about 5%. In the July 2007 survey which was later in July, the percentage increased to about 30%.

The proportion of chinook salmon from the South Thompson area as a percentage of only chinook salmon from the Fraser River changed from 6% and 4% in July 2008 and 2009 to 89% and 93% in September 2008 and 2009. In 2007, the percentage in July was higher (53%) and increased to 96% in the September survey. In mid July, the South Thompson chinook salmon in the Strait of Georgia averaged about 100 mm (Figure 4). By mid-September, the average length was about 150 mm, indicating that the fish were feeding and growing in the strait (Figure 5).

We estimated the abundance of juvenile chinook salmon in the Strait of Georgia during our surveys in July and September using the methods described by Beamish et al. (2000). In 2007, the abundance in September was only slightly larger than in early July. In 2008 the abundance was almost 30 times larger in September than in early July (Table 3). In 2009, the abundances of South Thompson populations were also about 30 times larger in September than in July (Table 3).

A survey in November 17-21, 2008 completed 14 sets only in the southern Strait of Georgia and is not representative of the distribution throughout the Strait of Georgia. However, the DNA from the sample of 55 chinook salmon indicated that South Thompson chinook salmon represented only 5% of the total sample (Figure 6) and 16% of all chinook salmon from the Fraser River. It is possible that this indicates that South Thompson chinook salmon had left the Strait of Georgia by November or died or both. The relatively few chinook salmon from the South Thompson group in November were much smaller than the other chinook salmon (Figure 7).

Discussion

Chinook salmon from the South Thompson watershed in the Fraser River watershed enter the Strait of Georgia in early July, about six to eight weeks after other juvenile chinook salmon. The juveniles move into the open Strait of Georgia by about mid July and by September they represent the dominant group of chinook salmon in the Strait of Georgia. They were not abundant in a November survey, indicating that most had left the Strait of Georgia or died or both. Juvenile Pacific salmon surveys on the west coast of Vancouver Island begin to catch juvenile chinook salmon from the South Thompson in the winter (Tucker et al. In review), indicating that they probably migrated out of the Strait of Georgia through Juan de Fuca Strait.

In another report we showed that virtually all juvenile sockeye salmon in the Strait of Georgia in September, in most years, were from the Harrison River. Thus, the sockeye and chinook salmon that entered the Strait of Georgia much later than other stocks of the same species were very abundant in September and are surviving very well in the Strait of Georgia. This indicates that conditions in the Strait of Georgia in July and August appear to be more suitable for the survival of juvenile chinook and sockeye salmon with a life history strategy of late entry into the ocean. Populations of pink and chum salmon that rear as juveniles in the Strait of Georgia are at high and even record high levels of abundance. Both of these species enter the ocean earlier in the year, before most of the juveniles of the other major species of Pacific salmon. It is possible that a very early and a very late ocean entry are currently life history strategies that best match the current state of the Strait of Georgia ecosystem. Research that identifies exactly why the specific ocean entry times are better for a particular species and population most likely would assist in hatchery management as well as identify better management options for wild stocks.

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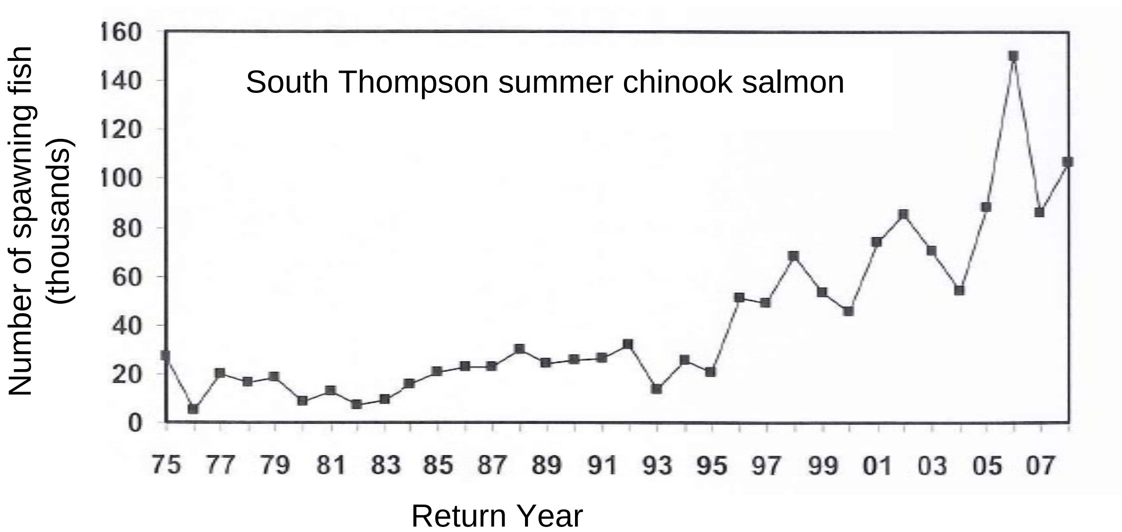

Figure 1. Escapements of Fraser River summer-run populations including five stocks that spawn in the South Thompson watershed - Middle Shuswap, Lower Shuswap, Lower Adams, Little River and South Thompson River. Also included are escapements to the Maria Slough located in the Lower Fraser River watershed, but have the same life history as the South Thompson chinook salmon. Other South Thompson stocks are the Lower Adams, Bessette, Duteau Creek, Eagle River, Harris Creek, Lower Thompson, Salmon River, Seymour River @ Thompson River and Scotch Creek.

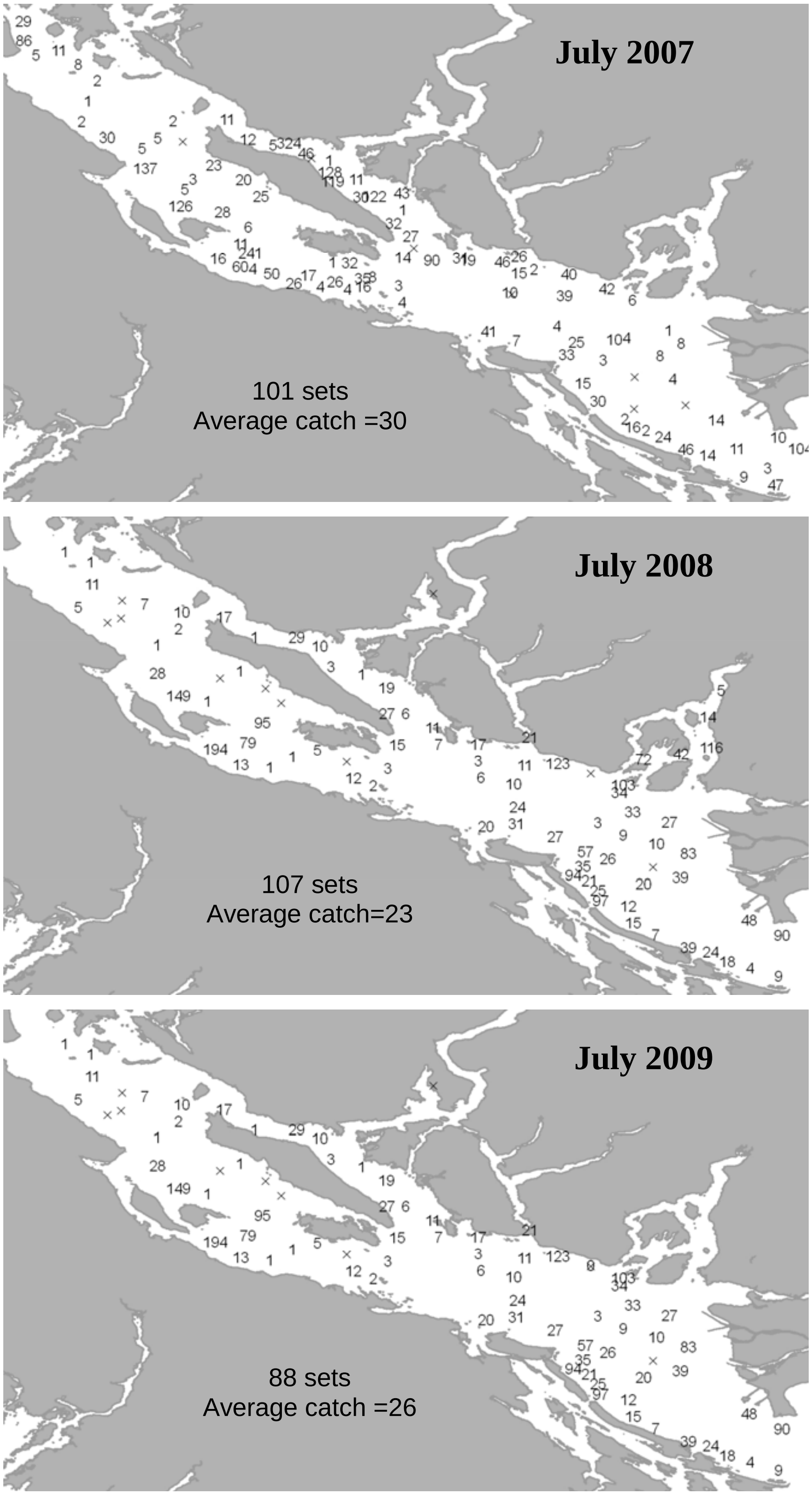

Figure 2A. Catches of juvenile chinook salmon in the standard 30 minute sets in the July surveys. Sets with 0 catch are identified by an X.

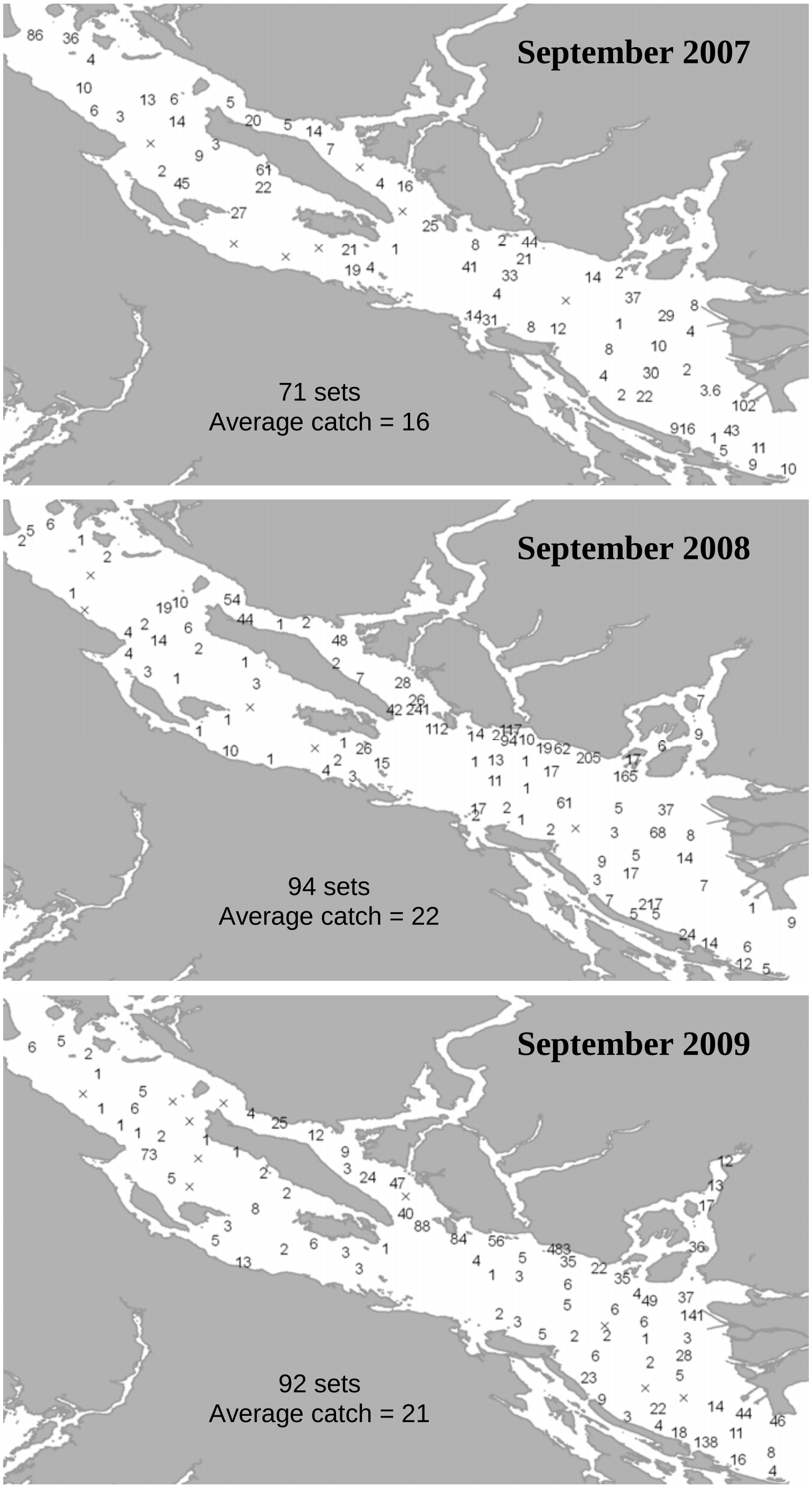

Figure 2B. Catches of juvenile chinook salmon in the standard 30 minute sets in the September surveys. Sets with 0 catch are identified by an X.

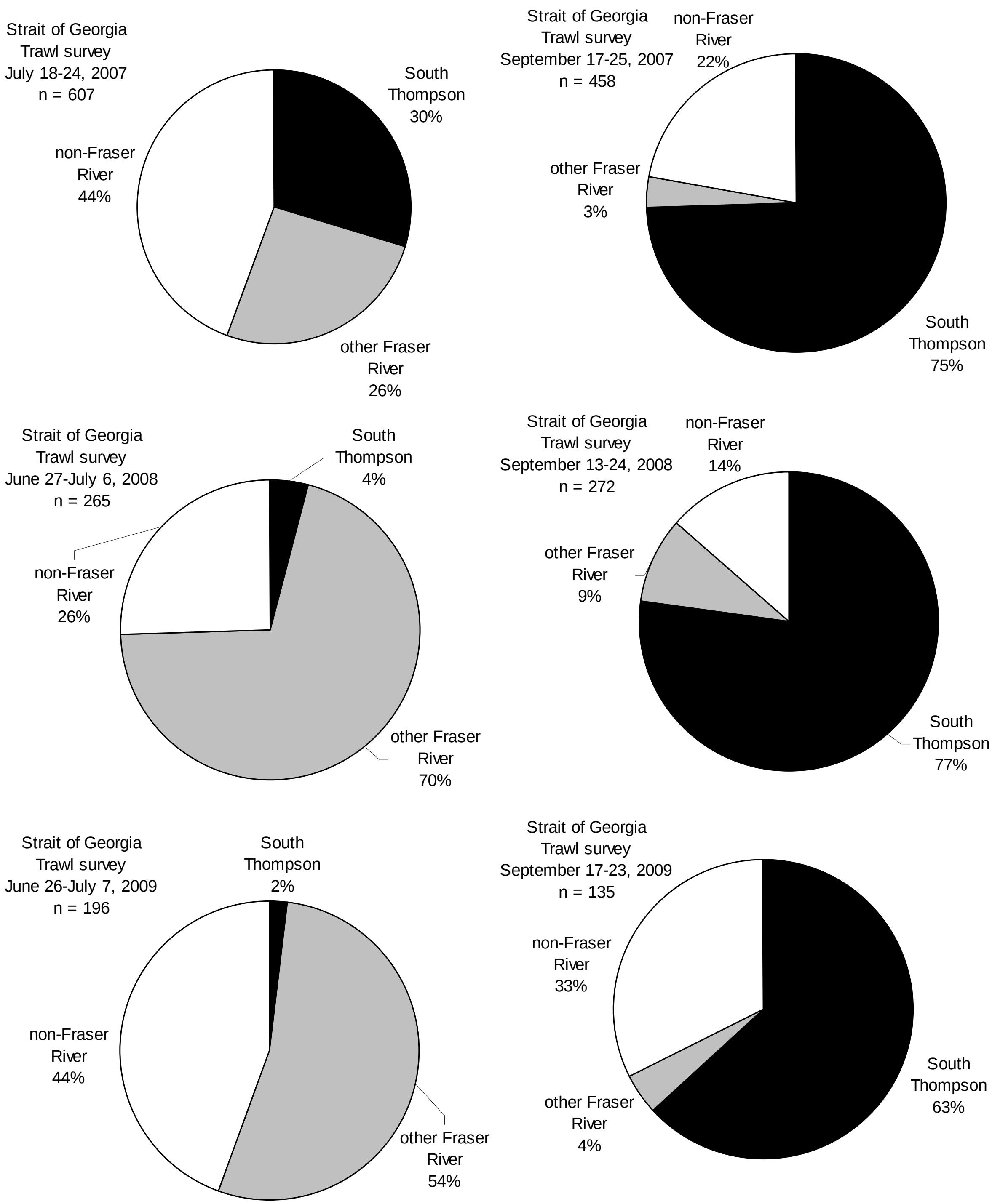

Figure 3. DNA stock composition of chinook salmon captured in the Strait of Georgia in the July and September surveys from 2007-2009.

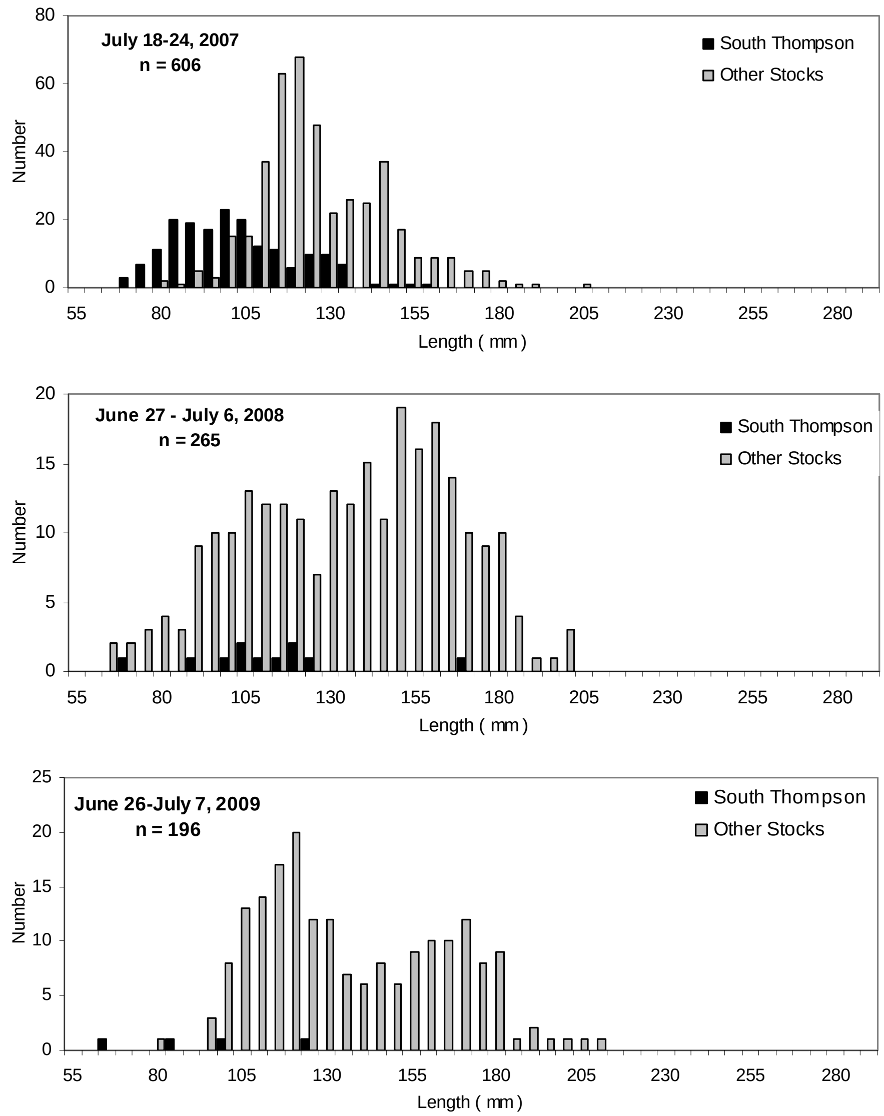

Figure 4. Lengths of South Thompson summer chinook salmon and other stocks of chinook salmon captured in the Strait of Georgia during July surveys, 2007-2009, as identified by the DNA analysis.

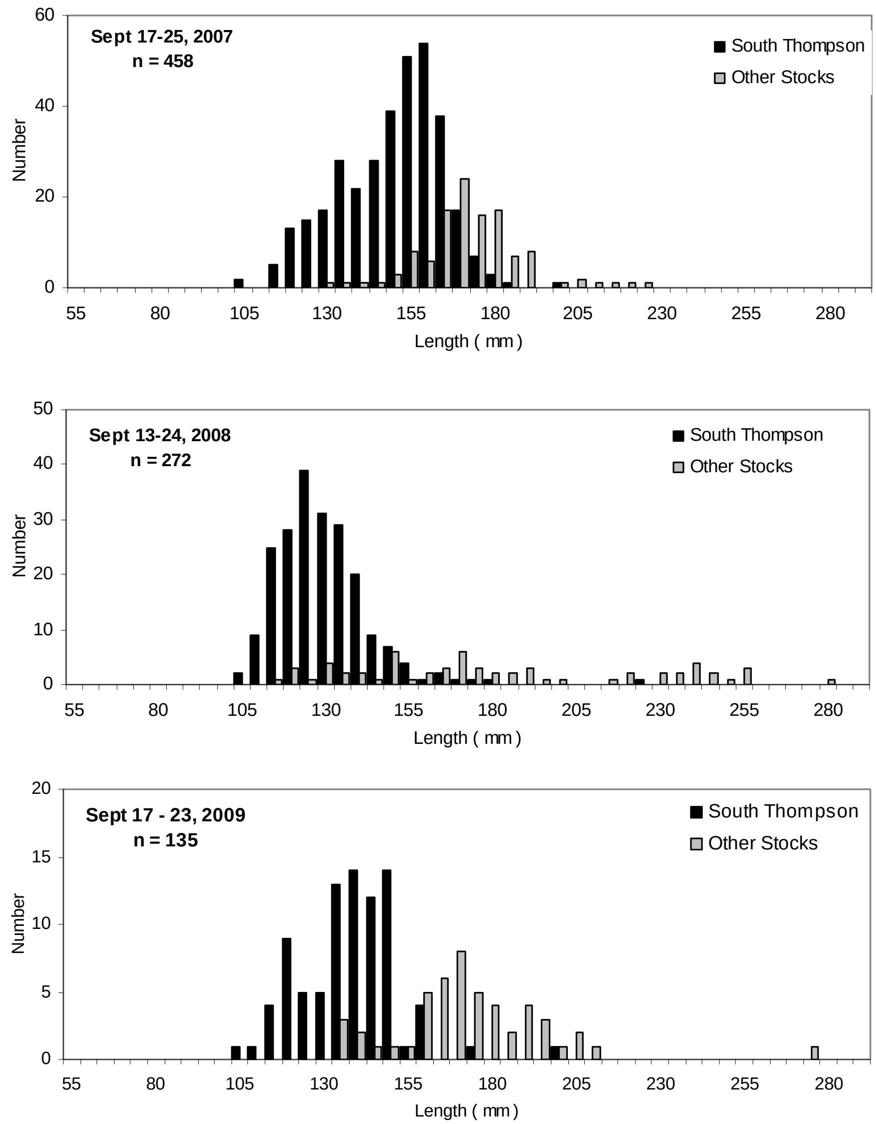

Figure 5. Lengths of South Thompson summer chinook salmon and other stocks of chinook salmon captured in the Strait of Georgia during September surveys, 2007-2009, as identified by the results of the DNA analysis.

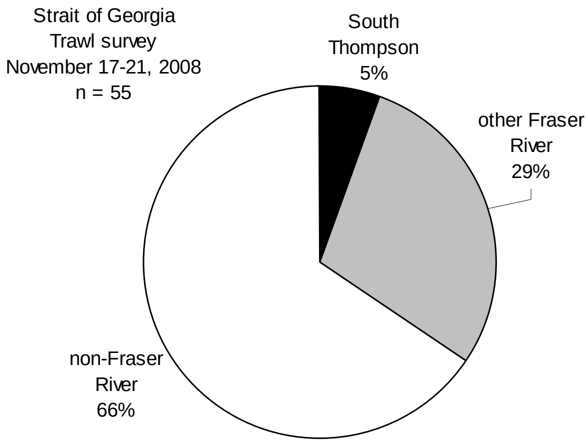

Figure 6. DNA stock composition of chinook salmon captured in the trawl surveys in the Strait of Georgia, November 2008.

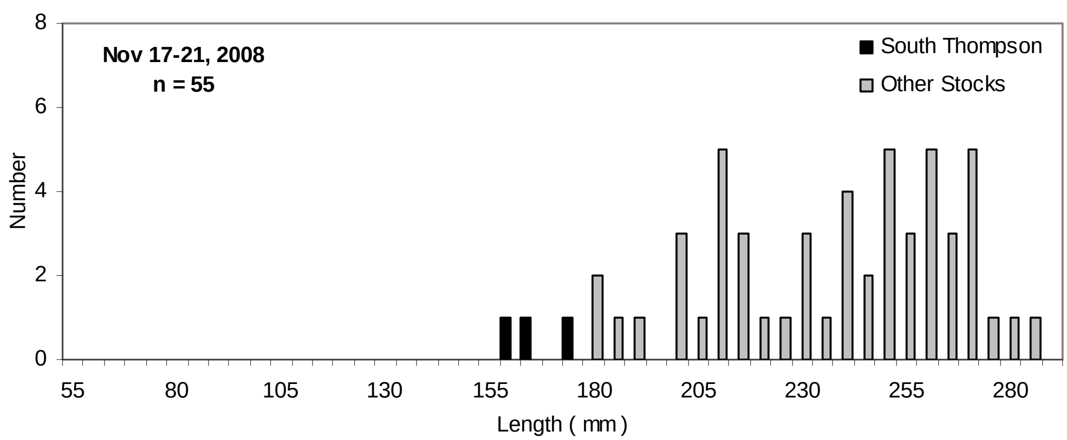

Figure 7. Lengths of South Thompson summer chinook salmon and other stocks of chinook salmon captured in the Strait of Georgia during November 2008 survey, as identified by the results of the DNA analysis.

Table 1. Populations of chinook salmon in the Fraser River summer-run chinook salmon that spawn in the South Thompson watershed within the Fraser River watershed.

South Thompson Watershed
Bessette River
Duteau Creek
Eagle River
Harris Creek
Lower Adams River
Lower Shuswap @ Upper Adams
Lower Shuswap
Lower Thompson
Little River
Mid Shuswap
Salmon River @ SA
Scotch Creek
Seymour River @ Thompson River
South Thompson

Table 2. Lengths of juvenile chinook salmon sampled in the July and September surveys in 2007, 2008 and 2009 in the Strait of Georgia.

Year	Average length (SD) in the July survey	Average length (SD) in the September survey
2007	107 (20.0) n = 1809	152 (18.2) n = 1124
2008	128 (30.9) n = 1674	128 (26.4) n = 1476
2009	133 (27.2) n = 1845	147 (31.4) n = 1393

Table 3. Abundance estimates of chinook salmon stocks in July and September 2007-2009.

Survey	Total	South Thompson	
	Abundance	Abundance	Percentage
July 8-15, 2007	5,915,000	1,775,000	30
Sept 17-25, 2007	2,606,000	1,955,000	75
June 27–July 6, 2008	3,260,000	130,000	4
Sept 13-24, 2008	4,853,000	3,737,000	77
June 26-July 7, 2009	4,968,000	99,000	2
Sept 16-25, 2009	4,255,000	2,681,000	63