NPAFC
Doc. 982
Rev. ______

Evidence of a linkage between fall-winter ocean conditions and the critical size hypothesis for a study of pink salmon in the central coast area of British Columbia

by

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Submitted to the

North Pacific Anadromous Fish Commission

by

CANADA

October 2006

This paper may be cited in the following format:
Beamish, R., E. Gordon, C. Neville and R. Sweeting. 2006. Evidence of a linkage between fall-winter ocean conditions and the critical size hypothesis for a study of pink salmon in the central coast area of British Columbia. (NPAFC Doc. 982). 14 p. Fisheries and Oceans Canada, Science Branch – Pacific Region, Pacific Biological Station, Nanaimo, B.C., Canada V9T 6N7.

Abstract

Intercirculi spacing of scales from the even year line of pink salmon from stocks in areas of the central coast of British Columbia was measured for the 2003/2004 and 2005/2006 brood years. All juvenile pink salmon in the 2003 sample had five circuli by the end of June. The average spacing of the first five circuli of juveniles in 2003 was larger than the spacing of the first five circuli on the scales of the adults from the same brood year that returned to spawn in 2004. In 2006, the spacing observed on the scales of returning adult pink salmon from the same line (even year) was significantly larger than the spacing observed on scales of juveniles in 2005. The marine survival was exceptionally high in 2003/2004 and lower in 2005/2006. We propose that there was not a critical size effect in 2003/2004 because the feeding and ocean conditions were favourable for juvenile pink salmon after they left the coastal area in 2003. The ocean conditions probably were less favourable for growth and survival in 2005/2006, resulting in large mortalities of the smaller pink salmon consistent with the critical size-critical period hypothesis. The timing of the size-based mortality is not known except that significant mortality of the smaller pink salmon occurred after June, 2005.

Introduction

All animals evolve a life history strategy that optimizes their ability to reproduce. Pacific salmon are anadromous and semelparous. The anadromy ensures that spawning and the early development of young occurs in a relatively safe environment. The large number of stocks for any particular species of salmon distributes reproduction throughout a large area of freshwater and marine habitats. The spreading of reproduction throughout a diversity of habitats provides resiliency to environmental variation for the population that is made up of these numerous stocks. The large number of juveniles produced in fresh water greatly exceeds the capacity of the ocean to support them. Thus high mortalities in the ocean would be expected. It is known that these early mortalities can be caused by predation, but predation based mortality has a random component which might be expected to result in some extreme variation in natural mortality in the ocean. In fact, this does not appear to be the case. There is some variation, but interannual variation in marine mortality does not show large fluctuations. Equally important is the observation that complete recruitment failure of stocks is virtually unheard of. These observations suggest that the marine mortality may be programmed into the life history strategy of the species.

Beamish and Mahnken (2001) proposed that juvenile Pacific salmon must grow to a critical size if they are to survive the period of net energy loss during the first marine winter. The idea was tested with coho salmon in the Strait of Georgia (Beamish et al. 2004) by comparing the width of the intercirculi spacing on scales of young coho with the width of the spacing for the same area of the scale for adults. We repeated the “coho” study using pink salmon. We compared the average intercirculi spacing from scales of pink salmon originating from rivers flowing into waters on the eastern side of Queen Charlotte Strait in the central coast region of British Columbia (Figure 1). In this paper we report the results from the even year line, sampled in 2003-2004 and 2005-2006.

Methods

Juvenile pink salmon were captured in July 31 to August 3, 2003 during standard trawl surveys (Beamish et al. 2000). Juvenile pink salmon were captured in June 21-23, 2005 using beach and purse seines. Adult pink salmon were captured in fresh water in their natal river (Glendale River) using beach seines, August 20, 2004 and August 23, 2006 (Figure 1). Pink salmon were measured for fork length (to the nearest millimeter) and fish were weighed (to the nearest gram). Scales were removed from the preferred area, on a diagonal from the posterior of the dorsal fin toward the origin of the anal fin and two rows above the lateral line. Scales were removed from the fish, stored in scale books on gum cards and later used to make acetate impressions.

Circuli and annuli were counted and measured using the digitizing software OPTIMUS version 4.02. Acetate impressions were viewed under an Olympus microscope and calibrated with a micrometer (to the nearest millimeter) under 4-power magnification. Only scale impressions with a well defined focus (growth center of the scale) were used and digitized. The scale image was displayed on a TV monitor for a larger field of view as well as for clarity. Once the scale was enlarged and the focus was determined it was marked with an X (reference point). A line was drawn to link the focus with the exterior edge of the scale. Individual circuli were marked electronically from the focus to the edge of the scale and the distances between circuli were calculated.

Results

All juvenile fish sampled in June 2005 had at lest 5 circuli (Figure 2). One hundred and thirty-four of the scales were digitized from juvenile pink salmon collected in the summer of 2003.   The average intercirculi space for the first 5 circuli was 0.040 mm (SD=0.006) with a range of 0.25-0.59 (Figure 3A).   In 2004, the 71 one adults sampled from this same brood year had an average intercirculi space for the first 5 circuli of 0.037 (SD=0.006) and a range of 0.26-0.55 (Figure 3B). The intercirculi spacing on these adult fish was significantly smaller than the spacing on the juvenile fish (t test, $p<0.01$), however, the range of intercirculi spaces similar (Figure 3).

The 115 scales digitized from juvenile salmon collected in 2005 had an average intercirculi spacing of the first 5 circuli of 0.034 mm (SD = 0.005) and a range of 0.22-0.45 (Figure 4A). The 88 adult pink salmon that were sampled from this same brood year in 2006 had an average intercirculi space for the first 5 circuli of 0.040 (SD = 0.005) and a range of 0.032-0.054 (Figure 4B). The intercirculi spacing on the adult pink salmon was significantly larger than on the juvenile salmon (t-test, $p<0.01$). The range of intercirculi spaces in the adult pink salmon was also different than in the juveniles (Figure 4).

Discussion

Scales form to protect a fish, thus there should be a relationship between scale length and fish length. There also should be a relationship between scale length and the number of circuli. The scale length, fish length relationship for the juvenile sample in June 2005 had an r^2 value of 0.81 and the fish length, scale intercirculi relationship had an r^2 value of 0.91. The sample of juveniles in June 2005 had circuli numbers ranging from 100% with 5 circuli to 2% with 12 circuli (Figure 2). The circuli number, fish length relationship relationship can be used to show that it is the fish with the smaller fork length that disappear from the sample of adults collected in 2006.

In 2003/2004 the intercirculi spacing on the adult pink salmon was smaller than in the juveniles but the ranges were similar. In 2005/2006, the mean intercirculi spacing of adults in 2006 was significantly larger than the juveniles in 2005 and the range of the adults was also larger. We suspect that the different response is associated with marine survival. In 2002, the escapement of pink salmon to the rivers in the study area was used to estimate the number of juveniles entering the ocean in 2003 (Beamish et al. 2006). We compared this estimate to the adult return to all streams in 2004 and calculated a marine survival of 34%. We do not believe that this estimate is accurate, rather we consider that it is an indication of very good marine survival. It is too early in 2006 to make a similar calculation, but the escapements to all areas as of October 3, 2006 are about 32% of the escapements at the same time in 2004. In fact, there is evidence of poor pink salmon returns in all marine areas off the coast of British Columbia and perhaps into Alaska. At this time, it seems reasonable to conclude that there has been a large scale synchronous reduction in pink salmon marine survival. Assuming this is true, we consider that it would be winter conditions in the ocean that would most likely cause the synchronous impact on pink salmon. If these speculations are valid, the explanation for the different responses would be that the smaller pink salmon were unable to survive in the winter of 2005/2006.

However, there are other explanations. Our sample sizes are small and we have not completed a study of the variation in mean circuli spacing that occurs in juveniles. Our preliminary examination indicates that our sample sizes are adequate. Adult sampling occurs in fresh water, before scales are resorbed. Sampling in the river that is the major producer of pink salmon requires flying in by helicopter and avoiding the frequent challenges of grizzly bears. Consequently, we have not determined if our sample is representative of the population.

Despite these important problems, we believe that our results are real and indicate a relationship between the intercirculi spacing and marine survival when there are extremes in survival. Importantly, the results indicate that a linkage between early marine growth and pink salmon marine survival is part of a life history strategy that selects for the faster growing individuals while ensuring that a small number of individuals return for virtually all stocks.

Literature Cited

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Figure Captions

Figure 1. Location of study area on central coast of British Columbia.

Figure 2. Percentage of juvenile pink salmon sampled, June 21-23, 2005, that had 5-12 intercirculi spaces.

Figure 3. Average intercirculi spacing of first 5 marine circuli for (A) juvenile pink salmon collected by surface trawl, July 31-August 3, 2003 and (B) adult returning pink salmon collected in the Glendale River, August 20, 2004.

Figure 4. Average intercirculi spacing of first 5 marine circuli for (A) juvenile pink salmon collected by beach and purse seine June 21-23, 2005 and (B) adult returning pink salmon collected in the Glendale River, August 23, 2006.

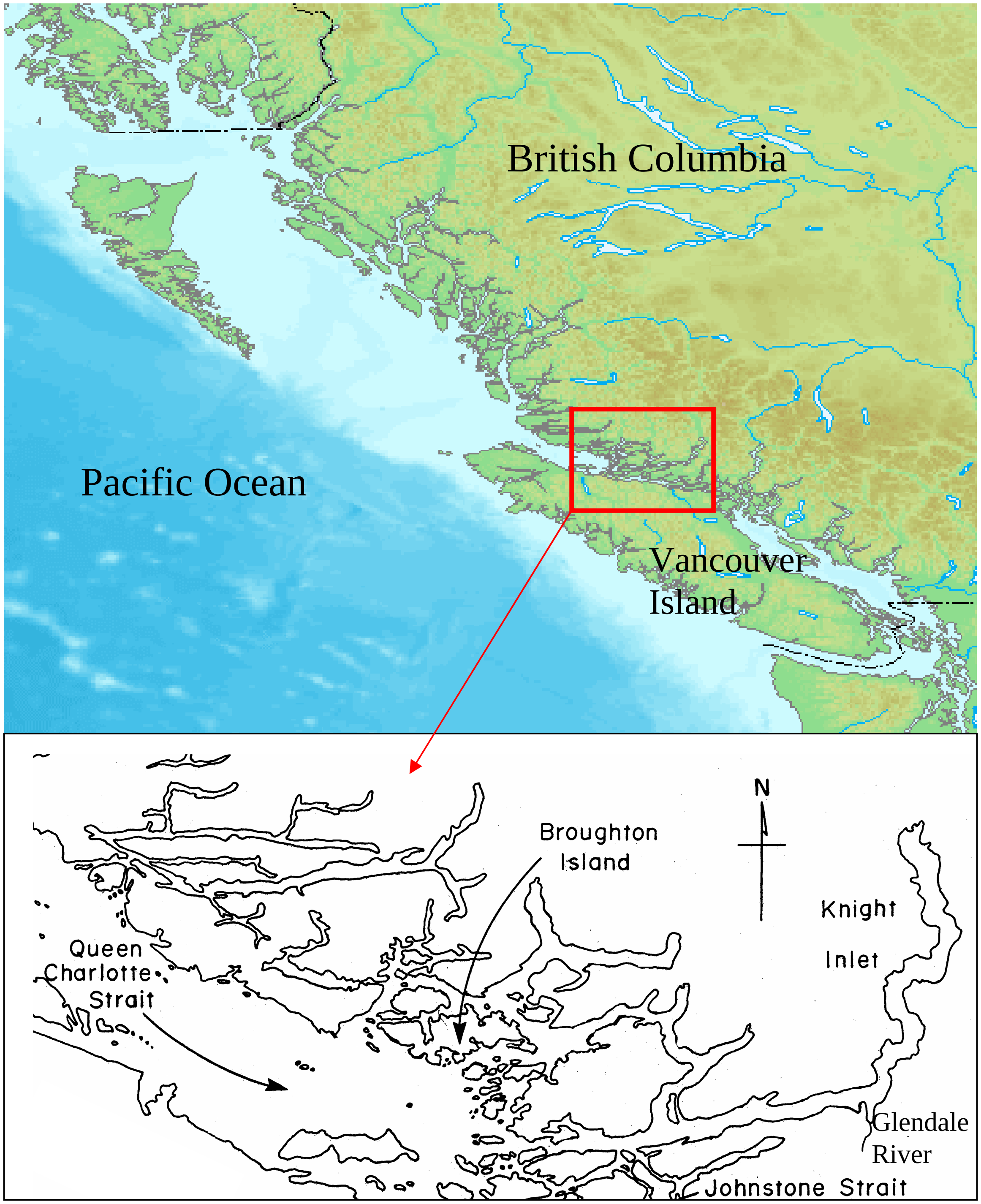
British Columbia
Pacific Ocean
Vancouver Island
Broughton Island
N
Knight Inlet
Queen Charlotte Strait
Glendale River
Johnstone Strait

Figure 1.

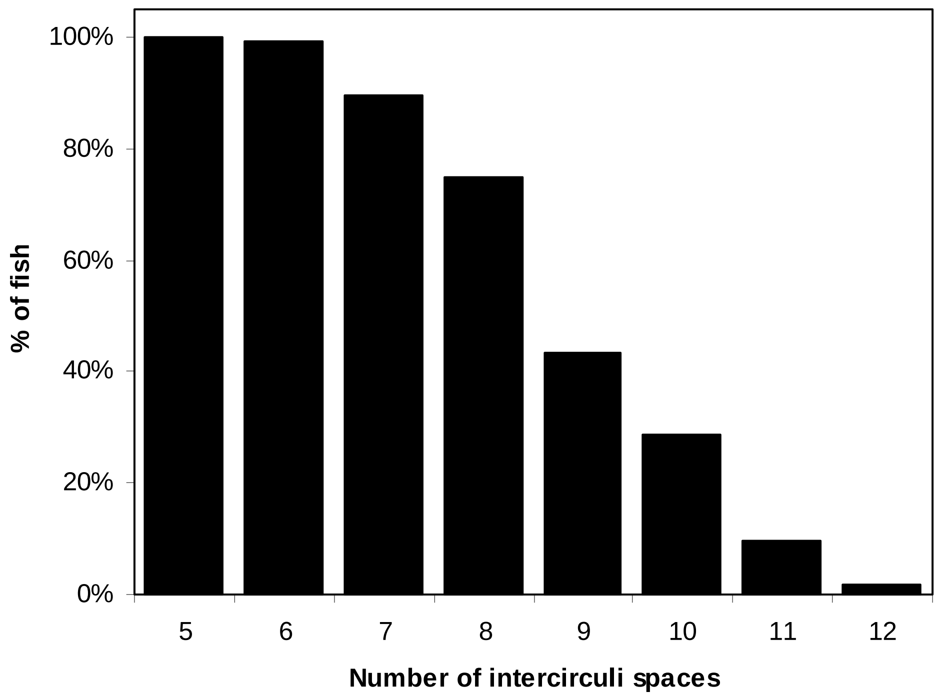
100%
80%
60%
40%
20%
0%
% of fish
5
6
7
8
9
10
11
12
Number of intercirculi spaces

Figure 2.

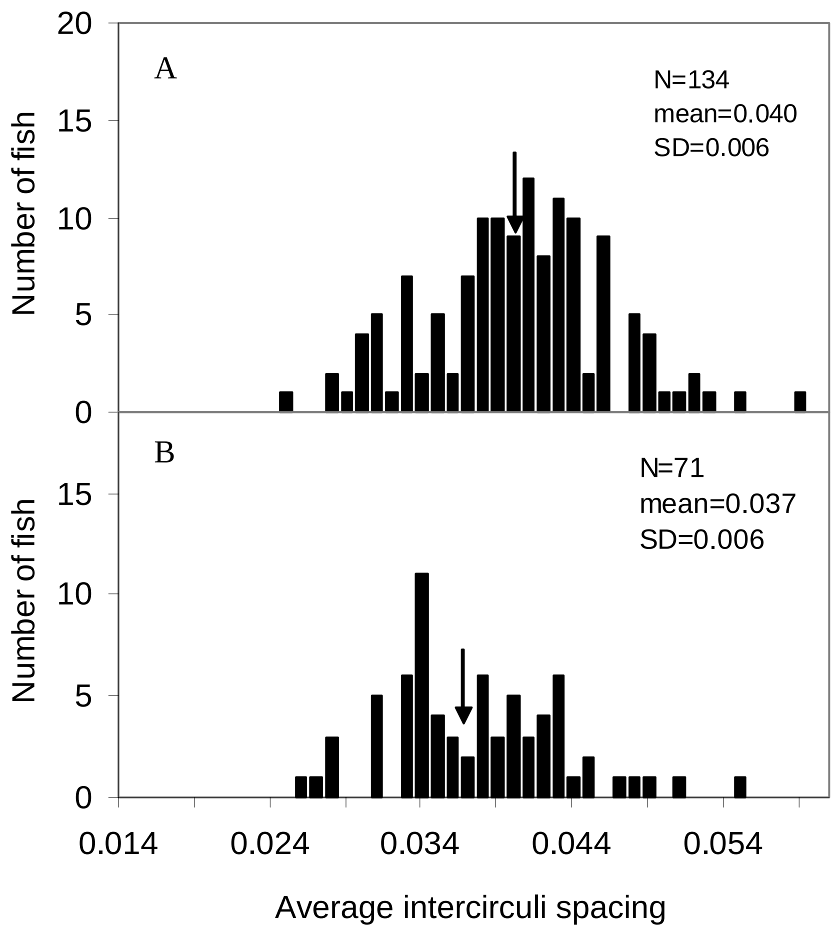
A
N=134
mean=0.040
SD=0.006
B
N=71
mean=0.037
SD=0.006
Number of fish
Number of fish
20
15
10
5
0
15
10
5
0
0.014
0.024
0.034
0.044
0.054
Average intercirculi spacing

Figure 3.

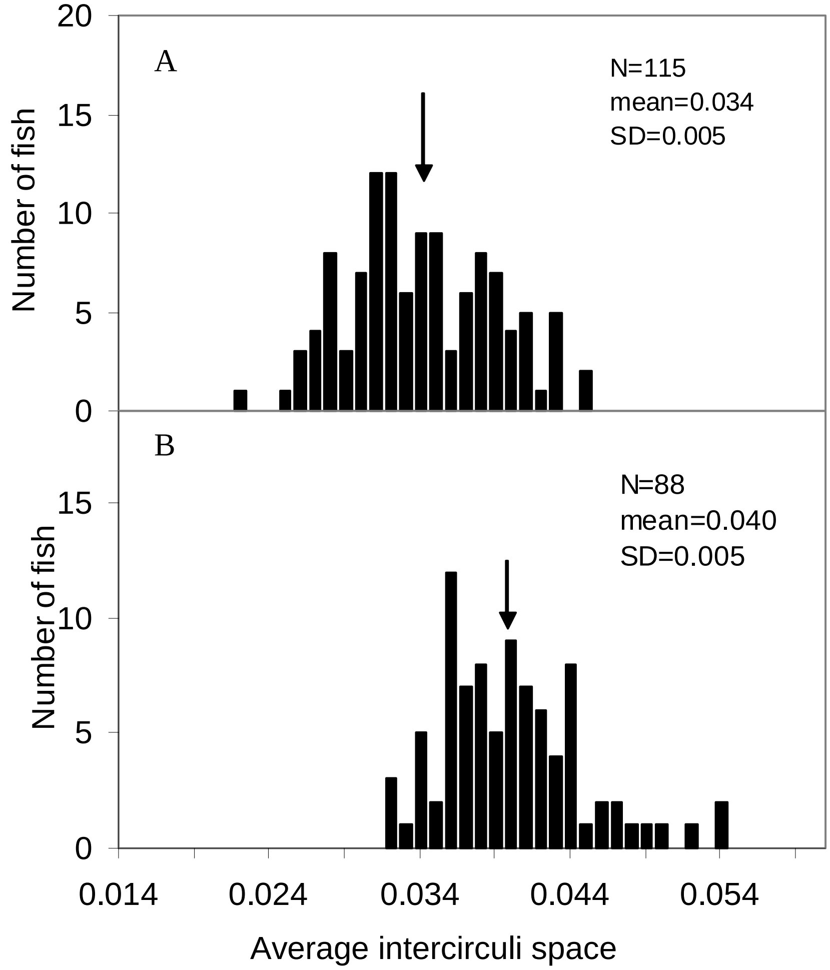
20
15
10
5
0
A
N=115
mean=0.034
SD=0.005
Number of fish
B
N=88
mean=0.040
SD=0.005
15
10
5
0
Number of fish
0.014
0.024
0.034
0.044
0.054
Average intercirculi space

Figure 4.