Variation of Chinook salmon fecundity between the main stem of the Naknek River and a tributary stream, Big Creek in southwestern Alaska

for submission to the

North American Journal of Fisheries Management

Matthew L. Albert

Department of Fish and Wildlife Resources

University of Idaho

Moscow, Idaho 83844-1136

(208) 301-3658

albe6322@uidaho.edu

Abstract

I estimated fecundities for two stocks of Chinook salmon *Oncorhynchus tshawytscha* from the same drainage in southwestern Alaska using a length based linear regression. Female Chinook salmon from the main stem of the Naknek River had a mean fecundity of 9,852 eggs per fish. Big Creek, a tributary stream, had a mean fecundity of 9,060 eggs per female. The observed difference in fecundities was found to be significant ($p < 0.001$). I was able to attribute this difference primarily to a difference between the size class structures of the two stocks. I also eliminated other alternative hypothesis as to why these stocks had different fecundities. I then speculated that there are selective pressures selecting for smaller spawners in Big Creek mainly due to shallow water depth. Further research is needed before this hypothesis can be validated or management recommendations can be made.

Accurate fecundity estimates are important for understanding dynamics of fish populations, predicting trends in population abundance, and estimating spawning-stock biomass (Eldridge and Jarvis 1995). Reproductive potential influences the ability of a species to respond to abiotic and/or biotic stresses. Knowledge of the fecundity of a stock is needed to quantify the effects of external stresses such as fishing, on the reproductive potential of the species (Nitschke and Mather 2001). Fecundity is also of theoretical interest because the energy invested in egg production cannot be used for other functions like growth, escaping predators, or foraging (Healey and Heard 1984).

In Pacific salmon *Oncorhynchus spp*., fecundity varies widely between species, with in populations and even more so between populations (Healy and Heard 1984).

Understanding fecundity in salmonids is of interest because they produce a relatively small number of large eggs compared to other fish species. This suggests a demonstrable relationship between the reproductive potential of the spawning stock and the numbers of young surviving (Rounsefell 1957). For salmonids, there is a positive relationship between body length of a mature female and fecundity (Fleming and Gross 1990).

The Naknek River Drainage supports anadromous runs of all five species of Pacific salmon and numerous resident fish species. Chinook salmon *O. tshawytscha* return to the Naknek River from late May through August. The Naknek River is one of the most accessible rivers in southwest Alaska. It also supports one of the largest Chinook salmon returns in the region. Consequently, the river supports a large sport fishery for Chinook salmon. Recent creel surveys have shown effort to be at 15,512 angler-days which constitutes 16 percent of the effort in southwest Alaska (Dunaway et al. 2000).

Fisheries managers should take fecundity of the specific stocks that they are monitoring into account when making decisions about harvest and escapement goals, especially in a mixed stock fishery with stocks that have significantly different fecundities. The goal of this study is to determine if the main stem of the Naknek River and Big Creek Chinook Salmon have different fecundities and if so what changes to the management of the fishery should occur to keep both stocks at maximum sustained yield.

Study Area

The Naknek River drainage is in the Bristol Bay region of Southwest Alaska (Figure 1). The Naknek River originates from Naknek Lake and flows for approximately

40 km before entering Bristol Bay. It is a large clear water river with a maximum width of approximately 100 m and strong flow (Schwanke 2002). Big Creek is an important Chinook salmon producing tributary of the Naknek River. In 2003, Big Creek had a Chinook salmon return of 10,063 fish. It originates in the mountains south of Brooks Lake in Katmai National Park and flows northwest for approximately 60 km before joining the Naknek River. Big Creek is a clear water stream with a maximum width of approximately 15 m and riffle-run-pool format (Anderson et al. 2004).

Methods

As part of a larger mark-recapture/radio telemetry study taking place during the summer of 2003, Chinook salmon were sampled from the main stem of the Naknek River and Big Creek for age, sex, and length data. For this analysis, fish from the main stem of the Naknek River and Big Creek will be considered as different stocks, which was defined by Cushing (1981) as a group of fish spawning in a particular lake or stream at a particular season, which to a substantial degree do not interbreed with any other such group. Because of large river size (prevents the use of a weir) the main stem fish were sampled by drifting 14 and 19.1 cm (stretched mesh size) multifilament gillnets through known pre-spawn (sexually mature) staging concentrations in the upper river between Rainbow Bend and Shawbeck's Cabin (Figure 1). Fish were sampled for mid-eye to fork length (mm) and sex and returned to the river. Big Creek fish were sampled at a nontraditional resistance board weir approximately 35 km upstream from its confluence with the Naknek River (Anderson et al. 2004).

Data analysis

Healy and Heard (1984) used previously collected data (from 1968, provided by Alaska Dept. of Fish and Game) to develop a regression line to estimate fecundity based on length for the Nushagak River Chinook salmon stock. The Nushagak River is approximately 75 km northwest from the Naknek River. I will use the parameter estimates from Healy and Heard (1984) to estimate fecundity (F) of the Naknek River and Big Creek stocks of Chinook salmon. The regression calls for the length of the fish to be measured from the posterior margin of the orbit to the end of the hypural plate (POH). Fecundity can be calculated with the following equation:

$$F = 1.63 * L^{1.3108} \qquad (1)$$

where F = fecundity and L = POH in mm. However, the length data was collected as mid-eye to fork length (MEF). These lengths can be transformed from MEF to POH by using a simple equation as described by Healy and Heard (1984). All lengths are in mm. The transformation equation is:

$$POH = 0.859 * MEF + 25.7 \qquad (2)$$

Fecundity will be estimated for each fish and then averaged to give the mean fecundity for each stock. A statistical *t*-test will be used to test for a significant difference between same length classes from each sample stock. Each sample set will be divided up into 100 mm length classes for population size structure analysis.

Results

Mean fecundity of fish from the main stem of the Naknek River (n = 442) was 9,867 versus fish from Big Creek (n = 198) with a mean fecundity of 9,069. The 798 egg difference between the main stem of the Naknek River and Big Creek was found to be significant ($p < 0.001$, df = 233). To better understand the difference between the two stocks, I compared the size distribution of females sampled from each population (Figure 2). The majority of the fish from each stock were in the 800 mm size class, but the Big Creek fish showed a wider range of sizes with a trend towards smaller fish. Thirty-three percent of the samples from Big Creek had a MEF length of < 800 mm. The main stem of the Naknek River fish were primarily made up of 800 mm (60%) and 900 mm (29%) size class fish.

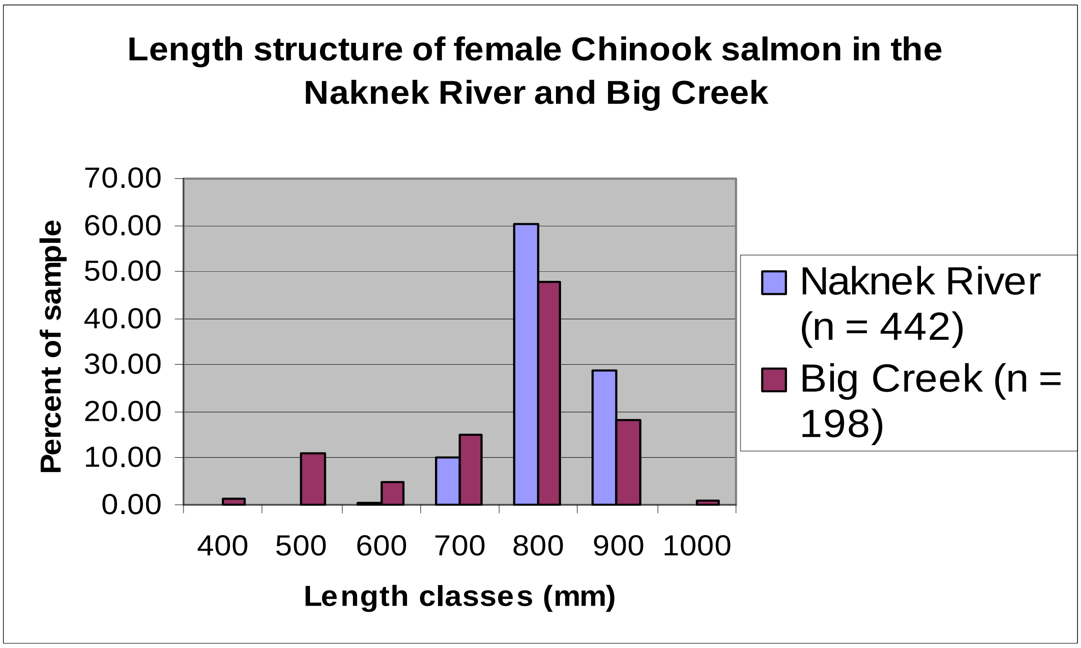

Figure 2. Sample population length structure of female Chinook salmon from the main stem of the Naknek River and Big Creek.

Discussion

Fecundities of both stocks were estimated using the same linear regression that was based on the length of the fish. These estimates of fecundity do not take factors other than length into account for estimating fecundity. This prevents me from determining if there is a difference in fecundity between the two stocks for a given length class. The differences in the estimated fecundities can be attributed to differences in the size structure of the two stocks sampled.

Factors other than length can affect fecundity as well. Fecundity of Pacific salmon has been found to increase with latitude (Fleming and Gross 1990). Fleming and Gross (1990) speculated that this increase in fecundity with increasing latitude was do to egg size. The amount of energy available to expend on egg production is limited (Smith and Fretwell 1974). A fish can produce more eggs if the eggs are smaller (Fleming and Gross 1990, Healy and Heard 1984).

If there are fewer juvenile competitors and size-selective predators existing at northern latitudes this might reduce the selective advantage of larger egg sizes and increase the mean fecundities of the stocks (Fleming and Gross 1990). The juvenile Chinook salmon from both streams will have relatively few competitors (primarily other juvenile salmonids). Both streams have high populations of piscivorous rainbow trout *O. mykiss* and arctic char *Salvelinus alpinus* that target juvenile salmon during certain times of the year. For this analysis I have assumed that the juveniles from each stream face similar predation rates and competition patterns which would have similar affects upon the selection for egg size and fecundities in each stream.

Fleming and Gross (1990) also stated that egg size, which they used as a surrogate for fecundity, was affected by incubation temperature of the fertilized eggs. Incubation temperatures can influence the efficiency of yolk conversion to body tissue (Heming 1982). Beacham and Murray (1985) found that chum salmon *O. keta*, produced smaller alevins and fry for a given egg size at higher incubation temperatures. In colder temperatures, we can expect to find smaller eggs, but more of them. No data on winter water temperatures is available for the Naknek River or Big Creek. I have assumed that both streams have similar winter water temperatures because of their close proximity to each other and observations that they both at least partially freeze over in the winter (C. J. Schwanke, Alaska Dept. of Fish and Game, personal communication). The assumed similar winter time temperatures in both streams will have similar effects to the mean fecundities of female Chinook salmon from both streams.

Most of the high fecundity Chinook salmon populations are stream-type which will require a higher fecundity to off-set pre-productive mortality and an older age of maturity versus ocean-type which migrate to the ocean as age-0 smolts (Healy and Heard 1984). The Chinook salmon in both the Naknek River and Big Creek are stream type as determined by the aging of scales taken during the study. All fish aged (Naknek River, n = 388; Big Creek, n = 162) showed one year of freshwater residence before migrating to the ocean which indicates that both populations are comprised entirely of stream-type fish.

Both the Naknek River and Big Creek fish seem to lack differential effects on their fecundities by predation, competition, incubation water temperature, and race. I can begin to speculate about other forces that may influence fecundity of the Naknek River and/or Big Creek.

Quinn et al. (2001) examined stream size and predation effects on sockeye salmon *O. nerka* morphology in the Wood River drainage in Southwestern Alaska. They found that streams with shallower depths selected for smaller sized fish to successfully spawn. They also concluded that while predation by brown bears *Ursus arctos* was significant, the average body size was more closely related to habitat than predation. Based on conclusions by Quinn et al. (2001), I hypothesize that the shallower spawning habitat in Big Creek is selecting for the smaller sized females that were found in the Big Creek sample population. The upper reaches of Big Creek (approximately river km 60 and above) are characterized by small pools and runs (< 2 m in depth) connected with fast moving, shallow riffles and channels (< 0.33 m in depth) (author's observations, summer 2002-2004). The smaller sized females will be better able to swim in shallower water and secondarily, be more successful at avoiding predation. Larger individuals will be selected against because they could be excluded from large portions of spawning habitat and will be easier for predators (primarily brown bears and river otters *Lontra canadensis*) to see and catch in the shallower water. My hypothesis is supported by the length structures for Big Creek and the Naknek River (Figure 2).

Management Implications

Due to the inconclusiveness of this study, I can not make any recommendations for future management of the Naknek River and Big Creek Chinook fishery. Currently, there is a conservative bag limit for Chinook salmon of one fish over 28 inches (711.2 mm) and two below 28 inches (711.2 mm) in the Naknek River and lower Big Creek. Only artificial lures are allowed. In the upper portion of Big Creek there is no retention of Chinook salmon allowed. All fish must remain in the water and be released and only single hook artificial lures are allowed (C. J. Schwanke, Alaska Dept. of Fish and Game, personal communication). Further research is needed before any management recommendations can be made.

References

Anderson, J. L., K. S. Whitton, K.K. Cornum, and T.D. Auth. 2004. Abundance and run timing of adult Pacific salmon in Big Creek, Becharof National Wildlife Refuge, 2003. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series, King Salmon.

Bell, G. 1980. The costs of reproduction and their consequences. American Naturalist 116: 45-76.

Cushing, D. H. 1981. Fisheries biology. The University of Wisconsin Press, Madison, WI, USA.

Dunaway, D. O., G. P. Naughton, M. J. Jaenicke. 2000. Area management report for the recreational fisheries of the Southwest Alaska sport fish management area 1998. Alaska Department of Fish and Game, Fishery Management Report Series, Anchorage.

Eldridge, M. B. and B. M. Jarvis. 1995. Temporal and spatial variation in fecundity of yellowtail rockfish. Transactions of the American Fisheries Society 124(1):16-25.

Fleming, I. A. and M. R. Gross. 1990. Latitudinal clines: a trade-off between egg number and size in Pacific salmon. Ecology 71(1): 1-11.

Healey, M. C., and W. R. Heard. 1984. Inter- and intra-population variation in the fecundity of Chinook salmon (*Oncorhynchus tshawytscha*) and its relevance to life history theory. Canadian Journal of Fisheries and Aquatic Sciences 41: 476–483.

Heming, T. A. 1982. Effects of temperature on utilization of yolk by chinook salmon (Oncorhynchus tshawytscha) eggs and alevins. Canadian Journal of Fisheries and Aquatic Sciences 39: 184-190.

Nitschke, P. and M. Mather. 2001. A comparison of length-, weight-, and age-specific fecundity relationships for cunner in Cape Cod Bay. North American Journal of Fisheries Management 21: 86-95.

Quinn, T. P., L. Wetzel, S. Bishop, K. Overberg, and D. E. Rogers. 2001. Influence of breeding habitat on bear predation and age at maturity and sexual dimorphism of sockeye salmon populations. Canadian Journal of Zoology 79: 1782-1793.

Rounsefell, G. A. 1957. Fecundity of North American salmonidae. U.S. Fish and Wildlife Service, Fishery Bulletin 122.

Schwanke, C. J. 2002. Abundance and movement of the rainbow trout spawning stock in the Upper Naknek River, Alaska. Masters thesis, University of Wyoming Graduate School, Laramie, Wyoming.

Smith, C. C., and S. D. Fretwell. 1974. The optimal balance between size and number of offspring. American Naturalist 108: 499-506.

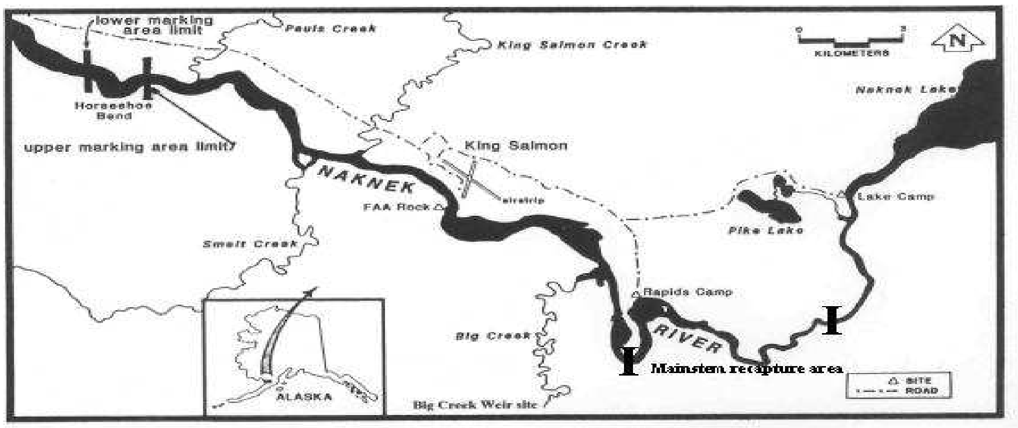

Figure 1. Naknek River Study area. The main stem capture area and Big Creek weir site are marked on the map.

List of Figures