# Assessing growth and survival of juvenile Chinook and coho salmon off the West coast of Vancouver Island.

**Brian Beckman[1] and Marc Trudel[2]**

**Report to the Pacific Salmon Commission for 2007**

[1]NWFSC, NOAA
2725 Montlake Blvd E
Seattle, WA USA 98112
Brian.Beckman@NOAA.gov

[2]PBS, DFO
3190 Hammond Bay Road
Nanaimo, B.C., Canada
V9T 6N7
TrudelM@pac.dfo-mpo.gc.ca

## Introduction

Ocean survival of Pacific salmon is both variable and to this point unpredictable. This variability presents obvious and substantial difficulties for the management of ocean and terminal salmon fisheries. A longstanding hypothesis in the scientific community is that ocean survival of salmon may depend on growth during their first summer at sea (Holtby et al. 1988; Pearcy 1992). To date, this hypothesis has not been critically tested due to the considerable cost of sampling salmon in the ocean and the difficulties of actually measuring salmon growth at sea. Recently, Beckman et al. (2004) have suggested that blood levels of the hormone IGF-I may provide a reliable index of the instantaneous growth rate of salmon.

Accordingly, the PSC Southern Fund provided resources that enabled plasma samples to be obtained from juvenile coho and Chinook salmon captured off of Vancouver Island in the Fisheries and Oceans Canada (CDFO) June 2007 cruise. These samples constitute a first step towards assessing inter-annual variability in early ocean growth of salmon in this area. In addition, these samples represent an opportunity to examine regional variation in juvenile salmon growth.

## Materials and Methods

CDFO survey techniques used for the capture of salmon and sampling locations have been described previously (Welch et al. 2003). Briefly, a rope-trawl manufactured by Cantrawl Nets Ltd. (Richmond, BC) and later modified by the fishing crew was towed at the surface for 30 minutes at 5 knots. Salmon were then removed from the trawl, placed on crushed ice and bled within 45 minutes of the trawl coming on board. Blood samples were kept on ice (up to 4 hours) prior to centrifugation. Plasma was removed from the centrifuged samples and frozen on board the ship, then transferred to Seattle (on dry ice) where they were placed in a –80ºC freezer until the samples were assayed by radioimmunoassay according to the methods of Shimizu et al. (2000).

Salmon length and weight were measured directly on board the research vessel following blood extraction. Otoliths and scales were removed from these fish for age determination. A tissue sample was also taken from the operculum using a hole punch and preserved in 70% ethanol for stock identification (Beacham et al. 2006).

## Results

In the June 2007 CDFO Southern BC cruise 75 yearling Chinook and 155 yearling coho salmon were collected and bled from 48 different stations (Table 1). Of the Chinook salmon, all originated from the Columbia River (Trudel et al. unpublished). Mean IGF-I levels of coho salmon varied regionally, with fish collected from northern stations having higher IGF-I levels than those found in Strait of Juan de Fuca, Southern Vancouver Island and inside of Vancouver Island Inlets (Figure 1). Chinook salmon were not distributed as widely, though fish collected off the North-Central Vancouver Island coast also had the highest IGF-I levels (Figure 2). There was a significant, positive relation between mean

IGF-I levels of coho and Chinook salmon when they were collected together at the same station (Figure 3). The regional correspondence in IGF-I level suggests that these fish may be responding somewhat similarly to regional differences in productivity. However, the relation between coho and Chinook salmon IGF-I levels was not strong (r = 0.59); suggesting species specific differences in how prey resources were exploited or differences in residence times and migration rates between the species.

One may place the IGF-I samples obtained on the June 2007 CDFO Southern BC cruise into better context by comparing them to other samples obtained regionally in 2007 (June 2007 CDFO Northern BC cruise). IGF-I values from different Columbia River Chinook salmon stocks vary with region (Figure 4). Average IGF-I levels in Summer/Fall run up-river bright Chinook salmon were higher than found in Columbia/Snake River spring Chinook salmon off Vancouver Island and Hecate Strait. Willamette River stock spring Chinook salmon had lower levels of IGF-I than Columbia/Snake River spring Chinook salmon off Vancouver Island and the Queen Charlotte Islands but we found higher IGF-I levels in these same fish in southeast Alaska.

In addition we can compare a) IGF-I values from coho salmon from both the June 2007 CDFO Southern cruise to values found in b) the NOAA June 2007 cruise (Washington) and c) the NOAA June 2000 cruise (Washington) and d) the June 2000 CDFO Southern BC cruise. The mean IGF-I level in 2007 coho salmon for Vancouver Island and Washington Coasts was reduced as compared to 2000 (Figure 5).

**Discussion**

2007 was the first year in which the Pacific Salmon Commission supported (through the Southern Fund) the collection of blood samples and assessment of plasma IGF-I values as an index of salmon growth in Southern BC waters. These samples, by themselves provide some perspective on regional variation in growth of juvenile salmon off the west coast of Vancouver Island. IGF-I values for both coho and Chinook salmon were higher north of Estevan Point (~49.5ºN). Perry et al (1996) found fuller stomachs and higher condition in pink salmon captured off the northern coast of Vancouver Island than off the southern coast in the summer of 1992. Chum salmon also had fuller stomachs off the northern coast than the southern coast, although condition of chum salmon captured in these areas did not differ. Ware et al. (2005) documented regional differences in primary production off the west coast of North America and suggested that these differences drove differential fish production. The plasma IGF-I data we present herein suggests corresponding differences in growth rate of juvenile salmon in different regions. Moreover, IGF-I levels measured further north were even higher, justifying the commonly held assumption that salmon grow faster in northern waters.

Juvenile coho and Chinook salmon generally feed on relatively similar prey in coastal waters (Brodeur et al. 2007), thus we might expect to see similar regional variation in IGF-I levels between the species. Our results do tend to suggest that regional variation in IGF-I level among coho and Chinook salmon were similar; yet, this relation is certainly not perfect. An obvious issue is that we sampled fewer Chinook than coho salmon, thus our assessment of Chinook salmon IGF-I levels are more subject to sampling error than our coho salmon IGF-I estimates. Moreover, IGF-I level reflects feeding and growth processes over at least the past several days and may extend to an integrated signal of over a weeks worth of activity (Beckman et al. 2004). We do not know if there were differences in residence time between Chinook and coho salmon at any one of the stations we sampled in 2007; however, based on current estimates of migratory activity of tagged smolts it would be surprising if differences did not exist (Morris et al. 2007).

No one may evaluate inter-annual variations in growth based upon one year of samples. However, plasma samples were obtained from juvenile coho salmon in a June 2000 CDFO cruise along the west coast of Vancouver Island. In addition, plasma IGF levels in juvenile coho salmon have been measured off the coast of Washington in every year since 2000. Thus a comparison of mean coho salmon IGF-I between 2000 and 2007 and revealed that IGF-I levels were significantly higher in 2000. Simplistically, we would thus expect that adult coho salmon returns will be lower in 2008 than those found in 2001, for stocks whose juveniles are found off the Northern Washington Coast and the west coast of Vancouver Island. Continued sampling along with assessment of adult return will be required to evaluate the efficacy of this prediction and develop reliable forecasting models of salmon returns.

## Summary

Plasma samples were successfully obtained during the CDFO cruise, transported to NOAA in Seattle and the IGF assay was successfully performed.

Differences in plasma IGF-I values between stations for both coho and Chinook salmon indicated that regional variation in growth rates existed.

Differences in plasma IGF-I levels for different Chinook salmon stocks suggest that growth rates at sea vary with regard to both geographic location and population of origin.

Significant differences in IGF-I levels between juvenile coho salmon collected in 2000 and 2007 suggests that growth varies inter-annually off the West Coast of Vancouver Island and that this may relate to overall adult return.

NOAA Fisheries and CDFO successfully collaborated in all the phases of this project, from its conception, to the execution, analyses, and dissemination of the results.

## Prognosis

This PSC Southern Fund project builds directly upon ongoing research conducted by CDFO and NOAA Fisheries on early ocean growth and survival of juvenile coho and Chinook salmon. This work effectively fills a gap by adding direct estimates of instantaneous growth rate to salmon smolts already sampled in the June/July CDFO cruise off of Vancouver Island. This takes advantage of an in place research platform off the Canadian Coast and provides samples to a functioning physiology laboratory that is wellversed in performing the IGF-I assay. We are confident that this work, if continued, will provide useful information on inter-annual variation in juvenile salmon growth and early-ocean survival. In addition, this work is providing insight into the growth of coho and Chinook salmon smolts from the Columbia River and Washington Coast as they transition from US to Canadian waters and move further north towards Alaska. This builds upon IGF-I levels measured during May and June research cruises off the Oregon and Washington Coasts by NOAA Fisheries and adds to our knowledge of regional variation in growth. This current report does not fully illustrate the value of the information obtained as it only represents one year of sampling and the requirements of reporting annual results by a given date have precluded these data from being fully integrated with data obtained from the May and June 2007 NOAA Fisheries cruises. Future reports should provide a more comprehensive picture of inter-annual and regional variation in juvenile salmon growth and how this growth variation links to variation in survival.

**Acknowledgements**

We thank the crew of the *CCGS W.E. Ricker*, L. Felli, J. Morris, T. Zubkowski, Dr. J. Curtis, M. Thiess, and H. Maclean, for their valuable help in the field and Kathy Cooper for superb performance in running the IGF-I assay in the laboratory. We also thank Fisheries and Oceans Canada, NOAA Fisheries, the Bonneville Power Administration, and the Southern Endowment Fund for providing financial support for this research.

**References**

Beacham, T.D., J.R. Candy, K.L. Jonsen, K.J. Supernault, M. Wetklo, L. Dend, K.M. Miller, R.E. Whitler, and N. Varnavskaya. 2006. Estimation of stock composition and individual identification of Chinook salmon across the Pacific Rim by use of microsatellite variation. Trans. Am. Fish. Soc. 135: 861-888.

Beckman, B.R., Fairgrieve, W., Cooper, K. A., Mahnken, C.V.W., and R. J. Beamish. 2004. Evaluation of endocrine indices of growth in post-smolt coho salmon (*Oncorhynchus kisutch*). Trans. Am. Fish. Soc 133:1057-1067.

Brodeur, R.D., Daly, E.A., Studervant, M.V., Miller, T.W., Moss, J.H.,Thiess, M., Trudel, M., Weitkamp, L.A., Armstrong, J., and Norton, E.C. 2007. Regional comparisons of juvenile salmon feeding in coastal marine waters off the West Coast of North America. . *In* Ecology of Juvenile Salmon in the Northeast Pacific Ocean: Regional Comparisons. *Edited by* Grimes, C.B., Brodeur, R.D., Halderson, L.J., and McKinnell, S.M. American Fisheries Society.

Holtby, L.B., B.C. Anderson, and R.K. Kadowaki. 1988. Importance of smolt size and early ocean growth to interannual variability in marine survival of coho salmon (*Oncorhynchus kisutch*). Can. J. Fish. Aquat. Sci. 47: 2181-2194.

Morris, J.T., Trudel, M., Theiss, M.E., Sweeting, R.M., Fisher, J., Hinton, S.A., Fergusson, E.A., Orsi, J.A., Farley, E.V., and Welch, D.A. 2007. Stock-Specific Migrations of Juvenile Coho Salmon Derived from Coded-Wire Tag Recoveries on the Continental Shelf of Western North America. *In* Ecology of Juvenile Salmon in the Northeast Pacific Ocean: Regional Comparisons. *Edited by* Grimes, C.B., Brodeur, R.D., Halderson, L.J., and McKinnell, S.M. American Fisheries Society.

Pearcy, W.G. 1992. Ocean ecology of North Pacific salmonids. Washington Sea Grant.

Perry, R.I., Hargreaves, N.B., Waddell, B.J., Mackas, D.L. 1996. Spatial variations in feeding and condition of juvenile pink and chum salmon off Vancouver Island, British Columbia. Fish. Oceanog. 5: 73-88.

Shimizu, M., Swanson, P., Fukada, H., Hara, A. Dickhoff, W.W. 2000. Comparison of extraction methods and assay validation for salmon insulin-like growth factor-I using commercially available components. Gen. Comp. Endocrinol. 119:26-36.

Ware, D.M., and Thomson, R.E. 2005. Bottom-up ecosystem trophic dynamics determine fish production in the northeast Pacific. Science 308:1280-1284.

Welch, D.W., Morris, J.F.T., Thiess, M.E., Trudel, M., and Anderson, D.J. 2003. CCGS W.E. Ricker Gulf of Alaska salmon survey, June 27 to July 6, 2000. Can. Data Rep. Fish. Aquat. Sci. 1125: 110 p.

Table 1. Number of yearling salmon sampled for blood by station and species for the 2007 DFO southern BC cruise.

| station | region | subregion | date | lat | long | # coho | # chinook |
|---|---|---|---|---|---|---|---|
| JF02 | JuandeFuca | JuandeFuca | June 20, 2007 | 48.34 | 123.86 | 2 | |
| JF06 | JuandeFuca | JuandeFuca | June 20, 2007 | 48.55 | 124.72 | 13 | |
| JF07 | JuandeFuca | JuandeFuca | June 20, 2007 | 48.61 | 124.91 | 4 | |
| IVI01 | VancouverIsland | VanIslandInlet | June 21, 2007 | 48.95 | 125.12 | 6 | 1 |
| IVI02 | VancouverIsland | VanIslandInlet | June 21, 2007 | 48.91 | 125.21 | 5 | 2 |
| IVI03 | VancouverIsland | VanIslandInlet | June 21, 2007 | 48.83 | 125.27 | 5 | |
| VI01 | VancouverIsland | SouthVanIsland | June 21, 2007 | 48.75 | 125.41 | 1 | |
| VI02 | VancouverIsland | SouthVanIsland | June 21, 2007 | 48.68 | 125.57 | 5 | |
| VI03 | VancouverIsland | SouthVanIsland | June 21, 2007 | 48.57 | 125.72 | 4 | |
| VI04 | VancouverIsland | SouthVanIsland | June 21, 2007 | 48.51 | 125.89 | 8 | 1 |
| VI05 | VancouverIsland | SouthVanIsland | June 22, 2007 | 49.09 | 126.02 | 9 | 2 |
| VI06 | VancouverIsland | SouthVanIsland | June 22, 2007 | 49.04 | 126.12 | 1 | 1 |
| VI07 | VancouverIsland | SouthVanIsland | June 22, 2007 | 48.97 | 126.22 | 11 | |
| VI08 | VancouverIsland | SouthVanIsland | June 22, 2007 | 48.92 | 126.30 | 3 | 3 |
| VI12 | VancouverIsland | SouthVanIsland | June 22, 2007 | 48.85 | 126.54 | | 2 |
| EP01 | VancouverIsland | SouthVanIsland | June 23, 2007 | 49.34 | 126.55 | 9 | 9 |
| EP02 | VancouverIsland | SouthVanIsland | June 23, 2007 | 49.31 | 126.62 | 13 | 6 |
| EP03 | VancouverIsland | SouthVanIsland | June 23, 2007 | 49.28 | 126.69 | 15 | 1 |
| EP04 | VancouverIsland | SouthVanIsland | June 23, 2007 | 49.24 | 126.76 | 5 | 1 |
| EP06 | VancouverIsland | SouthVanIsland | June 23, 2007 | 49.16 | 126.92 | | 1 |
| VI13 | VancouverIsland | CentVanIsland | June 24, 2007 | 49.64 | 126.95 | 13 | 4 |
| VI14 | VancouverIsland | CentVanIsland | June 24, 2007 | 49.59 | 127.04 | 15 | 2 |
| VI15 | VancouverIsland | CentVanIsland | June 24, 2007 | 49.54 | 127.14 | | 1 |
| VI17 | VancouverIsland | CentVanIsland | June 24, 2007 | 49.73 | 127.34 | | 3 |
| VI18 | VancouverIsland | CentVanIsland | June 24, 2007 | 49.79 | 127.34 | 1 | 4 |
| VI19 | VancouverIsland | CentVanIsland | June 24, 2007 | 49.89 | 127.35 | 15 | 1 |
| VI20 | VancouverIsland | CentVanIsland | June 25, 2007 | 49.93 | 127.36 | 7 | 3 |
| VI22 | VancouverIsland | CentVanIsland | June 25, 2007 | 49.99 | 127.59 | 1 | 4 |
| VI23 | VancouverIsland | CentVanIsland | June 25, 2007 | 50.00 | 127.70 | 3 | |
| VI24 | VancouverIsland | CentVanIsland | June 25, 2007 | 50.05 | 127.85 | 30 | 3 |
| VI25 | VancouverIsland | CentVanIsland | June 25, 2007 | 50.11 | 127.98 | 21 | 1 |
| VI26 | VancouverIsland | CentVanIsland | June 25, 2007 | 50.25 | 128.05 | 10 | 3 |
| IVI04 | VancouverIsland | VanIslandInlet | June 26, 2007 | 50.47 | 127.94 | 30 | 2 |
| VI27 | VancouverIsland | NorthVanIsland | June 26, 2007 | 50.41 | 128.02 | 4 | |
| VI28 | VancouverIsland | NorthVanIsland | June 26, 2007 | 50.35 | 128.11 | 2 | 3 |
| VI29 | VancouverIsland | NorthVanIsland | June 26, 2007 | 50.29 | 128.21 | 8 | |
| VI30 | VancouverIsland | NorthVanIsland | June 26, 2007 | 50.25 | 128.28 | 14 | 5 |
| VI31 | VancouverIsland | NorthVanIsland | June 26, 2007 | 50.18 | 128.38 | | 2 |
| IVI05 | VancouverIsland | VanIslandInlet | June 27, 2007 | 50.45 | 127.52 | 15 | |
| IVI06 | VancouverIsland | VanIslandInlet | June 27, 2007 | 50.51 | 127.69 | 15 | |
| IVI07 | VancouverIsland | VanIslandInlet | June 27, 2007 | 50.48 | 127.80 | 19 | |
| VI32 | VancouverIsland | NorthVanIsland | June 27, 2007 | 50.45 | 128.16 | 4 | 2 |
| VI33 | VancouverIsland | NorthVanIsland | June 27, 2007 | 50.50 | 128.27 | | 1 |
| VI34 | VancouverIsland | NorthVanIsland | June 27, 2007 | 50.59 | 128.35 | 1 | |
| T01 | VancouverIsland | TriangleIsland | June 28, 2007 | 51.29 | 128.35 | 1 | |
| T02 | VancouverIsland | TriangleIsland | June 28, 2007 | 51.22 | 128.44 | 4 | |
| T03 | VancouverIsland | TriangleIsland | June 28, 2007 | 51.15 | 128.58 | 3 | |
| T06 | VancouverIsland | TriangleIsland | June 28, 2007 | 50.95 | 128.98 | | 1 |
| | | | | | | **355** | **75** |

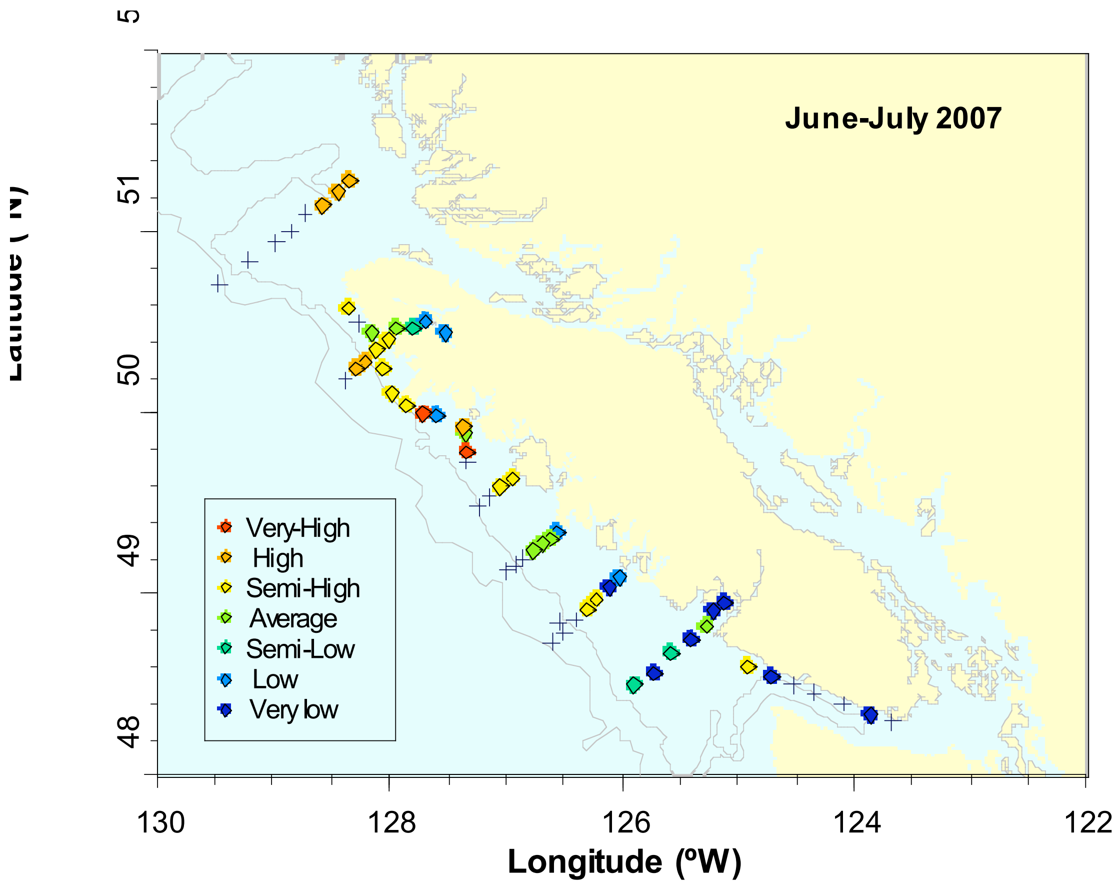


Figure 1. Mean IGF-I concentration of juvenile coho salmon by station. IGF-I levels are categorized by standard deviations (sd) from the overall mean (average = +/- 0.25 sd from the overall mean, each additional category represent another 0.5 sd increment from the overall mean, very high > 1.75 sd greater than average, very low > 1.75 sd less than average). The lines beyond the shorelines represent the 200 m and 1,000 isobath.

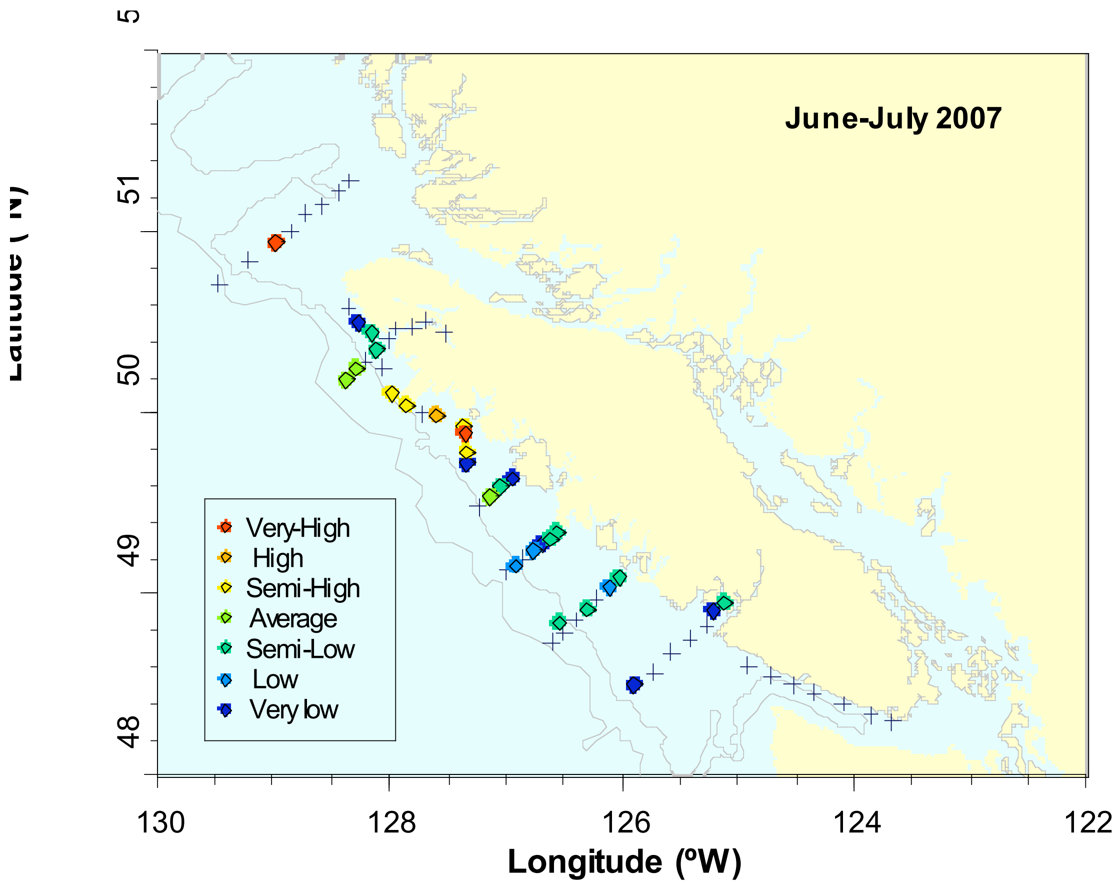


Figure 2. Mean IGF-I concentration of juvenile Chinook salmon by station IGF-I levels are categorized by standard deviations (sd) from the overall mean (average = +/- 0.25 sd from the overall mean, each additional category represent another 0.5 sd increment from the overall mean, very high > 1.75 sd greater than average, very low > 1.75 sd less than average). The lines beyond the shorelines represent the 200 m and 1,000 isobath.

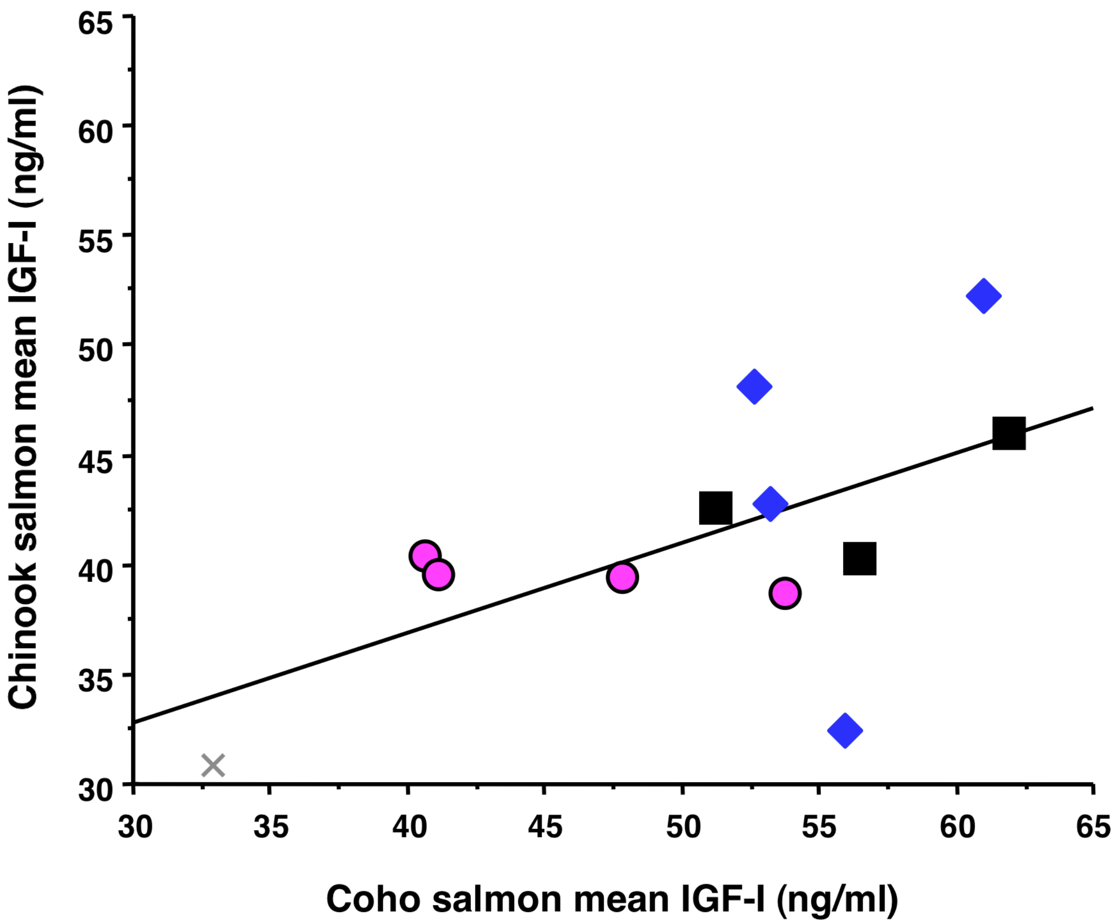


Figure 3. Relation between mean IGF-I levels of Chinook and coho salmon sampled at the same stations off of Vancouver Island (VI) BC (Pearson correlation r=0.59, p=0.03). Pink circles indicate fish caught off the southern coast, blue diamonds off the central coast, black squares off the north coast and a x signifies fish caught within an inlet.

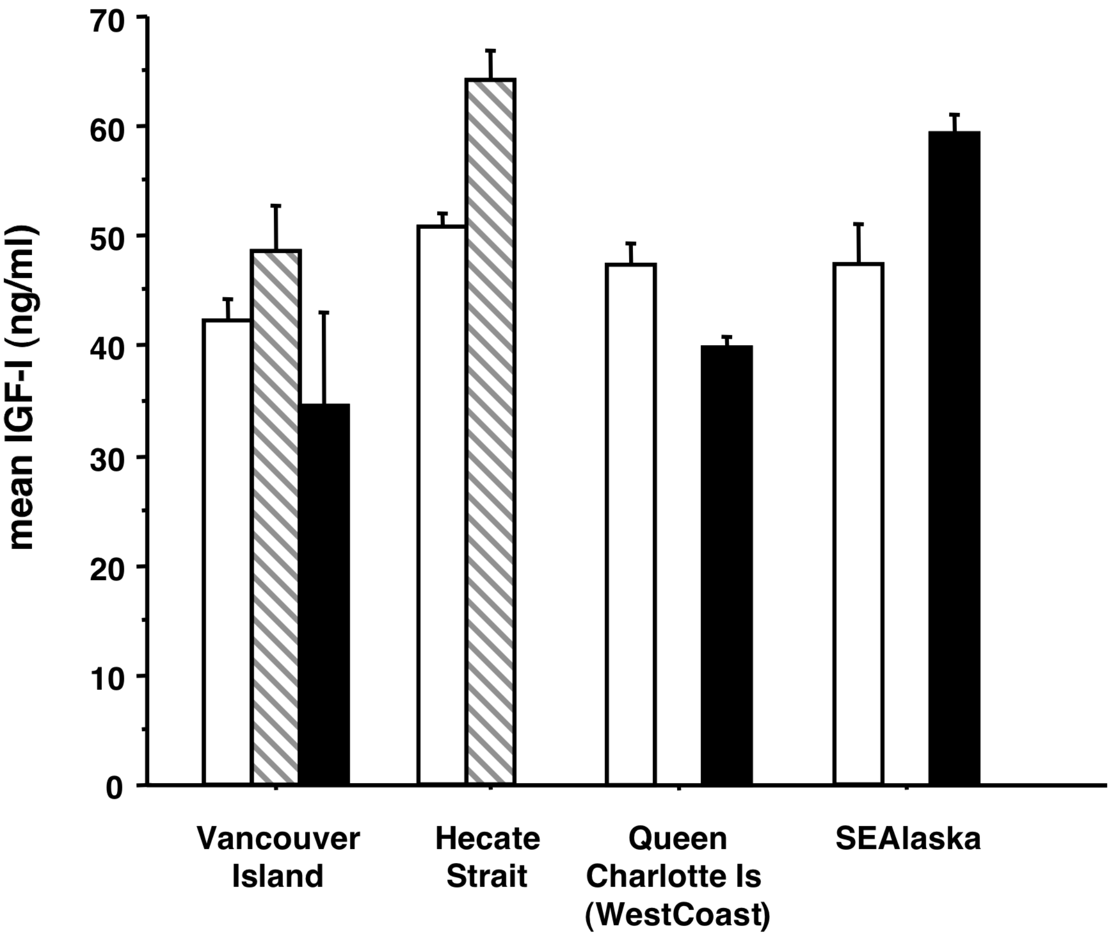


Figure 4. Mean IGF-I level of Columbia River Chinook salmon from different metapopulations caught on the Southern and Northern June 2007 DFO cruises. Open columns represent Snake/Columbia River spring-run Chinook salmon, diagonally striped columns represent up-river fall bright fall Chinook salmon and filled columns represent Willamette River spring-run Chinook salmon.

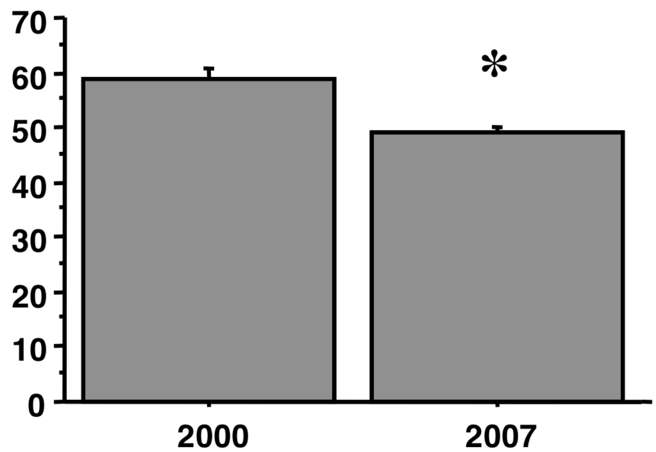


Figure 5. Mean IGF-I level (ng/ml) of coho salmon collected in the waters off northern Washington and the Vancouver Island coast in 2000 and 2007. Levels found in 2007 were significantly lower than found in 2000 ($F=15.8$, $p = 0.002$).