Assessing growth of juvenile salmon in the Strait of Georgia

Brian Beckman[1], Meredith Journey[2], Ruston Sweeting[3], Chrys Neville[3], Marc Trudel[3]

[1]Northwest Fisheries Science Center, NOAA Fisheries, Seattle, WA
206 860-3461, Brian.Beckman@noaa.gov

[2]Frank Orth and Associates, Seattle, WA

[3]Pacific Biological Station, DFO, Nanaimo, BC

Annual Report, Pacific Salmon Commission Southern Fund, Agreement: SF-2012-I-18

Abstract

In the summer of 2012 plasma samples were obtained from juvenile salmon captured during the annual DFO survey of the Strait of Georgia. These samples were used to assess levels of the hormone insulin-like growth factor 1, an index of growth rate for juvenile fish, including salmon. A grand total of 1148 plasma samples were collected. Patterns of IGF1 variation differed across regions and differed between species. IGF1 levels were highest in pink salmon from southeasterly areas: the Gulf Islands and Puget Sound, this was a unique pattern among the 5 species of juvenile salmon sampled. In contrast, coho salmon IGF1 levels were highest in samples from the northern Strait of Georgia – specifically, samples from Desolation Sound and near the Discovery Islands. IGF1 values were low for three of the four species sampled in Queen Charlotte Strait/Johnstone Strait, this was the only region where IGF1 values were consistently low across species. In general there was a positive correlation between pink, chum and sockeye salmon IGF1 values for fish caught in the same set. Similarly, there was a positive correlation between coho and Chinook salmon IGF1 values for fish caught in the same set. There was no correlation between coho and pink nor coho and chum salmon IGF1 values.

Introduction

In the summer of 2012 plasma samples were obtained from juvenile salmon captured during the annual DFO survey of the Strait of Georgia (Beamish et al. 2008, 2010). These samples were used to assess levels of the hormone insulin-like growth factor 1, an index of growth rate for juvenile fish, including salmon (Beckman 2011).

Early marine growth has been shown to relate to survival in a number of studies of juvenile salmon (sockeye salmon (*Oncorhynchus nerka*), Farley et al. 2011, chum salmon (*O. keta*), Healey 1982, Chinook salmon *O. tshawytscha*, Tomaro et al. 2012, and coho salmon (*O. kisutch*), Holtby et al. 1990). Samples collected in 2012 will provide species specific assessments of early ocean growth in the Strait of Georgia for juvenile Chinook, sockeye and coho salmon from the Fraser River and other rivers tributary to the Strait of Georgia. These data will result in development of improved information for resource management, including better stock assessment, data acquisition and improved scientific understanding of factors limiting salmon production in marine environments.

This work represents a collaborative effort between DFO and NOAA Fisheries to better understand how the marine environment regulates salmon productivity and to develop an index of marine salmon survival for salmon stocks that rear in the Strait of Georgia and the greater Salish Sea.

Methods

Survey: Figures 1 shows the regional areas in which samples were obtained: Strait of Georgia (SOG), Queen Charlotte Strait/JohnstoneStrait (QCS/JS) and Puget Sound (PS). Figure 2 shows specific trawl sites in the SOG and the physical characters of these sites are described in Table 1. DFO survey techniques for the capture of salmon in the Strait of Georgia have been described in Beamish et al. (2008). Briefly, juvenile salmon were obtained from surface trawls conducted throughout the Strait of Georgia. Salmon were removed from the trawl, placed on crushed ice and bled within 45 minutes of the trawl coming on board using a heparinized syringe.

Blood processing and hormone analysis: 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 –80^{o}C freezer until the samples are assayed by TRF-immune assay according to a modification of the methods of Small and Peterson (2005).

Results

A grand total of 1148 plasma samples were obtained from juvenile salmon in the summer of 2012 for analysis of the hormone IGF1. Samples were obtained from Queen Charlotte/Johnstone Strait (QCS/JS), the Strait of Georgia (SOG) and Puget Sound (PS). Samples were relatively evenly distributed between coho, Chinook, sockeye, pink and chum salmon. Most samples (913, 80%) were obtained from SOG, the focus of the PSC funded study (Tables 1, 2 and 3).

Coho salmon IGF1 values were highest in the northern regions of SOG, including Desolation Sound, Discovery Island, and NSOG. Lower levels were found in the Malaspina and Gulf Island regions of SOG; in addition, lower levels were also found in PS and the lowest levels were found in QCS/JS (Table 4, Figure 3 and 8).

Chinook salmon IGF1 values varied between 60 and 75 ng/ml across SOG, with no significant different differences between regions. Values found in PS were significantly lower than found in SOG (Table 4, Figure 4 and 8).

Sockeye salmon IGF1 values varied from 25 to 55 ng/ml across the sampling region. No significant differences were found between regions; however, note that the small sample size associated with quite low values in QCS/JS precluded any statistical test of significance (Table 4, Figure 5 and 8).

Chum salmon IGF1 values varied between 35 and 45 ng/ml across the SOG, with no significant difference found between regions. Chum salmon IGF1 values from fish sampled in QCS/JS averaged about 30 ng/ml and were significantly less than found in most regions across SOG (Table 4, Figure 6 and 8).

Pink salmon IGF1 values varied significantly across SOG, PS and QCS/JS. Highest values were found in the Gulf Islands, Southern SOG and Puget Sound. The lowest values were found in QCS/JS (Table 4, Figure 7 and 8).

Patterns of IGF1 variation differed across regions and differed between species (Figure 8). IGF1 values were low for three of the four species sampled in QCS/JS, this was the only region where IGF1 values were consistently low across species. IGF1 levels were highest in pink salmon from southeasterly areas: the Gulf Islands and PS, this was a unique pattern among the 5 species of juvenile salmon sampled. In contrast, coho salmon IGF1 levels were highest in samples from the northern SOG – specifically, samples from Desolation Sound and near the Discovery Islands. Chinook salmon IGF1 levels were unique in having low values for fish sampled in PS.

In general there was a positive correlation between pink, chum and sockeye salmon IGF1 values for fish caught in the same set (Table 5). Similarly, there was a positive correlation between coho and Chinook salmon IGF1 values for fish caught in the same set. There was no correlation between coho and pink nor coho and chum salmon IGF1 values.

Finally, it was possible to compare coho salmon IGF1 values for samples obtained in 2000 and 2001 in the Southern SOG to those obtained in the present study (Table 6). Values obtained in 2012 were significantly higher than found in either 2000 or 2001.

Discussion

This initial survey of summer growth rates of juvenile salmon in the Strait of Georgia generated several findings worthy of note, including both 1) variation in growth across the region within each species and 2) differences in spatial variation between the species examined.

The growth of both juvenile coho and pink salmon varied considerably across the Strait of Georgia. However, this variation occurred in an opposing manner. Values for coho salmon were high in the Northern SOG, Desolation Sound and Discovery Island and low in the Gulf Islands while values for pink salmon were high in the Gulf Islands and Southern SOG and lower in the Northern SOG and Desolation Sound. These data suggest regional differences in prey abundance in the Strait of Georgia as differences in food consumption are one of the main drivers of differences in IGF1. However, these data then also suggest coho and pink salmon are exploiting differing spectrums of the prey field as high and low growth rates are found in different regions for these two species. This suggestion is supported by other studies that have found that juvenile coho salmon tend to eat small juvenile fish and larger zooplankton (euphausiids, crab larvae, amphipods) while juvenile pink salmon tended to eat smaller copepods and soft-bodied zooplankton (larvaceans) (Brodeur et al. 2007). Definitive conclusions would require both examination of the stomach contents of these salmon species and sampling of the zooplankton community.

The general concordance in pink, chum and sockeye salmon growth rates provide additional data to support the speculation that zooplankton communities differ across the SOG. Pink, chum and sockeye salmon all consume relatively small zooplankton that occur at a relatively lower trophic level than the small fish that coho and Chinook salmon consume (Brodeur et al. 2007).

Beyond the SOG, IGF1 levels suggest depressed growth occurs in the QCS/JS region, with coho, pink and chum salmon IGF1 levels all relatively low in this area. Furthermore, sockeye salmon IGF1 levels were low, but not enough individuals were caught to form any statistically robust conclusions. The mechanism(s) generating the low growth rates found in QCS/SJ await further investigation. However, it is notable that this was the only region in which low growth rates were found across four salmon species.

Limited sampling also occurred in PS during 2013. Contrasting values with the SOG were found, with low levels of IGF1 in juvenile Chinook salmon and high levels in juvenile pink salmon. It is interesting to note the similarly high IGF1 levels in pink salmon across the Southern SOG, Gulf Islands and PS. Overall, differences in juvenile salmon growth within the SOG as well as contrasting differences with QCS/SJ and PS emphasize the heterogeneity of the marine environment of the Salish Sea and suggest that significant differences in productivity and/or zooplankton community structure exist within this area. Continued sampling coupled with studies of food habits and zooplankton analysis will be needed to understand this variation.

If juvenile salmon growth is related to subsequent survival, as has been found in other studies (Farley et al. 2011, Healey 1982, Holtby et al. 1990, Tomaro et al. 2012) these data suggest that relative survival of pink and coho salmon will vary across the SOG, with coho salmon surviving better in Northern regions of the SOG and pink salmon better in Southern regions. However, we can't make any definitive conclusions about differences in regional survival without knowledge of the relative mixing of different stocks within the SOG and the relative abundance of coho and pink salmon juveniles in different regions.

Acknowledgements

Thanks to those that collected and processed plasma samples: Deb Harstad (QCS) and Correigh Greene (PS).

References

Beamish, R.J., Sweeting, R.M., Lange, K.L., and C.M. Neville. 2008. Changes in the population ecology of hatchery and wild coho salmon in the Strait of Georgia. Trans. Am. Fish. Soc. 137-503-520.

Beamish, R.J., Sweeting, R.M., Lange, K.L., Noakes, D.J., Preikshot, D., and Neville, C.M. 2010. Early marine survival of coho salmon in the Strait of Georgia declines to very low levels. Mar. Coast. Fish. 2:424-439.

Beckman, B.R. 2011. Perspectives on concordant and discordant relations between insulin-like growth factor 1 and growth in fishes. Gen. Comp. Endocrinol. 170:233-252.

Brodeur, R.D., Daly, E.A., Sturdevant, M.V., Miller, T.W., Moss, J.H., Thiess, M.E., Trudel, M., Weitkamp, L.A., Armstrong, J., Norton, E.C. 2007. Regional comparisons of juvenile salmon feeding in coastal marine waters off the west coast of North America. In: Grimes, C.B., Brodeur, R.D., Haldorson, L.J., McKinnell S.M. (eds) American Fisheries Society Symposium, Book 57. Amer Fisheries Soc, 5410 Grosvenor Lane, Ste 110, Bethesda, Md 20814-2199 USA.

Farley E.V., Starovoytov A., Naydenko S., Heintz R., Trudel M., Guthrie C., Eisner L., Guyon J.R. 2011. Implications of a warming eastern Bering Sea for Bristol Bay sockeye salmon. ICES J Mar Sci 68:1138-1146.

Healey M.C.1982. Timing and relative intensity of size-selective mortality of juvenile chum salmon (*Oncorhynchus keta*) during early sea life Can. J. Fish. Aquat. Sci. 39:952-957

Holtby, L.B., Andersen, B.C., Kadowaki, R.K. 1990. Importance of smolt size and early ocean growth to interannual variability in marine survival of coho salmon (Oncohynuchus kisutch) Can. J. Fish. Aquat. Sci. 47:2181-2194

Small, B.C. and B.C. Peterson. 2005. Establishment of a time-resolved fluroimmunoassay for measuring plasma insulin-like growth factor I (IGF-I) in fish: effect of fasting on plasma concentrations and tissue mRNA expression of IGF-I and growth hormone (GH) in channel catfish (Ictalurus punctatus). Dom. Anim. Endocrinol. 28:202-215.

Tomaro, L.M., Teel, D.J., Peterson, W.T., Miller, J.A. 2012. When is bigger better? Early marine residence of middle and upper Columbia River spring Chinook salmon. Mar. Ecol-Prog. Ser. 452:237-252.

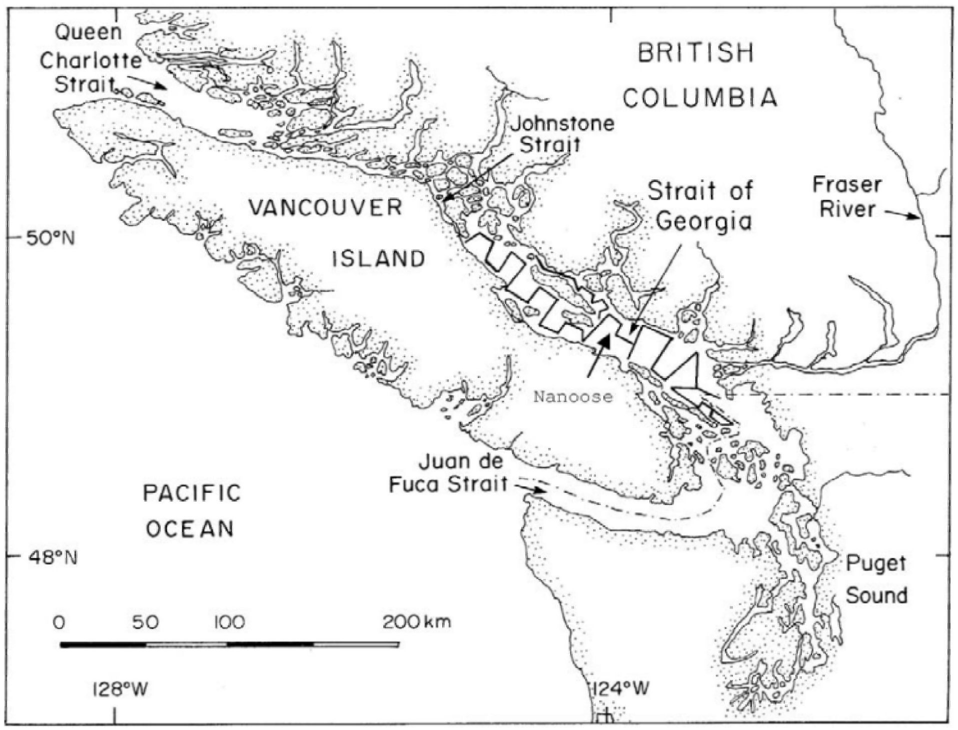

Figure 1. A map of the regions in which IGF1 values were measured from juvenile salmon in July 2012, including the Strait of Georgia, Puget Sound, Queen Charlotte Strait and Johnstone Strait.

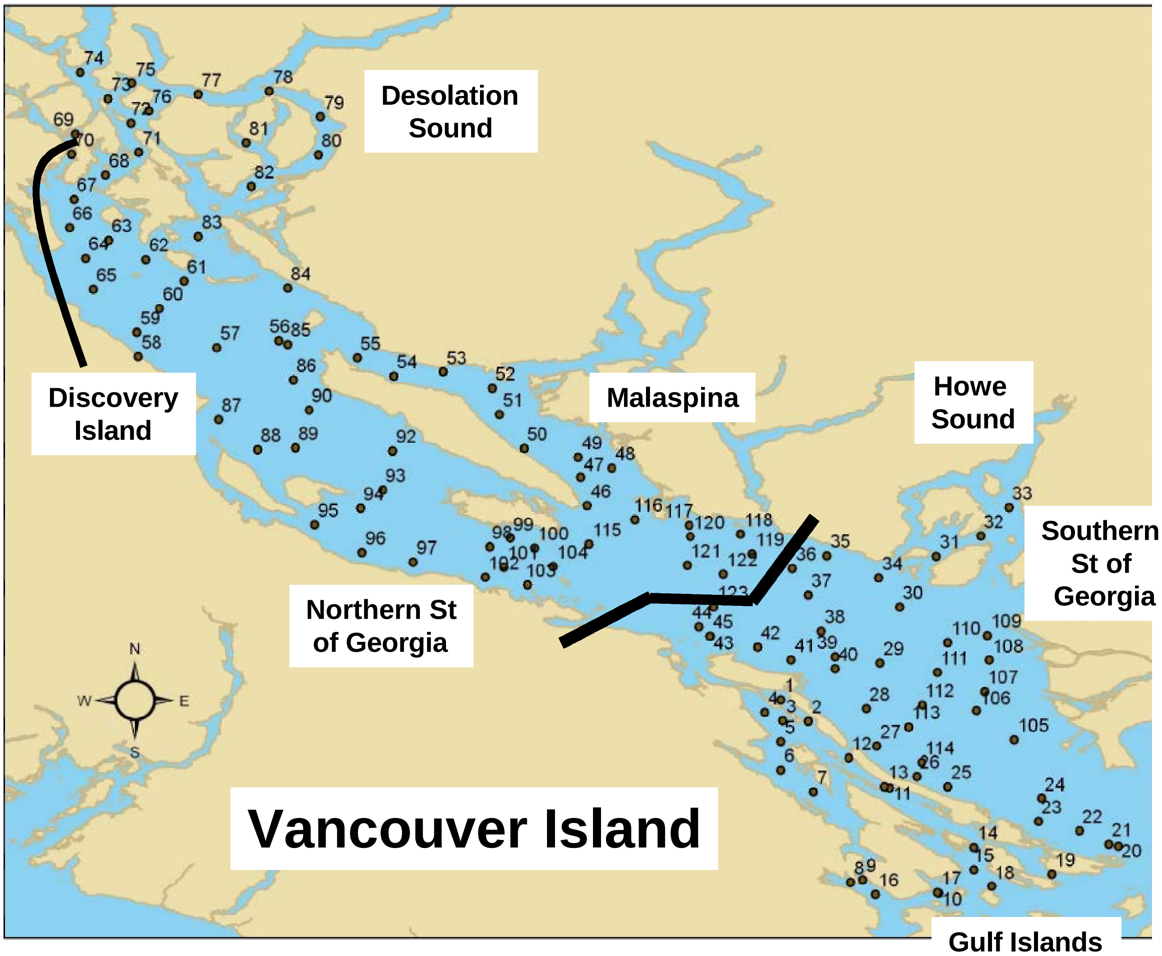

Figure 2. A map of the Strait of Georgia showing where trawls for juvenile salmon occurred in July of 2012. Each trawl is given a set number and these numbers match those found in Tables 1, 2 and 4. Northern and Southern Strait of Georgia are delineated by a dashed line and based on Beamish et al. 2000.

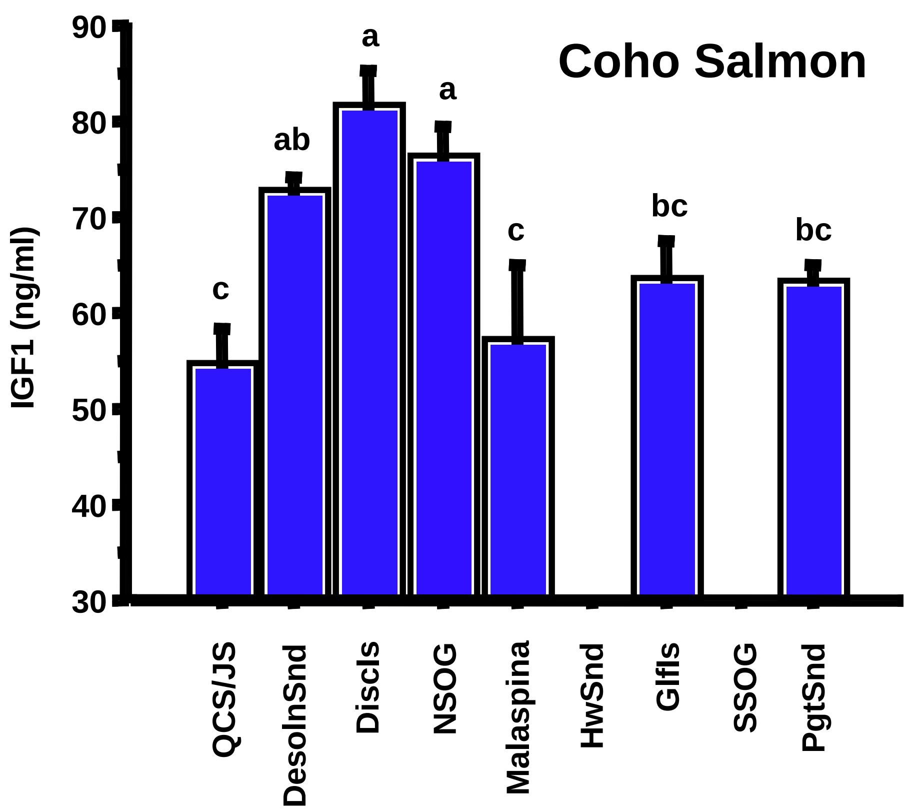

Figure 2. Mean IGF1 values (+ se) of juvenile coho salmon collected from Queen Charlotte Strait (QCS), several locations in the Strait of Georgia and Puget Sound (PgtSnd). Means were generated from the mean IGF1 value of sets within each region. Columns with differing letters above them are significantly different ($p < 0.05$).

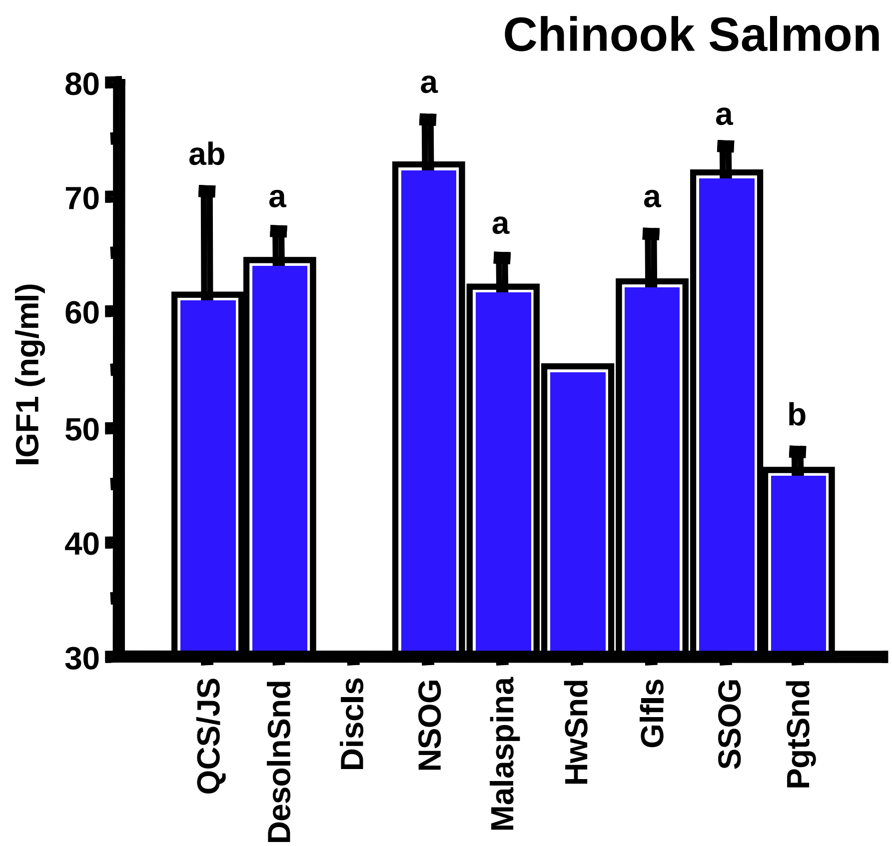

Figure 3. Mean IGF1 values (+ se) of juvenile Chinook salmon collected from Queen Charlotte Strait (QCS), several locations in the Strait of Georgia and Puget Sound (PgtSnd). Means were generated from the mean IGF1 value of sets within each region. Columns with differing letters above them are significantly different ($p < 0.05$).

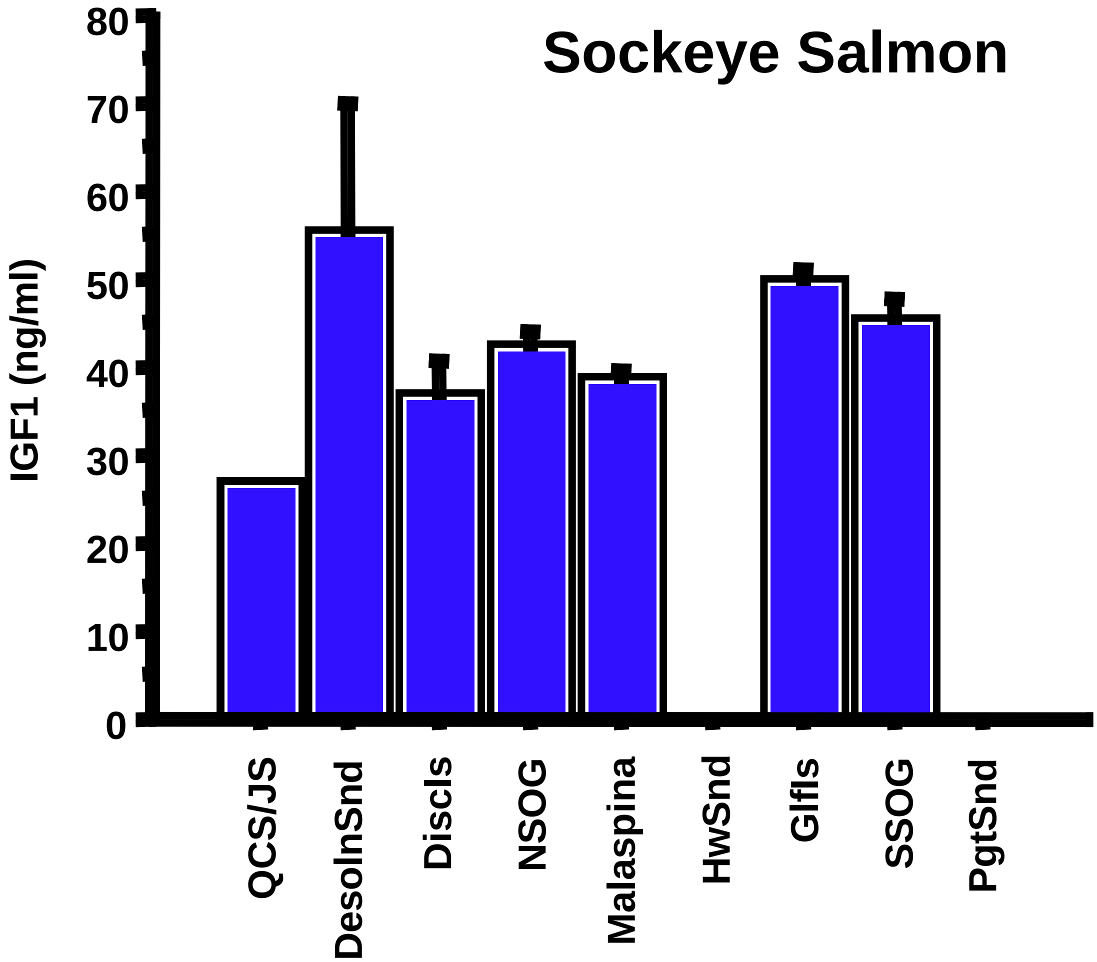

Figure 4. Mean IGF1 values (+ se) of juvenile sockeye salmon collected from Queen Charlotte Strait (QCS), several locations in the Strait of Georgia and Puget Sound (PgtSnd). Means were generated from the mean IGF1 value of sets within each region. No significant differences in IGF1 values between regions were found ($p > 0.05$).

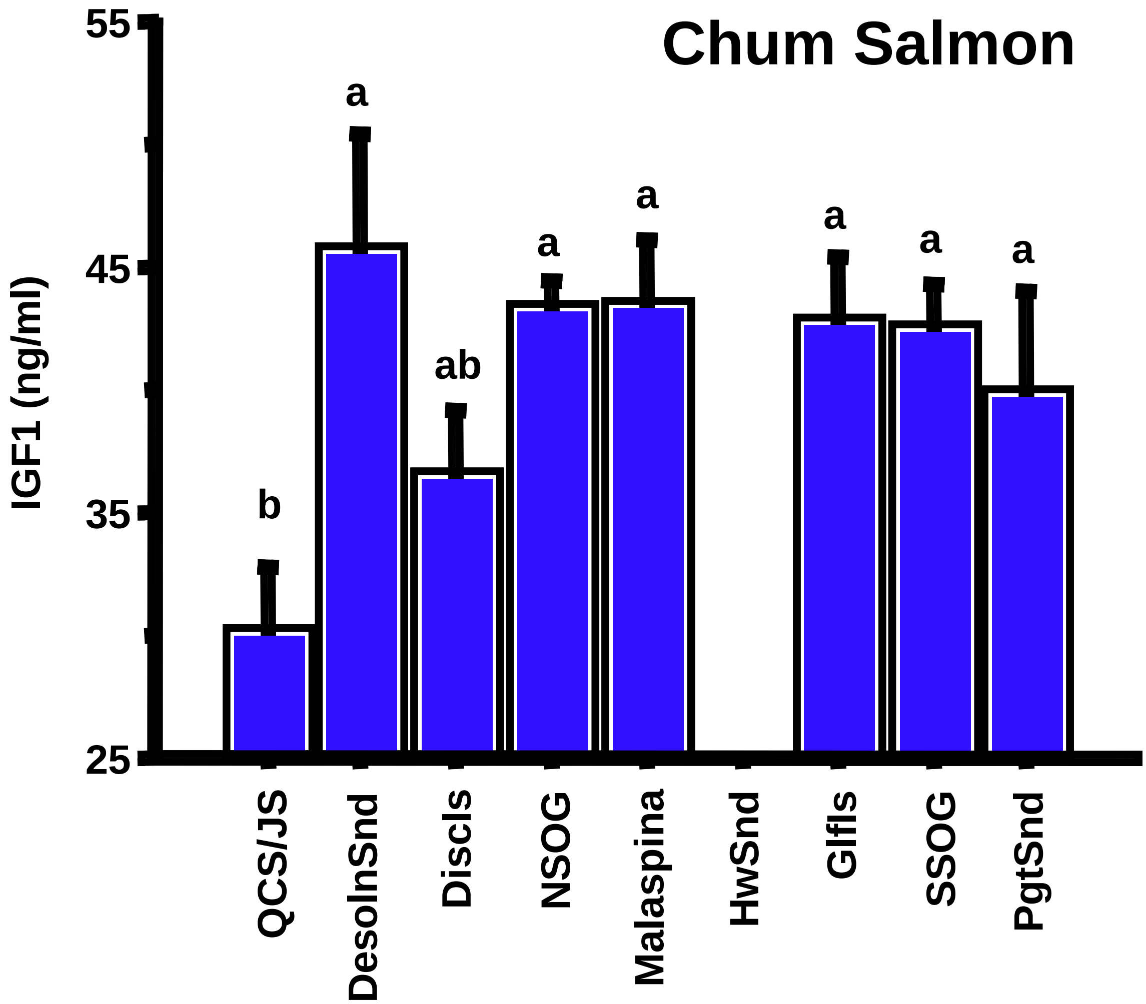

Figure 5. Mean IGF1 values (+ se) of juvenile chum salmon collected from Queen Charlotte Strait (QCS), several locations in the Strait of Georgia and Puget Sound (PgtSnd). Means were generated from the mean IGF1 value of sets within each region. Columns with differing letters above them are significantly different ($p < 0.05$).

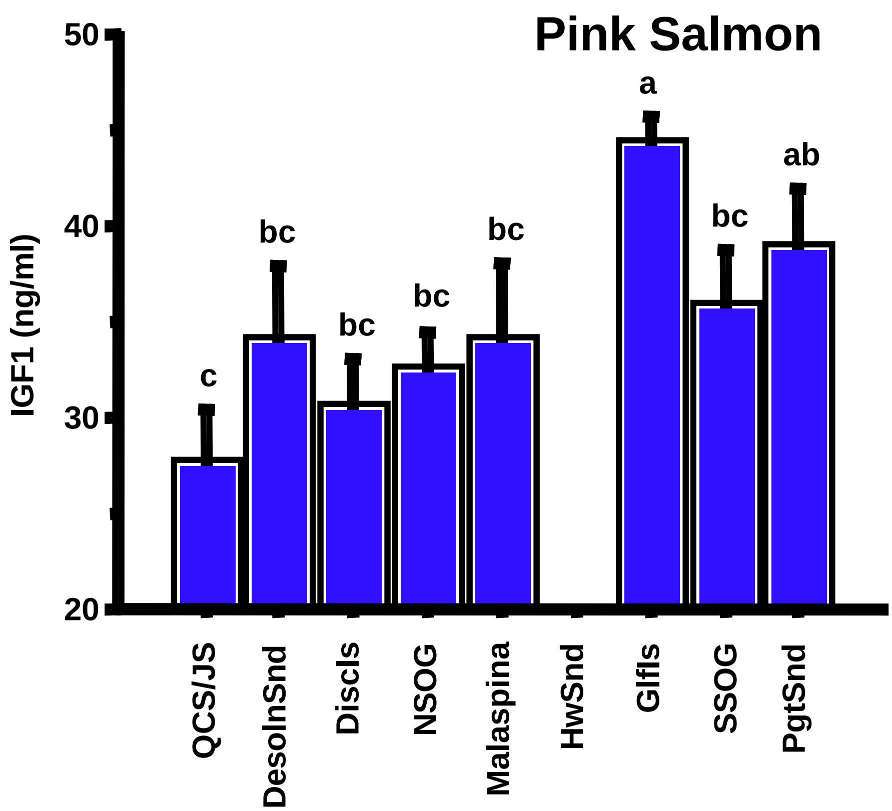

Figure 6. Mean IGF1 values (+ se) of juvenile pink salmon collected from Queen Charlotte Strait (QCS), several locations in the Strait of Georgia and Puget Sound (PgtSnd). Columns with differing letters above them are significantly different ($p < 0.05$). Means were generated from the mean IGF1 value of sets within each region.

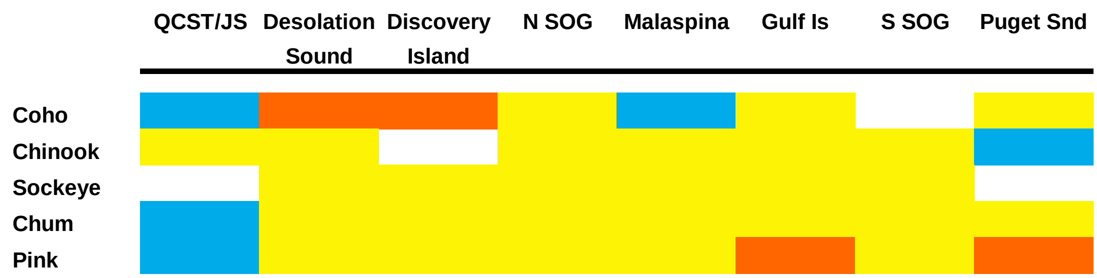

Figure 6. A stoplight chart displaying spatial differences in growth of juvenile salmon (as assessed by plasma IGF1 levels) among regions. IGF1 levels of regions in orange were significantly greater than intermediate regions (yellow), IGF1 levels of regions in blue were significantly less than found in intermediate regions. Regions are arrayed from Northwest (Queen Charlotte Strait) to Southeast (Puget Sound) across the Strait of Georgia. Areas of no color indicate insufficient data.

Table 1. Characteristics of stations where juvenile salmon were sampled for plasma IGF1. Samples were obtained during both the DFO survey of the Strait of Georgia (RV Ricker) and during the DFO survey of the West Coast of Vancouver island (FV Viking Storm) in July of 2012.

Month	Day	Year	Area	Location	Set #	depth	Lat	Long	temp
6	21	2012	Gulf Islands	Pylades Channel	2	49	49.065	123.673	9.9
6	21	2012	Gulf Islands	Stuart Channel	4	58	49.083	123.759	11
6	21	2012	Gulf Islands	Stuart Channel	6	65	48.969	123.727	12.2
6	21	2012	Gulf Islands	Stuart Channel	7	104	48.926	123.663	12.9
6	22	2012	Gulf Islands	Cowichan Bay	8	56	48.746	123.588	10.9
6	22	2012	Gulf Islands	Sansum Narrows	9	69	48.752	123.564	11.8
6	22	2012	gulf islands	Satellite Channel	10	76	48.726	123.414	11
6	22	2012	Gulf Islands	Trincomali Chan	11	40	48.935	123.512	12.5
6	22	2012	Gulf Islands	Trincomali Chan	12	62	48.993	123.592	11.4
6	22	2012	Gulf Islands	Swanson Channel	14	85	48.816	123.344	12.1
6	22	2012	Gulf Islands	Swanson Channel	15	94	48.772	123.344	10.2
6	23	2012	Gulf Islands	Satellite Channel	16	94	48.723	123.540	10.8
6	23	2012	Gulf Islands	Satellite Channel	17	96	48.727	123.416	11.3
6	23	2012	Gulf Islands	Plumber Snd	19	87	48.763	123.190	10.8
6	23	2012	SSOG	N East pt	20	180	48.819	123.059	11
6	23	2012	SSOG	N East pt	21	214	48.822	123.077	10.5
6	23	2012	SSOG	Bell Chain Islets	22	199	48.848	123.135	10.2
6	24	2012	SSOG	Galiano Island	25	167	48.937	123.396	10.3
6	24	2012	SSOG	Galiano Island	27	185	49.017	123.536	10.8
6	24	2012	Howe Sound	Collingwood Channel	31	164	49.392	123.418	12.6
6	24	2012	Howe Sound	Hope pt	32	241	49.433	123.331	10.5
6	25	2012	SSOG	Roberts Creek	35	152	49.394	123.635	12.3
6	25	2012	SSOG	White Is/Halibut Bank	36	165	49.369	123.703	9.8
6	25	2012	SSOG	Halibut Bank	37	173	49.316	123.672	12.1
6	25	2012	SSOG	Thrasher Rock	40	207	49.171	123.620	12.8
6	25	2012	SSOG	Gabriola Isl	41	201	49.187	123.706	12.2
6	25	2012	SSOG	Entrance Island	42	83	49.213	123.773	12.5
6	25	2012	SSOG	Snake Is	44	252	49.253	123.889	11
6	25	2012	SSOG	Snake Is	45	140	49.234	123.867	12.6
6	26	2012	Malaspina		46	366	49.493	124.111	14.4
6	26	2012	Malaspina		47	370	49.550	124.124	11.3
6	26	2012	Malaspina		48	151	49.567	124.062	9.3
6	26	2012	Malaspina		49	270	49.588	124.128	14.4
6	26	2012	Malaspina		50	218	49.607	124.235	12.5
6	26	2012	Malaspina		51	365	49.674	124.284	11.5
6	26	2012	Malaspina	Mcrae Islet	52	134	49.726	124.298	15.4
6	26	2012	Malaspina	Albion Pt	53	88	49.758	124.396	15.5
6	26	2012	Malaspina	Raven Bay	54	168	49.749	124.493	11.6
6	26	2012	Malaspina		55	303	49.786	124.566	10.5
6	27	2012	NSOG	Harwood Island	56	139	49.820	124.721	14
6	27	2012	NSOG	E Cape Lazo	57	333	49.806	124.844	13.8

Table 1. continued

Month	Day	Year	Area	Location	Set #	depth	Lat	Long	temp
6	27	2012	NSOG	Kitty Coleman	58	55	49.789	125.000	11.2
6	27	2012	NSOG	Conawaga Beach	59	114	49.837	125.003	10
6	27	2012	NSOG	Montgomery Bank	60	182	49.884	124.958	10.9
6	27	2012	NSOG	Savory Island	61	47	49.938	124.909	16.7
6	27	2012	NSOG	Mitlenatch is	62	152	49.981	124.985	13.7
6	27	2012	NSOG	Wilby Shoals	64	79	49.984	125.103	11.3
6	28	2012	Discovery Is	Sutlil Channel	66	213	50.043	125.137	15.5
6	28	2012	Discovery Is	Sutlil Channel	67	259	50.099	125.128	11.8
6	28	2012	Discovery Is	Sutlil Channel	68	348	50.148	125.064	15.1
6	28	2012	Discovery Is	Settlers Group	69	87	50.229	125.125	12.9
6	28	2012	Discovery Is	Sheer Pt	70	113	50.189	125.133	16.1
6	28	2012	Discovery Is	Sutlil Channel	71	512	50.193	124.999	15.2
6	28	2012	Discovery Is	Sutlil channel	72	456	50.251	125.014	14.9
6	28	2012	Discovery Is	Raza Pass	75	286	50.329	125.013	14.2
6	29	2012	Desolation Sound	Deer Pass	76	502	50.275	124.980	13.8
6	29	2012	Desolation Sound	N Homfray Ch	78	452	50.313	124.740	15
6	29	2012	Desolation Sound	Momfrey Ch	79	724	50.263	124.638	16.1
6	29	2012	Desolation Sound	Momfrey Ch	80	719	50.188	124.643	16.6
6	29	2012	Desolation Sound	Allies Is	81	279	50.212	124.786	16.7
6	29	2012	Desolation Sound		82	418	50.125	124.776	16.6
6	29	2012	Desolation Sound	Powell Islets	83	265	50.026	124.881	17.3
6	30	2012	NSOG	N. end Texada	85	130	49.812	124.704	15.1
6	30	2012	NSOG	NW Texada	86	358	49.742	124.693	15.5
6	30	2012	NSOG	btwn Hornby-Ajax Bank	89	138	49.607	124.689	13.1
6	30	2012	NSOG	Exeter Shore	90	182	49.682	124.662	10.6
6	30	2012	NSOG	Mouat Bay	91	354	49.661	124.566	15.2
6	30	2012	NSOG	Mouat Bay	92	253	49.601	124.495	11.3
6	30	2012	NSOG	Achilles Bank	93	201	49.524	124.515	10.8
7	1	2012	NSOG	S Hornby Is	94	119	49.488	124.560	12.6
7	1	2012	NSOG	S Hornby Is	95	69	49.455	124.650	11.5
7	1	2012	NSOG	Qualicum	96	68	49.400	124.557	10.6
7	1	2012	NSOG	Qualicum	97	92	49.381	124.455	12.7
7	1	2012	NSOG	Seal Reef	99	248	49.428	124.263	11.4
7	1	2012	NSOG	Sanster Is	100	318	49.409	124.215	13.6
7	1	2012	NSOG	French Creek	101	283	49.372	124.275	11.2
7	1	2012	NSOG	Parksville	102	73	49.352	124.312	13.4
7	1	2012	NSOG	Mistaken Is	103	189	49.336	124.229	10.1
7	1	2012	NSOG	Ballenas Is	104	334	49.373	124.177	11.8
7	2	2012	SSOG	Iona Is	109	166	49.236	123.318	12.8
7	2	2012	SSOG	Iona is	110	282	49.221	123.396	10.3
7	2	2012	SSOG	Iona is	111	234	49.162	123.416	13.5

Table 1. continued

Month	Day	Year	Area	Location	Set #	depth	Lat	Long	temp
7	2	2012	SSOG	iona is	111	234	49.162	123.416	13.5
7	2	2012	SSOG	TA Bouy	113	326	49.055	123.474	11.7
7	3	2012	NSOG	Young Pt	115	175	49.417	124.107	
7	3	2012	NSOG	Thormamby Is	116	167	49.465	124.015	9.7
7	3	2012	NSOG	Merry Is	117	228	49.454	123.908	9.6
7	3	2012	NSOG	Trail Is	118	194	49.437	123.807	10.5
7	3	2012	NSOG	Halibut Bank	119	114	49.398	123.784	10.3
7	3	2012	NSOG	Merry Is	120	214	49.432	123.906	12.8
7	3	2012	NSOG		121	392	49.375	123.913	9.4
7	3	2012	NSOG	North of Nanaimo	122	398	49.358	123.841	12.5
		2012	PS	CentralPugetSound	157		47.000	122.000	
		2012	PS	CentralPugetSound	158		47.000	122.000	
		2012	PS	CentralPugetSound	159		47.000	122.000	
		2012	PS	CentralPugetSound	160		47.000	122.000	
		2012	PS	CentralPugetSound	162		47.000	122.000	
		2012	PS	CentralPugetSound	163		47.000	122.000	
7	15	2012	JS		JS01		50.6	126.820	10.12
7	15	2012	JS		JS02		50.5	126.633	10.45
7	15	2012	JS		JS03		50.5	126.436	9.95
7	15	2012	JS		JS04		50.5	126.245	10.43
7	15	2012	JS		JS05		50.5	126.060	10.00
7	15	2012	JS		JS06		50.4	125.999	10.28
7	12	2012	QCST		QCST04		50.9	127.298	9.90
7	12	2012	QCST		QCST05		50.8	127.375	10.30
7	13	2012	QCST		QCST06		50.8	127.505	11.06
7	13	2012	QCST		QCST07		50.8	127.690	10.50
7	13	2012	QCST		QCST08		50.7	127.321	10.80
7	13	2012	QCST		QCST10		50.8	127.155	10.97
7	13	2012	QCST		QCST11		50.8	126.993	10.40
7	14	2012	QCST		QCST12		50.7	127.205	9.28
7	14	2012	QCST		QCST13		50.7	127.098	10.73
7	14	2012	QCST		QCST14		50.7	126.951	11.09
7	14	2012	QCST		QCST15		50.8	126.844	10.52
7	14	2012	QCST		QCST16		50.7	126.777	9.71
7	14	2012	QCST		QCST17		50.6	126.806	10.95

Table 2. Numbers of juvenile salmon obtained for plasma IGF1 analysis during the summer of 2012. Samples were obtained during both the DFO survey of the Strait of Georgia (RV Ricker) and during the DFO survey of the West Coast of Vancouver Island (FV Viking Storm).

							#samples				
Month	Day	Year	Area	Set #	Lat	Long	coho	chinook	sockeye	chum	pink
6	21	2012	Gulf Islands	2	49.065	123.673		5			
6	21	2012	Gulf Islands	4	49.083	123.759	4	5	5		
6	21	2012	Gulf Islands	6	48.969	123.727	6				
6	21	2012	Gulf Islands	7	48.926	123.663	4				7
6	22	2012	Gulf Islands	8	48.746	123.588	6	5	5	5	5
6	22	2012	Gulf Islands	9	48.752	123.564	3	5			
6	22	2012	Gulf Islands	10	48.726	123.414			5	5	4
6	22	2012	Gulf Islands	11	48.935	123.512		3	6		
6	22	2012	Gulf Islands	12	48.993	123.592					
6	22	2012	Gulf Islands	14	48.816	123.344		9			
6	22	2012	Gulf Islands	15	48.772	123.344		2	5	5	5
6	23	2012	Gulf Islands	16	48.723	123.540		5	5	5	5
6	23	2012	Gulf Islands	17	48.727	123.416		6	5	5	
6	23	2012	Gulf Islands	19	48.763	123.190			5	4	5
6	23	2012	SSOG	20	48.819	123.059		4		5	
6	23	2012	SSOG	21	48.822	123.077		5			
6	23	2012	SSOG	22	48.848	123.135		5			
6	24	2012	SSOG	25	48.937	123.396		6			
6	24	2012	SSOG	27	49.017	123.536		7			
6	24	2012	Howe Sound	31	49.392	123.418		4			
6	24	2012	Howe Sound	32	49.433	123.331					
6	25	2012	SSOG	35	49.394	123.635		7			
6	25	2012	SSOG	36	49.369	123.703		3		5	7
6	25	2012	SSOG	37	49.316	123.672		2			
6	25	2012	SSOG	40	49.171	123.620			3	6	5
6	25	2012	SSOG	41	49.187	123.706				2	5
6	25	2012	SSOG	42	49.213	123.773		5	4	4	
6	25	2012	SSOG	44	49.253	123.889		5	4	2	
6	25	2012	SSOG	45	49.234	123.867		3	4	3	3
6	26	2012	Malaspina	46	49.493	124.111	6	5	3		5
6	26	2012	Malaspina	47	49.550	124.124		7			
6	26	2012	Malaspina	48	49.567	124.062		2			
6	26	2012	Malaspina	49	49.588	124.128	3	3	6	5	
6	26	2012	Malaspina	50	49.607	124.235		6	7	4	
6	26	2012	Malaspina	51	49.674	124.284		4	7		
6	26	2012	Malaspina	52	49.726	124.298	2	2		2	9
6	26	2012	Malaspina	53	49.758	124.396	3			6	4
6	26	2012	Malaspina	54	49.749	124.493					
6	26	2012	Malaspina	55	49.786	124.566	5				

Table 2. continued

Month	Day	Year	Area	Set #	Lat	Long	#samples coho	chinook	sockeye	chum	pink
6	27	2012	NSOG	56	49.820	124.721	6				
6	27	2012	NSOG	57	49.806	124.844			5	5	
6	27	2012	NSOG	58	49.789	125.000			6	6	4
6	27	2012	NSOG	59	49.837	125.003			2	5	
6	27	2012	NSOG	60	49.884	124.958			5		
6	27	2012	NSOG	61	49.938	124.909	6	6	3		
6	27	2012	NSOG	62	49.981	124.985			7		
6	27	2012	NSOG	64	49.984	125.103	2		1	6	4
6	28	2012	Discovery Is	66	50.043	125.137	4		6	5	
6	28	2012	Discovery Is	67	50.099	125.128			8		
6	28	2012	Discovery Is	68	50.148	125.064			5	3	4
6	28	2012	Discovery Is	69	50.229	125.125			2	3	
6	28	2012	Discovery Is	70	50.189	125.133	5			4	3
6	28	2012	Discovery Is	71	50.193	124.999			3	2	
6	28	2012	Discovery Is	72	50.251	125.014			4		8
6	28	2012	Discovery Is	75	50.329	125.013	6			2	5
6	29	2012	Desolation Sound	76	50.275	124.980		2	4	2	3
6	29	2012	Desolation Sound	78	50.313	124.740	7			2	2
6	29	2012	Desolation Sound	79	50.263	124.638	5	2	2	4	2
6	29	2012	Desolation Sound	80	50.188	124.643	6				3
6	29	2012	Desolation Sound	81	50.212	124.786		4			4
6	29	2012	Desolation Sound	82	50.125	124.776		8	2		
6	29	2012	Desolation Sound	83	50.026	124.881	2	5	6		
6	30	2012	NSOG	85	49.812	124.704	7	4			
6	30	2012	NSOG	86	49.742	124.693	5		3		
6	30	2012	NSOG	89	49.607	124.689	5		7	5	
6	30	2012	NSOG	90	49.682	124.662	4				
6	30	2012	NSOG	91	49.661	124.566	5	3	6	3	
6	30	2012	NSOG	92	49.601	124.495			2		
6	30	2012	NSOG	93	49.524	124.515					
7	1	2012	NSOG	94	49.488	124.560	8				
7	1	2012	NSOG	95	49.455	124.650	3	5			5
7	1	2012	NSOG	96	49.400	124.557	5	7			
7	1	2012	NSOG	97	49.381	124.455	6	4	6	6	
7	1	2012	NSOG	99	49.428	124.263	5	8	2		
7	1	2012	NSOG	100	49.409	124.215	3	6			2
7	1	2012	NSOG	101	49.372	124.275		4	8		
7	1	2012	NSOG	102	49.352	124.312			3	10	3

Table 2. continued

Month	Day	Year	Area	Set #	Lat	Long	coho	chinook	sockeye	chum	pink
							#samples				
7	1	2012	NSOG	103	49.336	124.229				5	
7	1	2012	NSOG	104	49.373	124.177			5		
7	2	2012	SSOG	109	49.236	123.318		8			
7	2	2012	SSOG	110	49.221	123.396		9			
7	2	2012	SSOG	111	49.162	123.416		7			
7	2	2012	SSOG	113	49.055	123.474					
7	3	2012	NSOG	115	49.417	124.107	6	6	6		
7	3	2012	NSOG	116	49.465	124.015	2				
7	3	2012	NSOG	117	49.454	123.908		1			
7	3	2012	NSOG	118	49.437	123.807	4	7	3		3
7	3	2012	NSOG	119	49.398	123.784		6	8		
7	3	2012	NSOG	120	49.432	123.906	4	2	5	3	4
7	3	2012	NSOG	121	49.375	123.913	4	3	3	5	6
7	3	2012	NSOG	122	49.358	123.841	6			2	
7	7	2012	Puget Snd	157			5	5			
7	7	2012	Puget Snd	158			5	4		10	10
7	7	2012	Puget Snd	159			2	7		4	3
7	7	2012	Puget Snd	160			9	10		5	5
7	7	2012	Puget Snd	162				7		10	
7	7	2012	Puget Snd	163				10		2	2
7	15	2012	JS	JS01	50.6	126.820				4	5
7	15	2012	JS	JS02	50.5	126.633				2	
7	15	2012	JS	JS03	50.5	126.436				4	5
7	15	2012	JS	JS04	50.5	126.245					5
7	15	2012	JS	JS05	50.5	126.060	4				5
7	15	2012	JS	JS06	50.4	125.999	5	3			
7	12	2012	QCST	QCST04	50.9	127.298				2	
7	12	2012	QCST	QCST05	50.8	127.375	4			5	5
7	13	2012	QCST	QCST06	50.8	127.505	9	3			
7	13	2012	QCST	QCST07	50.8	127.690					
7	13	2012	QCST	QCST08	50.7	127.321			5	5	5
7	13	2012	QCST	QCST10	50.8	127.155					6
7	13	2012	QCST	QCST11	50.8	126.993				2	
7	14	2012	QCST	QCST12	50.7	127.205				4	4
7	14	2012	QCST	QCST13	50.7	127.098				5	5
7	14	2012	QCST	QCST14	50.7	126.951		2		5	5
7	14	2012	QCST	QCST15	50.8	126.844				4	5
7	14	2012	QCST	QCST16	50.7	126.777				4	2
7	14	2012	QCST	QCST17	50.6	126.806				5	

Table 3. Total number of juvenile salmon obtained for plasma IGF1 analysis during the summer of 2012. Samples were obtained during both the DFO survey of the Strait of Georgia (RV Ricker) and during the DFO survey of the West Coast of Vancouver Island (FV Viking Storm).

Region	Salmon Species					totals
	coho	chinook	sockeye	chum	pink	
SOG	173	247	217	161	134	932
Puget Sound	21	43	0	31	20	115
QCST/JS	13	5	5	41	37	101
totals	207	295	222	233	191	
grand total						1148

Table 4. Mean IGF1 levels of juvenile salmon obtained summer of 2012 from the Strait of Georgia, Puget Sound and Queen Charlotte Strait. Colored fill reflects variation between the IGF1 level found at a specific location and the grand mean IGF1 value (over all stations). IGF1 levels of stations in blue are < 0.5 sd from the grand mean and those in orange are > 0.5 sd from the grand mean.

Month	Day	Year	Area	Set #	Lat	Long	COHO	CHINOOK	SOCKEYE	PINK	CHUM
6	21	2012	Gulf Islands	2	49.065	123.673		63.9			
6	21	2012	Gulf Islands	4	49.083	123.759	68.3	59.3	39.0		
6	21	2012	Gulf Islands	6	48.969	123.727	71.6				
6	21	2012	Gulf Islands	7	48.926	123.663	57.2				47.9
6	22	2012	Gulf Islands	8	48.746	123.588	69.4	45.2	50.8	45.3	39.4
6	22	2012	Gulf Islands	9	48.752	123.564	50.8	55.6			
6	22	2012	Gulf Islands	10	48.726	123.414			48.8	42.6	31.1
6	22	2012	Gulf Islands	11	48.935	123.512		61.6	49.6		
6	22	2012	Gulf Islands	12	48.993	123.592					
6	22	2012	Gulf Islands	14	48.816	123.344		87.3			
6	22	2012	Gulf Islands	15	48.772	123.344		78.1	51.5	48.1	47.2
6	23	2012	Gulf Islands	16	48.723	123.540		56.8	55.5	46.8	45.0
6	23	2012	Gulf Islands	17	48.727	123.416		54.6	53.4	38.3	
6	23	2012	Gulf Islands	19	48.763	123.190			47.0	44.9	46.2
6	23	2012	SSOG	20	48.819	123.059		60.9		22.1	
6	23	2012	SSOG	21	48.822	123.077		81.8			
6	23	2012	SSOG	22	48.848	123.135		76.1			
6	24	2012	SSOG	25	48.937	123.396		77.9			
6	24	2012	SSOG	27	49.017	123.536		58.5			
6	24	2012	Howe Sound	31	49.392	123.418		55.0			
6	24	2012	Howe Sound	32	49.433	123.331					
6	25	2012	SSOG	35	49.394	123.635		67.1			
6	25	2012	SSOG	36	49.369	123.703		71.8		34.2	38.1
6	25	2012	SSOG	37	49.316	123.672		88.6			
6	25	2012	SSOG	40	49.171	123.620			46.8	37.2	47.1
6	25	2012	SSOG	41	49.187	123.706				43.5	43.1
6	25	2012	SSOG	42	49.213	123.773		64.0	37.8	40.2	
6	25	2012	SSOG	44	49.253	123.889		72.3	45.9	43.0	
6	25	2012	SSOG	45	49.234	123.867		56.6	49.7	30.3	41.7
6	26	2012	Malaspina	46	49.493	124.111	62.1	66.4	40.3		47.6
6	26	2012	Malaspina	47	49.550	124.124		68.3			
6	26	2012	Malaspina	48	49.567	124.062		57.9			
6	26	2012	Malaspina	49	49.588	124.128	51.3	68.2	39.7	32.0	

Table 4. continued

Month	Day	Year	Area	Set #	Lat	Long	COHO	CHINOOK	SOCKEYE	PINK	CHUM
6	26	2012	Malaspina	50	49.607	124.235		58.9	35.9	26.8	
6	26	2012	Malaspina	51	49.674	124.284		65.9	38.6		
6	26	2012	Malaspina	52	49.726	124.298	28.9	48.3		31.7	44.3
6	26	2012	Malaspina	53	49.758	124.396	68.5			45.5	38.4
6	26	2012	Malaspina	54	49.749	124.493					
6	26	2012	Malaspina	55	49.786	124.566	73.9				
6	27	2012	NSOG	56	49.820	124.721	75.8				
6	27	2012	NSOG	57	49.806	124.844			50.6	42.3	
6	27	2012	NSOG	58	49.789	125.000			34.6	36.6	42.5
6	27	2012	NSOG	59	49.837	125.003			23.1	34.1	
6	27	2012	NSOG	60	49.884	124.958			50.2		
6	27	2012	NSOG	61	49.938	124.909	84.9	84.7	42.5		
6	27	2012	NSOG	62	49.981	124.985			51.4		
6	27	2012	NSOG	64	49.984	125.103	123.2		49.8	31.0	42.9
6	28	2012	Discov Is	66	50.043	125.137	88.9		34.6	37.6	
6	28	2012	Discov Is	67	50.099	125.128			33.7		
6	28	2012	Discov Is	68	50.148	125.064			40.3	38.4	34.9
6	28	2012	Discov Is	69	50.229	125.125			51.2	26.5	
6	28	2012	Discov Is	70	50.189	125.133	78.3			23.8	41.2
6	28	2012	Discov Is	71	50.193	124.999			21.5	27.2	
6	28	2012	Discov Is	72	50.251	125.014			39.9		30.2
6	28	2012	Discov Is	75	50.329	125.013	77.3			30.0	40.1
6	29	2012	Desol Snd	76	50.275	124.980		67.9	44.8	27.8	29.4
6	29	2012	Desol Snd	78	50.313	124.740	68.1			33.3	59.1
6	29	2012	Desol Snd	79	50.263	124.638	73.9	59.0	39.5	41.1	46.3
6	29	2012	Desol Snd	80	50.188	124.643	76.4				48.3
6	29	2012	Desol Snd	81	50.212	124.786		59.3			45.6
6	29	2012	Desol Snd	82	50.125	124.776		62.1	99.6		
6	29	2012	Desol Snd	83	50.026	124.881	71.6	73.3	36.8		
6	30	2012	NSOG	85	49.812	124.704	77.7	87.9			
6	30	2012	NSOG	86	49.742	124.693	77.0		40.6		
6	30	2012	NSOG	89	49.607	124.689	77.4		44.7	44.9	
6	30	2012	NSOG	90	49.682	124.662	69.8				
6	30	2012	NSOG	91	49.661	124.566	87.2	68.5	45.2	32.6	
6	30	2012	NSOG	92	49.601	124.495			34.1		
6	30	2012	NSOG	93	49.524	124.515					
7	1	2012	NSOG	94	49.488	124.560	74.5				
7	1	2012	NSOG	95	49.455	124.650	74.1	61.4			48.2
7	1	2012	NSOG	96	49.400	124.557	75.8	55.2			
7	1	2012	NSOG	97	49.381	124.455	65.5	38.3	44.8	31.4	
7	1	2012	NSOG	99	49.428	124.263	85.7	89.1	36.2		
7	1	2012	NSOG	100	49.409	124.215	86.2	87.9			40.9
7	1	2012	NSOG	101	49.372	124.275		76.5	51.6		
7	1	2012	NSOG	102	49.352	124.312			38.2	33.0	42.9

Table 4. continued

Month	Day	Year	Area	Set #	Lat	Long	COHO	CHINOOK	SOCKEYE	PINK	CHUM
7	1	2012	NSOG	103	49.336	124.229				25.5	
7	1	2012	NSOG	104	49.373	124.177			49.1		
7	2	2012	SSOG	109	49.236	123.318		78.3			
7	2	2012	SSOG	110	49.221	123.396		72.3			
7	2	2012	SSOG	111	49.162	123.416		80.5			
7	2	2012	SSOG	113	49.055	123.474					
7	3	2012	NSOG	115	49.417	124.107	60.3	81.8	36.5		
7	3	2012	NSOG	116	49.465	124.015	56.7				
7	3	2012	NSOG	117	49.454	123.908		89.8			
7	3	2012	NSOG	118	49.437	123.807	61.9	62.1	48.3		41.6
7	3	2012	NSOG	119	49.398	123.784		62.5	40.4		
7	3	2012	NSOG	120	49.432	123.906	80.2	56.1	35.7	23.0	39.9
7	3	2012	NSOG	121	49.375	123.913	61.3	86.4	39.8	33.2	47.8
7	3	2012	NSOG	122	49.358	123.841	68.2			21.6	
7	7	2012	PgtSnd	157			65.1	51.4			
7	7	2012	PgtSnd	158			60.3	45.8		39.2	49.9
7	7	2012	PgtSnd	159			58.5	41.5		27.4	30.3
7	7	2012	PgtSnd	160			67.9	48.6		43.9	35.7
7	7	2012	PgtSnd	162				39.7		42.6	
7	7	2012	PgtSnd	163				48.5		41.5	43.3
7	15	2012	JS	JS01	50.6	126.820				20.9	28.8
7	15	2012	JS	JS02	50.5	126.633				24.0	
7	15	2012	JS	JS03	50.5	126.436				25.6	24.5
7	15	2012	JS	JS04	50.5	126.245					25.9
7	15	2012	JS	JS05	50.5	126.060	46.4				34.4
7	15	2012	JS	JS06	50.4	125.999	49.7	64.0			
7	12	2012	QCST	QCST04	50.9	127.298				47.0	
7	12	2012	QCST	QCST05	50.8	127.375	62.7			40.0	47.2
7	13	2012	QCST	QCST06	50.8	127.505	59.3	75.9			
7	13	2012	QCST	QCST07	50.8	127.690					
7	13	2012	QCST	QCST08	50.7	127.321			26.6	31.3	24.6
7	13	2012	QCST	QCST10	50.8	127.155					40.1
7	13	2012	QCST	QCST11	50.8	126.993				25.7	
7	14	2012	QCST	QCST12	50.7	127.205				32.7	26.2
7	14	2012	QCST	QCST13	50.7	127.098				30.4	40.7
7	14	2012	QCST	QCST14	50.7	126.951		44.2		21.4	34.0
7	14	2012	QCST	QCST15	50.8	126.844				34.4	19.0
7	14	2012	QCST	QCST16	50.7	126.777				12.0	17.0
7	14	2012	QCST	QCST17	50.6	126.806				14.8	

	COHO	CHINOOK	SOCKEYE	PINK	CHUM
mean IGF1	69.5	65.5	43.5	33.6	39.1
sd	14.5	13.7	11.3	8.7	8.9

Table 5. Correlations between mean IGF1 levels of juvenile salmon captured in different locations (sets) in the Strait of Georgia, Puget Sound and Queen Charlotte Strait. Count refers to the number of sets in which the relevant species pair were both caught.

	count	r	p
Coho vs Chinook	12	0.39	0.22
Coho vs Sockeye	7	0.32	0.51
Coho vs Pink	14	-0.16	0.59
Coho vs Chum	21	0.01	0.95
Chinook vs Sockeye	10	-0.23	0.54
Chinook vs Pink	15	0.11	0.71
Chinook vs Chum	20	0.27	0.26
Sockeye vs Pink	16	0.54	0.03
Sockeye vs Chum	19	0.36	0.13
Pink vs Chum	35	0.48	< 0.01

Table 6. A comparison of coho salmon IGF1 values obtained in 2000 and 2001 to values obtained in this study. Values from 2012 only include those obtained in northern and southern SOG, roughly comparable regions to those sampled in 2000 and 20011.

Year[1]	mean July IGF[2]	sd	n	Sept Len[3]	Sept CPUE[3]	% Survival[3] (ocean entry to Sept)
2000	48	2.5	89	248	32.5	10.7
2001	62	7.9	287	255	46.6	15.7
2012	71.6	10.1	119			

[1] 2012 values obtained in this study
[2] Beckman et al. unpublished
[3] Beamish et al. 2008