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SCALE GROWTH STUDIES FROM 1982-97 COLLECTIONS OF CHUM AND SOCKEYE SALMON SCALES IN THE GULF OF ALASKA

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ABSTRACT

Studies were conducted of growth on scales collected from salmon caught during high seas research cruises in the Gulf of Alaska. Measurements were made of scales from June and July 1982-1997 of ocean age .2 chum (*Oncorhynchus keta*) and sockeye salmon (*O. nerka*) that were also examined for stomach contents. Measurements were taken to the end of each annular mark and at the edge of the scale, and to every circulus on the scale. Scale measurements (particularly growth at the edge of the scale) were then compared to indices of stomach fullness and other measures of condition and growth. No correlations were found between three food habits variables (fullness, prey weight, and stomach content index) and edge growth variables (size, circulus spacing, and number of circuli of the last ocean zone, and size of the last circulus and last three circuli in that zone) for either sockeye or chum. Length and all edge growth variables on sockeye scales were significantly less in 1990s samples than in 1980s samples. Growth measures of the second and third ocean years on chum scales, and length, weight, and condition factor were also significantly smaller in 1990s samples. Sockeye salmon length and weight were positively correlated with growth variables in the second ocean year, while chum salmon length, weight, and condition factors were positively correlated with growth variables in all three ocean years. Sockeye salmon condition factor and edge growth variables were positively correlated with their counterparts in chum salmon. The results for sockeye salmon indicate that final size and trigger to mature may be at least partially set in the second ocean year. Successful chum salmon growth may be set relatively early, with a positive feed-forward effect of good growth leading to more good growth.

INTRODUCTION

A previous study investigated whether long-term collections of scale samples could provide further information on observations related to ocean growth and abundance of Pacific salmon (*Oncorhynchus* spp.; Walker et al. 1998a). Measurements made of growth patterns on scales of pink (*O. gorbuscha*) and chum (*O. keta*) salmon caught in the North Pacific Ocean south of the central Aleutian Islands showed chum salmon had significantly less growth at the edge of the scale after an oceanographic change in 1976-77. Pink salmon showed fewer differences in growth between periods, but abundance of pink salmon may have exerted a negative influence on the third-year growth of chum salmon in that area.

This study investigates patterns in scale growth reflected on scales of chum and sockeye (*O. nerka*) salmon in a different location in the North Pacific, the Gulf of Alaska. It is also an attempt to link scale growth studies with recent food habit studies by measuring scales of fish for which stomach content data is available. Of special interest in marine growth studies are the questions of where and when oceanographic and inter-specific effects on growth are occurring. Because the origin and prior travels of fish caught on the high seas are unknown, attention was

focused on growth at the edge of the scale, which most likely reflects response to conditions near the point of capture.

MATERIALS AND METHODS

Sample Sources and Study Area

The Fisheries Research Institute (FRI) of the University of Washington retains copies of scale samples collected during cooperative Japan-U.S. salmon research cruises aboard the Hokkaido University training ship *Oshoro maru* in the Gulf of Alaska from 1980 to 1998. Samples were collected from fish caught by varied mesh (non-selective) gillnet (48, 55, 63, 72, 82, 93, 106, 121, 121, 138, and 157 mm mesh). Studies of salmon food habits were conducted by scientists from Oregon State University from 1980 to 1985 (Pearcy et al. 1988) and by FRI scientists from 1993 to the present (Walker 1993, 1998b; Walker and Myers 1994; Myers et al. 1995, 1996, 1997).

Measurements were made of scales of chum and sockeye salmon from which stomach content data were available (Table 1). The fish were caught in the Gulf of Alaska (roughly 161° W to 138°W, between 48°N and 56°N) from 26 June to 24 July, 1982-84 and 1993-97. The majority of the samples were collected on transects along 55°N (1982-83), 155W° (1984) and 145°W (1994-97).

The Gulf of Alaska is a region of mixing of salmon from different areas of North America (a few chum salmon tagged in the area have been recovered in Asia). Tag recoveries indicate that chum salmon stocks in this area are predominantly Alaskan and British Columbian, with some fish from Washington and Oregon. Recoveries of sockeye salmon tagged in this area come from Alaska, British Columbia and Washington.

Scale Selection and Measurement

All non-regenerated scales with clean measurement axes were measured, up to 100 scales per year. In some cases, additional scales were measured to ensure a final sample of 100. When surplus samples were available from more than one day, scales were apportioned evenly between days.

Scales were measured along the longest anterior-posterior axis. Measurements of both chum and sockeye salmon were made on ocean age .2 scales, the most numerous age class of each species in the catches. Chum salmon were primarily immature (85%), and sockeye were mostly mature (74%). There was a higher percentage of maturing sockeye in the 1990s samples (82%) than in the early 1980s samples (64%). Maturity of chum salmon in the samples did not show a trend with time. Measurements were made to the outer edges of initial freshwater or coastal growth (if any), first and second ocean zones, to the edge of scale, and to every circulus on the scale. Life history zones were identified visually, based primarily on the appearance of circulus spacing. On chum scales, closely spaced circuli immediately surrounding the focus at the center of the scale were identified as "coastal" growth. More widely spaced circuli beyond the coastal growth, or surrounding the focus if coastal growth was not present, were identified as "offshore" growth in the first ocean summer. All scales were measured by one person using Optical Pattern Recognition System (OPRS; BioSonics, Inc.) image analysis software (at 75X and 94X magnification), and measurements were converted to microns.

Scale Variables

Variables used included scale edge measurements and early scale growth measurements (Table 2). Scale edge measurements consisted of size (radial distance) of the last (third ocean summer) ocean zone, number of circuli in the last ocean zone, average spacing of circuli in the last ocean zone, and size of the last three circuli at the edge of the scale (if fewer than three circuli were present between the last annulus and the edge, this measurement was to the annulus and might include two, one, or no circuli). Early scale growth measurements consisted of size, number of circuli, and average circulus spacing of the first and second ocean years.

Fish Body Size and Stomach Content Variables

Variables used included length of fish (tip of snout to fork of tail), weight, condition factor (CF; 10^6 x body weight/length^3), stomach fullness, prey weight, and stomach content index (SCI; 100 x prey weight/body weight; Table 2). Fullness was estimated on a scale from zero to four. Fullness data were collected in 1982-84, 1993-94, 1997, and part of 1995. Prey weights were collected in 1993-97; SCI could be calculated only for those years.

Statistical Analyses

Growth variables were tested for correlations of edge growth with food habits, body size and condition variables. Pearson r statistics were used to test mean annual values of scale edge growth variables for correlations with mean annual values of stomach fullness, prey weight, SCI, length, weight, and CF. Tests against food habits variables were conducted only for those scales for which the relevant data were available. Unpaired t-tests (2-tailed, α=0.01, assuming unequal variances) were used to test the hypothesis that there was no difference between growth in the earlier (1982-84) and later sampling periods (1993-97).

RESULTS

No correlations were found between the three food habits variables (fullness, prey weight, and SCI) and edge growth variables (size, circulus spacing, and number of circuli of the last ocean zone, and size of last three circuli and the last circulus in that zone) for either sockeye or chum (Table 3).

Sockeye salmon length and weight were positively correlated with growth variables in the second ocean year (Table 4), while chum salmon length, weight, and condition factors were positively correlated with growth variables in all three ocean years. For chum salmon scales, growth in the second ocean year was also correlated with growth in the third ocean year. First ocean zone size and spacing on sockeye scales was negatively correlated with third ocean year variables. Sockeye salmon condition factor and edge growth variables were positively correlated with their counterparts in chum salmon (Table 5).

All edge growth variables on sockeye scales were significantly less in 1993-97 samples than in 1982-84 samples but average fish length was greater ($p<0.001$ or greater; Fig. 1). Circulus number was larger and circulus spacing smaller in the first ocean zone in the latter period. Growth measures of the second and third ocean years on chum scales, and length, weight, and condition factor were also significantly smaller in 1993-97 ($p<0.01$ or greater; Fig. 2).

DISCUSSION

It is not surprising that stomach content variables do not correlate with scale growth. Meal sizes are highly variable and probably not of consistently the same size for an individual fish over the period of time necessary to be reflected by scale growth. As salmon are highly migratory, recent meals are possibly in a different oceanographic region from that where recent scale growth occurred. It is also possible that the period of time when these fish were caught (late June-mid-July) is not as important for feeding and growth as another period. LeBrasseur (1972) found sockeye and chum salmon stomachs in the Gulf of Alaska contained much more prey in March-May than in June-July.

Scale edge growth of both species and chum body length were less in the 1990s samples than in the 1980s samples. This is in keeping with other observations on decline in size of salmon in this period (e.g., Bigler et al. 1996). However, within the 1990s samples, there was not a clear trend. This also reflects other observations on salmon size. After a period of declining size in the 1980s, size at maturity of two North American chum salmon stocks was noted to remain stable or increase in the 1990s (Helle and Hoffman 1998). A shift in oceanographic regime in 1989 has also been postulated (Beamish et al. 1998), and the growth differences we see may reflect that change. Sockeye and chum salmon growth in the Gulf of Alaska at the times sampled seems to be equally affected in similar ways by oceanographic or feeding factors, as reflected in the correspondence in condition factor and measurements of scale edge growth. This is in contrast to the different responses of chum and pink salmon growth variables found in late June south of the central Aleutian Islands (Walker et al. 1998a). Chum salmon showed significant reductions in length, and early and edge scale growth in 1983-95 compared to 1956-70. While pink salmon length was also less in odd years in the latter period, scale growth variables were not smaller.

That sockeye salmon length and weight correlate well with scale growth variables in the second ocean year indicates final size and the trigger to mature may be at least partially set in that period. Most of the sockeye in this study are maturing fish, likely to be returning to south central Alaska, southeastern Alaska, and British Columbia. Welch (1994) also found that age at maturity of British Columbia sockeye appeared to be determined during the second ocean year. Rogers (1980) and Rogers and Ruggerone (1993) proposed that density-dependent growth occurs in maturing Bristol Bay sockeye salmon when they are concentrated north of the Alaska Peninsula during their final weeks at sea. The sampling period in this study may be too early and far offshore to detect similar effects on final size for the southern stocks in the study area.

In chum salmon, length, weight, and condition factor at time of capture correlate well with all indications of fish growth recorded on scales in all three years of life. Successful chum salmon growth may be set relatively early, with a positive feed-forward effect of good growth leading to more good growth. Aydin (1998) found such an effect in pink salmon, where reaching a large enough size by the beginning of the last year at sea was crucial for feeding on high calorie squid, and thus growing to a larger size.

It is planned to extend these studies by measuring scales from earlier (1960s-1970s) and intervening (1985-92) years, as well as measuring pink salmon scales.

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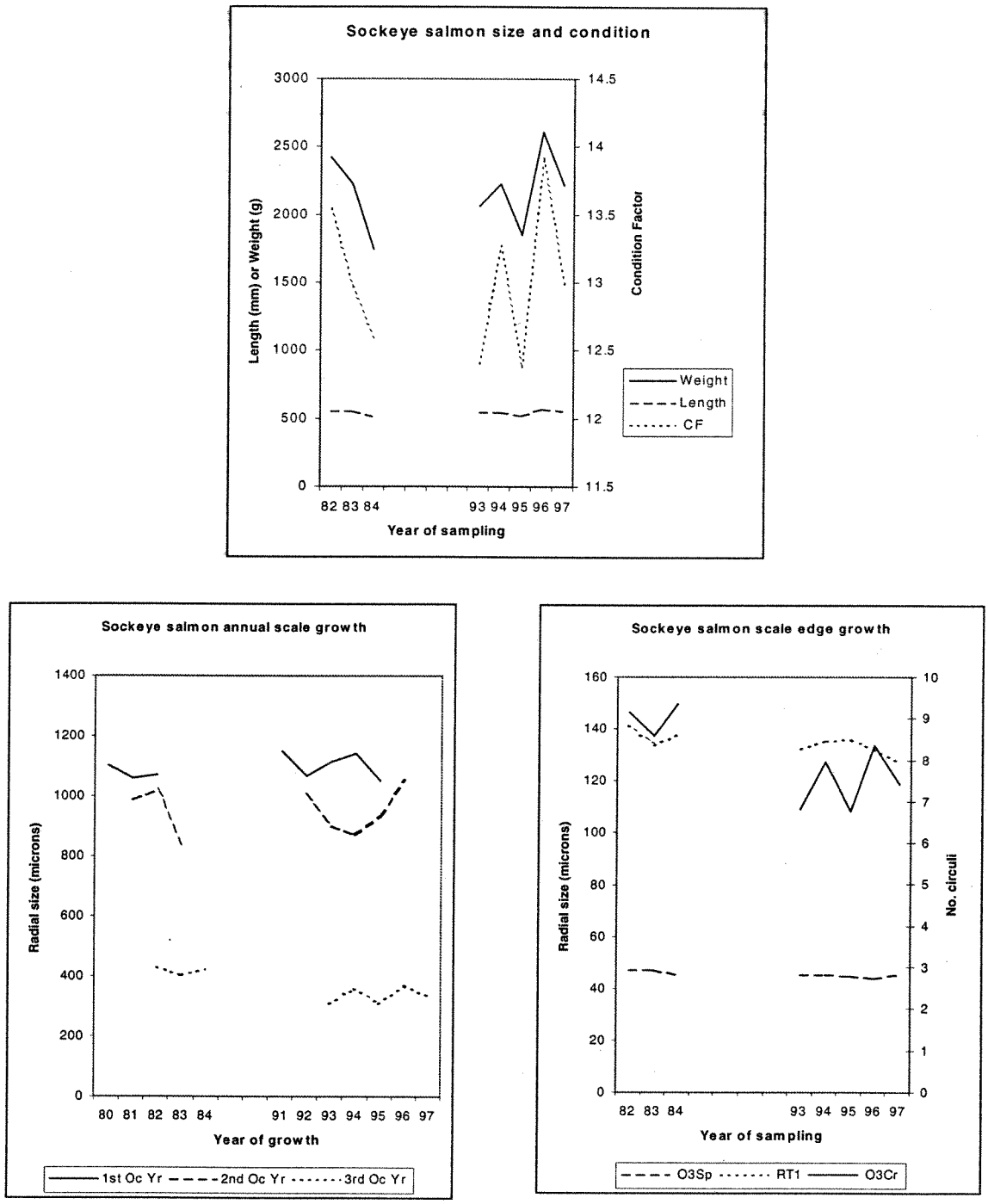
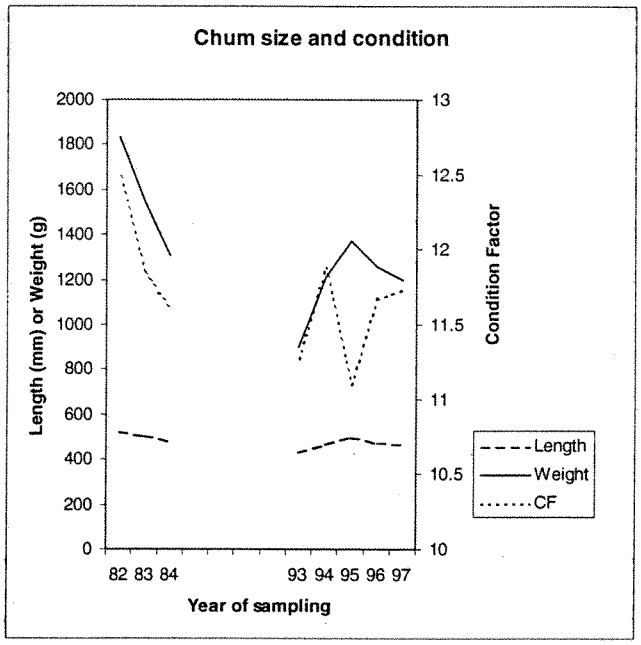
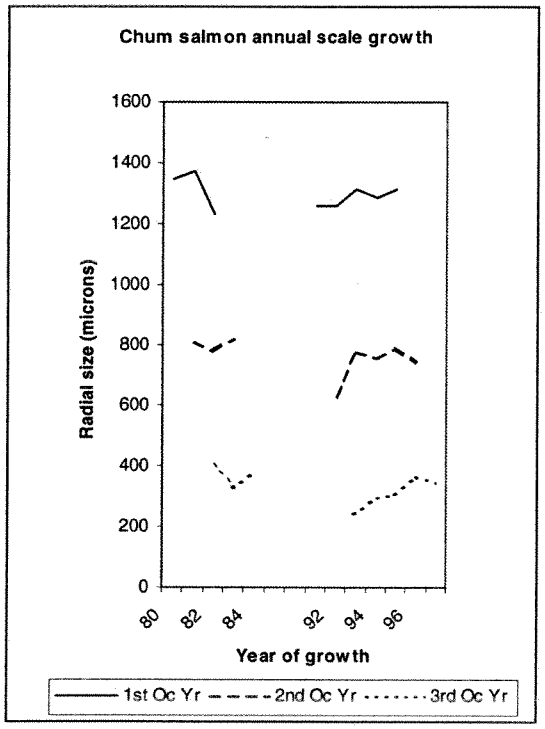


Fig. 1. Size and scale growth by year for sockeye salmon caught in the Gulf of Alaska, late June-mid-July, 1982-84 and 1993-97. O3Sp = circulus spacing in third ocean year; O3Cr = no. circuli in third ocean year; RT1 = radial size of last three edge circuli.





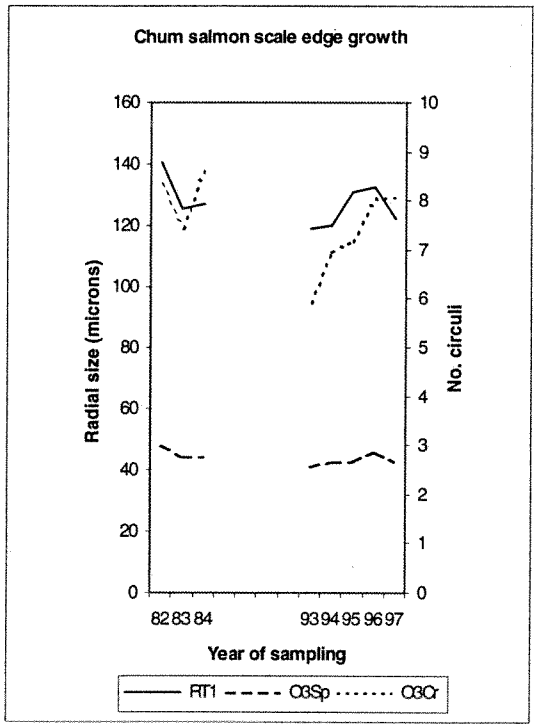


Fig. 2. Size and scale growth by year for chum salmon caught in the Gulf of Alaska, late June - mid-July, 1982-84 and 1993-97. O3Sp = circulus spacing in third ocean year; O3Cr = no. circuli in third ocean year; RT1 = radial size of last three edge circuli.

Table 1. Scale samples measured for growth studies. Scales were collected in the Gulf of Alaska, between 139°E and 160°W, and between 48°N and 56°N from June 26 to July 12, 1982-84 and 1993-97. Sources of the samples were research cruises by the T/S *Oshoro maru*.

Year	Sockeye N	Chum N	Dates Begin	Dates End	Ranges of latitude and longitude		Oceanographic Regions[1]
1982	119	75	7/17	7/24	55°N	139°-153°W	R,D
1983	55	73	7/1	7/7	55°N	140°-155°W	R,D
1984	92	106	7/17	7/23	48°-54°N	155°W	S,R,A
1993	50	19	6/28	7/4	51°-55°N	146°-160°W	R,D
1994	69	36	6/28	7/8	50°-56°N	145°-157°W	S,R,D
1995	51	62	6/26	6/30	50°-56°N	145°-161°W	S,R,D
1996	100	61	7/3	7/11	50°-56°N	141°-145°W	S,R,D
1997	104	113	7/3	7/12	50°-56°N	145°-150°W	S,R,D
Totals	640	564					

[1] A= Alaska Current
D= Dilute Domain
R= Ridge Domain
S= Subarctic Current

Table 2. Means and standard deviations for size, feeding, and scale growth variables measured from chum and sockeye salmon samples collected in June and July, 1982-97, in the Gulf of Alaska. Stomach fullness: 0=empty, 4=full
Condition factor = 10^6 x body weight/length^3. Stomach Contents Index (SCI) = 100 x prey weight/body weight
All scale measurements in microns.

a. Chum salmon

	1982	1983	1984	1993	1994	1995	1996	1997	All Years
N	75	73	106	38	36	62	61	113	564
Length (mm)	521.33	503.96	481.24	429.26	464.11	496.23	474.11	464.30	482.40
s.d.	51.02	38.49	31.94	21.33	31.82	36.82	35.89	39.50	44.47
Weight (g)	1833.07	1544.79	1307.92	896.32	1207.78	1370.97	1255.41	1194.76	1352.87
s.d.	670.94	403.89	263.89	160.26	312.20	293.38	277.71	326.46	443.71
Condition Factor	12.48	11.84	11.62	11.26	11.88	11.10	11.67	11.74	11.73
s.d.	1.19	0.93	0.94	1.12	1.46	1.22	1.37	1.23	1.21
Stomach Fullness	1.08	1.12	0.77	1.16	0.81	1.12[1]		1.06	1.00
s.d.	0.67	0.62	0.61	0.86	0.58	0.99[1]		0.88	0.74
Stomach Contents Index				379.76	154.67	331.42	175.84	443.50	179.77
s.d.				327.93	153.65	550.90	283.36	651.13	410.04
Early growth									
1st ocean year - size	1347.76	1373.97	1231.00	1260.87	1257.58	1311.63	1285.48	1312.35	1299.79
s.d.	115.77	115.49	91.40	142.82	103.83	130.31	124.51	143.95	129.80
1st ocn yr - no. circuli	29.41	31.92	26.12	27.11	27.83	31.19	26.97	29.02	28.66
s.d.	4.32	4.47	3.34	2.28	4.65	4.75	3.94	4.33	4.68
1st ocn yr - circ. spacing	46.51	43.66	47.70	46.66	46.03	42.94	48.52	45.91	46.06
s.d.	5.64	5.02	5.75	5.22	6.23	7.43	6.82	6.60	6.36
2nd ocean year - size	811.56	778.42	819.54	628.34	780.86	757.21	786.85	739.39	771.36
s.d.	143.57	126.28	122.35	85.04	124.66	154.00	135.28	128.11	138.08
2nd ocn yr - no. circuli	19.56	18.52	19.50	15.61	19.31	19.44	18.77	17.90	18.70
s.d.	3.70	2.99	2.80	2.13	3.33	3.38	3.28	2.83	3.23
2nd ocn yr - circ. spacing	41.81	42.22	42.29	40.53	40.81	38.97	42.21	41.35	41.44
s.d.	4.02	4.11	4.50	3.76	4.53	4.26	4.61	4.03	4.33
Edge growth									
3rd ocean year - size	402.55	327.84	382.23	245.92	297.11	305.84	368.89	348.57	346.69
s.d.	110.13	84.56	102.28	96.57	109.37	83.98	90.69	95.68	105.16
3rd ocn yr - no. circuli	8.32	7.42	8.64	5.92	6.94	7.18	8.05	8.06	7.81
s.d.	1.93	1.79	1.89	1.95	2.28	1.88	1.68	1.78	2.00
3rd ocn yr - circ. spacing	48.28	44.32	44.07	41.05	42.44	42.66	45.75	42.84	44.13
s.d.	5.25	6.24	5.20	5.89	4.97	4.80	5.27	6.07	5.85
Last 3 edge circuli - size[2]	140.65	125.14	126.92	119.00	119.83	131.02	132.26	121.89	127.55
s.d.	19.64	25.56	18.15	33.75	33.65	19.57	19.85	27.22	24.79

continued

[1] stomach fullness data for 18 of 62 fish

[2] distance from scale edge inward to third circulus from edge (or distance to second or first circulus, or no measurement, if there were not three circuli present between last annulus and edge)

Table 2. continued.

b. Sockeye salmon

	1982	1983	1984	1993	1994	1995	1996	1997	All Years
N	119	55	92	50	69	51	100	104	640
Length (mm)	553.86	554.67	512.13	545.36	548.58	524.47	571.48	552.81	546.94
s.d.	58.02	34.44	48.41	51.20	36.65	43.72	28.86	32.22	46.63
Weight (g)	2417.39	2221.64	1745.43	2066.40	2228.55	1848.24	2611.40	2217.88	2208.73
s.d.	872.19	415.03	584.84	619.28	495.06	617.35	414.50	433.17	649.87
Condition Factor	13.53	12.97	12.59	12.40	13.27	12.38	13.91	12.98	13.11
s.d.	1.39	1.85	1.26	1.67	1.25	1.84	1.41	1.13	1.51
Stomach Fullness	1.15	0.91	0.92	1.48	1.83	1.50[3]		1.93	1.38
s.d.	1.02	1.04	1.17	1.25	1.44	1.26[3]		1.17	1.24
Stomach Contents Index				318.52	959.36	562.35	909.20	991.67	476.34
s.d.				456.77	1418.42	1103.01	1051.24	1255.75	972.33
Early growth									
1st ocean year - size	1101.03	1056.93	1069.45	1147.88	1067.57	1112.41	1141.63	1052.35	1092.09
s.d.	155.80	135.13	137.45	130.76	129.32	141.27	121.58	128.26	139.60
1st ocn yr - no. circuli	27.46	28.35	26.35	29.50	28.30	29.57	28.68	28.26	28.12
s.d.	3.26	3.95	4.03	4.09	3.85	4.11	2.79	2.77	3.62
1st ocn yr - circ. spacing	40.11	37.51	40.95	39.32	37.94	37.92	39.86	37.32	39.04
s.d.	4.00	3.68	4.30	4.82	3.72	3.91	3.01	3.61	4.06
2nd ocean year - size	988.14	1019.91	832.21	1005.16	902.25	870.14	935.15	1050.51	952.98
s.d.	185.35	199.27	130.58	163.10	154.12	148.84	132.85	190.18	179.85
2nd ocn yr - no. circuli	23.51	23.75	20.84	24.48	21.81	21.35	22.30	24.90	22.90
s.d.	3.50	4.88	3.25	3.99	3.03	3.55	3.05	4.08	3.88
2nd ocn yr - circ. spacing	41.99	43.15	40.03	41.22	41.39	40.92	42.06	42.17	41.64
s.d.	4.30	4.21	3.70	3.41	3.56	4.33	3.58	3.58	3.92
Edge growth									
3rd ocean year - size	432.76	403.89	421.66	310.04	360.54	310.27	367.08	338.63	375.99
s.d.	95.46	81.42	89.07	83.27	77.98	117.89	81.07	125.48	105.42
3rd ocn yr - no. circuli	9.16	8.58	9.36	6.82	7.97	6.76	8.35	7.42	8.23
s.d.	1.64	1.67	1.88	1.69	1.68	2.45	1.75	2.66	2.15
3rd ocn yr - circ. spacing	47.19	47.25	45.20	45.30	45.49	44.82	44.03	45.37	45.60
s.d.	5.73	4.79	4.87	6.33	5.38	9.55	4.03	6.53	5.94
Last 3 edge circuli - size[2]	141.23	133.53	137.75	132.42	135.36	136.02	132.19	127.40	134.67
s.d.	21.46	19.51	21.77	27.38	18.81	39.32	17.08	31.37	24.99

[2] distance from scale edge inward to third circulus from edge (or distance to second or first circulus, or no measurement, if there were not three circuli present between last annulus and edge)

[3] stomach fullness data for 22 of 51 fish

Table 3. Correlations between three food habits variables and scale edge growth variables of ocean age .2 sockeye and chum salmon caught in the Gulf of Alaska from late June to mid-July, 1982-97. Fullness was estimated on a scale from zero to four. SCI=100 x prey weight/body weight.

	Fullness[1]	SCI[2]	Prey Weight[2]
Sockeye	n=511	n=374	n=374
Edge			
Size - 3rd ocean summer	-0.188	0.009	0.069
No. circuli - 3rd ocean summer	-0.176	0.004	0.055
Circ. spacing - 3rd ocean summer	-0.107	0.011	0.041
Spacing - last 3 edge circuli[3]	-0.174	-0.089	-0.050
Spacing - last edge circulus	-0.107	-0.010	-0.012
Chum	n=457	n=309	n=309
Edge			
Size - 3rd ocean summer	0.064	-0.002	0.058
No. circuli - 3rd ocean summer	0.064	0.032	0.091
Circ. spacing - 3rd ocean summer	0.028	-0.051	-0.024
Spacing - last 3 edge circuli[3]	-0.016	-0.030	0.007
Spacing - last edge circulus	-0.019	-0.034	-0.034

[1] = fullness data available for samples from 1982-84, 1993-94, 1997, and some samples from 1995

[2] = SCI and prey weight data available for samples from 1993-1997

[3] = distance from scale edge inward to third circulus from edge (or distance to second or first circulus, or no measurement, if there were not three circuli present between last annulus and edge)

Table 4. Correlations (Pearson r) between year, size, and scale growth variables for sockeye and chum salmon sampled in the Gulf of Alaska, 1982-84 and 1993-97. O1, O2, O3 = first, second, and third ocean years. Sz = radial size. Cr = circulus count. Sp = circulus spacing. RT1 = radial size of last 3 edge circuli.

Sockeye

	Year	*Length*	*Weight*	*CF*	*O1Sz*	*O1Cr*	*O1Sp*	*O2Sz*	*O2Cr*	*O2Sp*	*O3Sz*	*O3Cr*	*O3Sp*	*RT1*
Year	1													
Length	0.22	1												
Weight	0.12	0.96	1											
CF	-0.01	0.77	0.91	1										
O1Sz	0.29	0.20	0.22	0.06	1									
O1Cr	0.64	0.30	0.12	-0.20	0.53	1								
O1Sp	-0.41	-0.22	-0.03	0.16	0.42	-0.54	1							
O2Sz	0.03	0.67	0.51	0.18	-0.08	0.27	-0.43	1						
O2Cr	0.07	0.56	0.39	0.05	-0.01	0.29	-0.36	0.98	1					
O2Sp	-0.08	0.81	0.71	0.50	-0.18	0.24	-0.52	0.79	0.64	1				
O3Sz	-0.85	0.01	0.18	0.44	-0.40	-0.85	0.49	-0.10	-0.19	0.13	1			
O3Cr	-0.76	0.01	0.20	0.48	-0.35	-0.88	0.57	-0.19	-0.28	0.05	0.98	1		
O3Sp	-0.77	0.11	0.10	0.04	-0.45	-0.29	-0.15	0.45	0.39	0.50	0.57	0.41	1	
RT1	-0.68	-0.37	-0.16	0.05	0.08	-0.43	0.56	-0.51	-0.52	-0.35	0.59	0.54	0.39	1

Chum

	Year	*Length*	*Weight*	*CF*	*O1Sz*	*O1Cr*	*O1Sp*	*O2Sz*	*O2Cr*	*O2Sp*	*O3Sz*	*O3Cr*	*O3Sp*	*RT1*
Year	1													
Length	-0.62	1												
Weight	-0.69	0.97	1											
CF	-0.55	0.54	0.70	1										
O1Sz	-0.33	0.67	0.68	0.40	1									
O1Cr	-0.20	0.58	0.52	0.05	0.85	1								
O1Sp	0.05	-0.34	-0.24	0.25	-0.57	-0.92	1							
O2Sz	-0.46	0.76	0.72	0.56	0.17	0.07	0.10	1						
O2Cr	-0.31	0.77	0.69	0.40	0.14	0.19	-0.10	0.94	1					
O2Sp	-0.52	0.21	0.30	0.62	0.09	-0.31	0.58	0.46	0.14	1				
O3Sz	-0.46	0.68	0.70	0.64	0.22	-0.08	0.36	0.82	0.67	0.64	1			
O3Cr	-0.37	0.60	0.59	0.51	0.12	-0.11	0.33	0.83	0.68	0.60	0.97	1		
O3Sp	-0.56	0.77	0.84	0.77	0.46	0.07	0.28	0.70	0.56	0.57	0.86	0.71	1	
RT1	-0.41	0.79	0.80	0.46	0.42	0.18	0.08	0.58	0.59	0.17	0.73	0.59	0.88	1

Table 5. Correlations (Pearson r) between sockeye and chum salmon size and scale growth variables for fish sampled in the Gulf of Alaska, 1982-84 and 1993-97. CF= condition factor. O1, O2, O3 = first, second, and third ocean years. Sz = radial size. Cr = circulus count. Sp = circulus spacing. RT1 = radial size of last 3 edge circuli.

	Sok Len	*Sok Wt*	*Sok CF*	*Sok O1Sz*	*Sok O1Cr*	*Sok O1Sp*	*Sok O2Sz*	*Sok O2Cr*	*Sok O2Sp*	*Sok O3Sz*	*Sok O3Cr*	*Sok O3Sp*	*Sok RT1*
Chm Len	-0.03	0.12	0.29	-0.30	-0.37	0.06	-0.11	-0.24	0.27	0.65	0.56	0.55	0.61
Chm Wt	0.08	0.24	0.39	-0.29	-0.43	0.11	0.02	-0.11	0.34	0.73	0.63	0.67	0.64
Chm CF	0.43	0.57	0.69	-0.36	-0.58	0.18	0.30	0.21	0.43	0.78	0.72	0.65	0.40
Chm O1Sz	0.43	0.39	0.23	-0.21	0.17	-0.45	0.59	0.46	0.81	0.22	0.08	0.67	0.02
Chm O1Cr	0.04	-0.05	-0.18	-0.33	0.32	-0.68	0.32	0.22	0.54	-0.04	-0.20	0.57	0.04
Chm O1Sp	0.24	0.36	0.49	0.31	-0.42	0.73	-0.11	-0.06	-0.25	0.28	0.42	-0.39	-0.01
Chm O2Sz	-0.09	0.13	0.49	-0.46	-0.70	0.25	-0.44	-0.57	0.01	0.76	0.79	0.19	0.51
Chm O2Cr	-0.22	-0.01	0.35	-0.40	-0.51	0.13	-0.57	-0.69	-0.12	0.56	0.57	0.11	0.57
Chm O2Sp	0.34	0.42	0.56	-0.28	-0.70	0.42	0.20	0.13	0.33	0.78	0.83	0.29	0.03
Chm O3Sz	0.06	0.28	0.56	-0.27	-0.75	0.46	-0.12	-0.20	0.08	0.78	0.80	0.18	0.37
Chm O3Cr	-0.07	0.13	0.43	-0.40	-0.78	0.39	-0.20	-0.27	-0.01	0.71	0.75	0.08	0.25
Chm O3Sp	0.33	0.54	0.70	0.01	-0.50	0.46	0.04	-0.06	0.31	0.77	0.75	0.39	0.54
Chm RT1	0.10	0.31	0.45	0.24	-0.25	0.45	-0.15	-0.23	0.08	0.51	0.47	0.21	0.63