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Scale Growth and Life History Patterns of Pink Salmon in Periods of Low and High Abundance

by

Katherine W. Myers
Fisheries Research Institute WH-10
School of Fisheries
University of Washington
Seattle, WA 98195

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Abstract

A comparison of the scale patterns of maturing pink salmon caught in the North Pacific Ocean (just south of the central Aleutian Islands) in the 1970s showed statistically significant differences in both early ocean growth and winter growth between periods of low (1970-75) and high (1977-1978) abundance of Eastern Kamchatkan (odd-year) and western Alaskan (even-year) stocks. Fork lengths of fish in the low and high abundance groups were not significantly different. Statistically significant differences in scale growth and life history patterns suggest that western Alaskan pink salmon in the high abundance group spent more time rearing in coastal areas during their first summer at sea. The scales of both eastern Kamchatkan and western Alaskan stocks had significantly better winter growth (more circuli and larger size) in the high abundance group than in the low abundance group. These results may reflect the direct response of pink salmon to a climate change event that occurred in the winter of 1976-77. Pink salmon are the most abundant species of Pacific salmon in the North Pacific Ocean, and abrupt changes in their growth and life history patterns may have significant short- and long-term effects on North Pacific ecosystems. Better evidence, however, is needed to determine if the observed differences in scale growth are due to a single, major climatic disturbance or just due to year-to-year variation in the environment. In future analyses, the scale growth and life history patterns of pink salmon and other species of Pacific salmon sampled from years within climatic periods (and identified in the analysis to year of observation) will be measured to evaluate such a climatic effect.

Introduction

In the late 1970s, commercial catches of many stocks of Pacific salmon (*Oncorhynchus* spp.) in Asia and Alaska increased dramatically (Rogers 1984). This increase has been attributed to a variety of anthropogenic, physical, and biological factors such as good fisheries management, reduction in high-seas fishing, increased hatchery production, warmer temperatures in winter, improved freshwater survival, decreased predation by marine mammals, and increased ocean productivity (for example, Rogers 1984, Brodeur and Ware 1992, Beamish and Bouillon 1993, Rogers and Ruggerone 1993, Hare and Francis, in press). Because pink salmon (*O. gorbuscha*) migrate to the ocean early in their first year and spend only one winter in the ocean, they are a good species to use for examining responses of Pacific salmon to changes in the environment or other factors. In western Alaska and eastern Kamchatka, commercial catches of pink salmon were very low in the early 1970s, then (coincident with higher temperatures in the Gulf of Alaska and warmer winters in Bristol Bay beginning with the winter of 1976-77) catches and total abundance increased in the late 1970s to historical record levels in 1991 (Rogers and Ruggerone 1993, Karpenko 1994). Rogers (1984) found that return per spawner ratios for western Alaska pink salmon were significantly correlated (a positive correlate) with air temperatures at most life history stages, and that the highest correlations were those that included the winter months while the fish were at sea. He hypothesized that vulnerability to predation by marine mammals may increase in very cold winters because salmon distribution shifts farther to the south and fish are more concentrated than in warm winters, or simply because water temperatures are colder. Beamish and Bouillon (1993) found that trends in salmon abundance from 1925 to 1989 are associated with changes in the environment. They hypothesized that an intensification and shift in the center of the Aleutian low, which dominates the winter climate of the North Pacific region, may have resulted in increased ocean upwelling and subsequent increases in ocean productivity and salmon abundance. Hare and Francis (in press) hypothesized that "large-scale variability in salmon production is driven by large-scale climate change, reflected in North Pacific atmospheric/oceanic regime shifts." Relatively stable production under a particular regime, is followed by a rapid change to a new production level in response to the physical regime shift. Hare and Francis (in press) tentatively identified two such regime shifts that occurred in the winters of 1950-51 and 1976-77.

In this paper, I determine if there are differences in ocean growth or life history patterns on the scales of pink salmon caught in the central North Pacific Ocean in periods of low and high abundance in the 1970s. The results are discussed with respect to stock origins, migration patterns, and growth of pink salmon, and factors that may affect survival at various life history stages.

Methods

Study Area and Sampling Procedures

Pink salmon were caught during high-seas purse seine operations by the Fisheries Research Institute (FRI), University of Washington, in the central Aleutian Islands (International North Pacific Fisheries Commission (INPFC) statistical area W8050) in July 1970-78 (Hartt et al. 1972, 1974, 1975, 1977, 1979; Hartt and Dell 1973; Harris et al. 1979, 1980). The purse seine was 400 fm long by 22 fm deep. Fishing was conducted at five stations spaced at about 10-mile intervals along a transect extending from 5 to 50 miles south of Adak Island (Adak Index Area, Fig. 1). Scales (one per fish, taken from the standard INPFC body area) were sampled and mounted on gummed cards. Length of fish was measured from the tip of the snout to the fork of the tail. In the laboratory, acetate impressions of the scales were made with a heated hydraulic press (100°C, 5,000 psi).

Scale Selection and Measurement

Acetate impressions of scales were measured with an image analysis system (magnification 84X; Optical Pattern Recognition System (OPRS), BioSonics, Inc., Seattle, WA). All usable scales (non-regenerated, well-formed, and clean measurement axis) from fish caught in July 1970-76 were measured, and an approximately equivalent number of scales from fish caught in July 1977-78 were randomly selected and measured.

All scales were measured by the author using the radial extraction subroutine of the OPRS computer software and a standard reference line and measurement axis (Fig. 2).

The diameter of the focus was measured, and circulus counts and radial measurements were made in each of four life history zones: (1) "coastal" growth in the first ocean summer, (2) "offshore" growth in the first ocean summer, (3) "winter" growth in the first ocean year, (4) "summer" growth in the second ocean year. Fish length, sample date and location, and other identifiers, and circulus counts were recorded on a data form on the computer monitor. After each scale was measured, the data were automatically written to a binary file and saved on computer disk.

The scale focus and life history zones were identified visually, based primarily on the appearance of circulus spacing (Fig. 2). The "focus" was identified as the first complete circulus in the center of the scale. The diameter of the focus was measured by marking both the posterior and anterior edge of the focus along the radial axis.

The scales of pink salmon sometimes have a supplementary check (zone of closely spaced circuli) near the center of the scale, which may result from a change in the physical environment or food supply during the first year of life, or from some change in growth that occurs when the fish leave coastal waters and move offshore (Miyaguchi 1959, Eniutina 1962, Bilton and Ricker 1965). In the present study, a supplementary check near the center of the scale is called the "coastal" zone.

The "offshore" zone refers to all widely spaced circuli formed in the first summer that occur immediately after the focus on scales without a supplementary check or after the "coastal" zone on scales with a supplementary check. In turn, widely spaced "offshore" circuli formed in the first summer are followed by narrowly-spaced "winter" circuli in the annulus, and then by widely-spaced circuli in the "second summer" zone (Fig. 2).

Scale Variables

The original OPRS measurement data consisted of the distances from the posterior edge of the focus to the outer edge of each life history zone that was marked on the OPRS monitor. These data were reformatted, along with the recorded fish length and circulus counts, into a set of 16 variables: (1) fish length, (2) size of focus, (3-9) number of circuli in "coastal", "offshore", "first summer", "winter", "total first year", "second summer", and "total" zones, (10-16) the size of "coastal", "offshore", "first summer", "winter", "total first year", "second summer", and "total" zones. The number of circuli and sizes of the "first summer" zone were calculated by summing values of "coastal" and "offshore" variables. Similarly, the "first year" zone equals the sum of the "first summer" and "winter" zones, and the "total" zone equals the sum of the "first year" and the "second summer" zones (Fig. 2).

Statistical Analyses

The data were evaluated for missing values and normality. Two variables, the size and number of circuli in the "coastal" zone, were not normally distributed because the scales of some fish do not exhibit this character. These variables were retained, and analyzed using a non-parametric statistical method.

Because pink salmon in even and odd years are reproductively isolated, separate analyses were conducted for samples collected in odd and even years. In both analyses, the data were divided into two groups: low abundance (pre-1977) and high abundance (post-1976) groups. Unpaired t-tests (2-tailed, $\alpha = .01$) were used to test the hypothesis that there was no difference between years of low and high abundance. The "coastal" variables were analyzed with non-parametric, Mann-Whitney tests (with tied ranks, $\alpha = .01$).

Results

Odd-year Pink Salmon

Mean lengths of fish in the low and high abundance groups were not significantly different, but the observed mean length of fish in the low abundance group was larger, and mean circulus counts and measurements on the scales of the low abundance group were significantly larger than those of the high abundance group for most variables (Table 1). The mean circulus counts and sizes of the "winter" zone, however, were significantly smaller ($p \leq .01$) in the low abundance group than in the high abundance group. The size of the "second summer" zone was significantly less in the high abundance group than in the low abundance group.

Even-year Pink Salmon

Mean lengths of fish in the low and high abundance groups were not significantly different, but the observed mean length of fish in the high abundance group was larger (Table 2). Mean circulus counts and sizes of both "coastal" and "winter" zones were significantly larger ($p \leq .01$) and mean size of the "offshore" zone was significantly smaller in the high abundance group than in the low abundance group. Mean circulus counts and sizes of the "second summer" zone were not significantly different between the two groups. In contrast to results of the odd-year analysis, there were no significant differences between low and high abundance groups in the number of circuli and size of the "second summer" zone.

Because multiple testing increases the probability of erroneously rejecting one or more null hypotheses, the rejection error rate for any set of N tests, either dependent or independent, can be controlled by testing each component hypothesis at a smaller size of test (J. Pella, pers. com.). If each of the tests is conducted at size of test $\alpha* = \alpha/N$, then the rejection error rate for the collection of tests is no greater than α by the Bonferroni inequality (J. Pella, pers. com.; see equation 13 in Miller 1966). For example, if $\alpha = 0.01$ for the 16 odd-year tests, conducting each at $\alpha* = .0006$ will insure that the probability that none erroneously rejects a component null hypothesis is .01. By this method, ten of the tests in Table 1 remain 'significant', as do six of the tests in Table 2.

Discussion

Stock origins of pink salmon in the study area

Limited information from high seas tagging experiments indicates that maturing pink salmon in the Adak Index Area in June and July are predominantly from eastern Kamchatkan (primarily the Karaginski region, Cape Afrika to Cape Oliutorski) and western Alaskan stocks (Table 3). Eastern Kamchatkan pink salmon stocks are dominant in odd-year cycles, and western Alaskan pink salmon stocks are dominant in even-year cycles (Ricker 1962). Based on the results of previous high-seas tagging experiments, Harris et al. (1979) concluded that large catches of pink salmon in the study area in 1977 (Table 4) reflected a large run to the eastern Kamchatkan (Karaginski) region. A subsequent report showed that commercial catches of odd-year cycle pink salmon in eastern Kamchatka increased from 8,110 t in 1975 to 14,220 t in 1977 (Kazarnovsky 1989; Table 5). Similarly, Harris et al. (1980) noted that large catches in the Adak Index Area in July 1978 were followed by an extraordinarily large run of pink salmon to Bristol Bay (Table 6). The probable Bristol Bay origin of these fish was indicated by the recoveries in Bristol Bay in August 1978 of four tagged pink salmon that had been released in the study area in July 1978 (Harris et al. (1980) reported three Bristol Bay recoveries, and subsequently information on one additional Bristol Bay recovery was returned to FRI).

Although mean lengths of maturing Karaginski and western Alaskan pink salmon caught at the Adak Index Area were not significantly different between periods of low and high abundance, significant differences were observed in their scale growth at different life history stages (Tables 1 and 2).

Migrations and growth in the first summer

There are no data from tagging studies on the migrations of eastern Kamchatkan and western Alaskan pink salmon during their first year at sea. Research vessel catch data indicate that western Alaskan stocks migrate slowly in their first summer, and by September many are still within 250-300 nm from their rivers of origin (Takagi et al. 1981). Bristol Bay stocks are thought to rear in the area along the north side of the Alaska Peninsula within 50-60 nm of shore in their first summer. Takagi et al. (1981) postulated that juvenile eastern Kamchatkan pink salmon migrate close to shore, downstream (southwestward) in the East Kamchatka Current.

In recent studies, Russian researchers have found that juvenile pink salmon in the Karaginski region move offshore in August and early September, and that migration patterns, fish size, and scale patterns vary in cold and warm years (V. Karpenko, pers. com.) In cold years, sea surface temperature (SST) isotherms essentially run parallel to the East Kamchatka coast, and migration patterns of pink salmon are similar to those described by Takagi et al. (1981), but in warm years SST isotherms frequently run perpendicular to the coastline, and juveniles move directly offshore into the Bering Sea rather than following the coastline. In cold years, juveniles are smaller than in warmer years, the first circulus forms on the scale at a smaller size (45-50 mm in cold years and

50-60 mm in warm years), and circulus counts are similar to those of fish in warmer years. The relationship between size of fish and circulus count is similar in years of low and high abundance, but circulus spacing is narrower in cold years.

In the present analysis, differences in coastal growth between low and high abundance groups of eastern Kamchatkan pink salmon are similar to those described by Karpenko. Circulus counts in the coastal zone were similar between years of low and high abundance, but the size of the coastal zone was significantly smaller in the high abundance group than in the low abundance group (Table 1). However, coastal growth of fish in the high abundance group (maturing fish caught in 1977) occurred prior to the hypothesized climate event beginning in the winter of 1976-77.

Coastal scale growth in 1977 of western Alaskan pink salmon maturing in 1978 was significantly greater than that of fish caught in the early 1970s (Table 2). Warmer water temperatures in the eastern Bering Sea may have allowed juvenile pink salmon to remain for longer periods of time in productive shelf and coastal areas before moving well offshore. Brodeur and Ware (1992) found that zooplankton biomass in the Gulf of Alaska doubled between the 1950s and the 1980s, and hypothesized that juvenile salmonids in coastal areas have benefited through improved feeding conditions. Similar increases in zooplankton biomass may have also occurred in eastern Bering Sea rearing areas beginning in 1977.

Others factors besides improved feeding conditions may have benefited survival of western Alaskan salmon. For example, by rearing in coastal areas for a longer period, juveniles may have avoided competition with other stocks and species in offshore areas of intermingling. Ricker (1962) hypothesized that cannibalism can explain all known characteristics of naturally-occurring dominance in pink salmon, although he also reports that there are no data to support this hypothesis. By remaining in coastal areas, juvenile western Alaskan stocks may avoid cannibalism by large runs of adult Karaginski stocks in offshore areas.

Migrations and growth in winter

The routes and timing of migration of eastern Kamchatkan and western Alaskan pink salmon from the Bering Sea to the North Pacific Ocean, and whether or not some fish remain in the Bering Sea throughout winter, are not known (Takagi et al. 1981). By the following spring, however, tagging studies show some fish to be distributed well offshore in the central North Pacific and Gulf of Alaska (Takagi et al. 1981; Myers et al. 1990). The scales of maturing pink salmon at the Adak Index Area in 1977 and 1978 exhibited significantly more winter growth (more circuli and larger "winter" zone size) than fish caught in the early 1970s (Tables 1 and 2). These results support Roger's (1984) hypothesis of the importance of the winter months at sea to pink salmon survival. Increased feeding activity and growth of pink salmon in winter may reduce predation by marine mammals, which is thought to be a major cause of ocean mortality of Pacific salmon (Rogers 1984).

Migrations and growth in the last summer at sea

Information from tagging experiments and research vessel sampling shows that in the spring and summer maturing eastern Kamchatkan and western Alaskan pink salmon migrate northward out of the Gulf of Alaska and central North Pacific, westward in the Alaskan Current close to the south side of the Aleutians, and then northward into the Bering Sea through the Aleutian passes (Takagi et al. 1981). Differences in the results of the odd- and even- year analysis of variables in the "second summer" zone may be related to differences in oceanographic and biological conditions in the central Aleutian Islands area in 1977 and 1978. In the odd-year analyses, pink salmon in the high abundance group (1977) had significantly less scale growth in the "second summer" zone than fish caught in the low abundance group (1971, 1973, and 1975), whereas in the even-year analysis there were no significant differences in "second summer" growth between fish caught in high (1978) and low (1970, 1972) abundance groups (Tables 1 and 2). Mean SSTs at the Adak Index Area in 1977 were the highest on record for these stations (10.1°C), and there were also exceptionally large catches of Pacific pomfret (*Brama japonica*) and Pacific saury (*Cololabis saira*) (Harris et al. 1979). Mean SSTs in 1978 were cooler (8.3°C, which nearly equals the unweighted mean SSTs for the years 1968-1976), and in contrast to 1977 there were no catches of Pacific pomfret or Pacific saury (Harris et al. 1980). In addition, Atka mackerel (*Pleurogrammus monopterygius*) were less abundant in 1978 than in 1977, and adult pollock (*Theragra chalcogramma*) were encountered much more frequently and abundantly in 1978 than in any year since inception of the Adak sampling design in 1967. Growth of maturing pink salmon in the summer of 1977 may have been affected by the unusually warm SSTs or possibly by food competition from Pacific pomfret and other warmer water species not usually present in the study area.

Differences in the results of the odd- and even- year analysis of variables in the "second summer" zone may also reflect density effects on growth. The higher abundance of pink salmon in the Aleutian Islands area in odd-year cycles reflects the higher abundance of eastern Kamchatkan stocks in comparison to western Alaskan stocks (Tables 5 and 6). Catches and catch per unit effort of pink salmon were higher at the study area in 1977 than in 1978 (Harris et al. 1979, 1980; Table 4). Rogers and Ruggerone (1993) hypothesized that density effects on growth of Bristol Bay sockeye salmon (*O. nerka*) are most likely to occur during their homeward migration because the fish are concentrated and actively feeding, and suggested that concern for carrying capacity limitations should be placed on the migratory routes of returning adults. Ogura et al. (1991) found strong odd-even year fluctuations in the last summer of ocean growth for coho salmon sampled in the western North Pacific Ocean from 1973-1987. They hypothesized that this was due primarily to the overlap of diet between coho and pink salmon. Davis et al. (1993) reported significant changes in the food habits of Pacific salmon in the central North Pacific Ocean and Bering Sea in recent years of high (odd years) and low (even years) abundance of pink salmon. When pink salmon abundance is low, chum salmon have more euphausiids, copepods, and squid and less gelatinous zooplankton in their stomach contents than when pink salmon abundance is high (Davis et al. 1993, Ishida et al. 1993a).

Information on circulus counts

Recently, some researchers exploring the relationships between salmon size, abundance, environmental conditions, and survival have measured only the sizes of annular scale zones, which have been used as an index of growth during each year at sea (for example, Ogura et al. 1991, Ishida et al. 1993b, Rogers and Ruggerone 1993). The results for even-year pink salmon showed that while differences in the total size of first year zone between groups were not significant, there were significant differences in the number of circuli in first year zone (Table 2). Because circulus counts can provide significant information on salmon growth, I encourage researchers to also use these measures.

Conclusions

The scale growth and life history patterns of fish caught at the Adak Index Area in 1977 and 1978 may reflect the direct response of pink salmon to a climate change event or regime shift that may have occurred in the winter of 1976-77 (Hare and Francis, in press). Pink salmon are the most abundant species of Pacific salmon in the North Pacific Ocean, and abrupt changes in their growth and life history patterns may have significant short- and long-term effects on North Pacific ecosystems. Better evidence, however, is needed to determine if the observed differences in scale growth are due to a single, major climatic disturbance or just due to year-to-year variation in the environment. In future analyses, the scale growth and life history patterns of pink salmon and other species of Pacific salmon sampled from years within climatic periods (and identified in the analysis to year of observation) will be measured to evaluate such a climatic effect.

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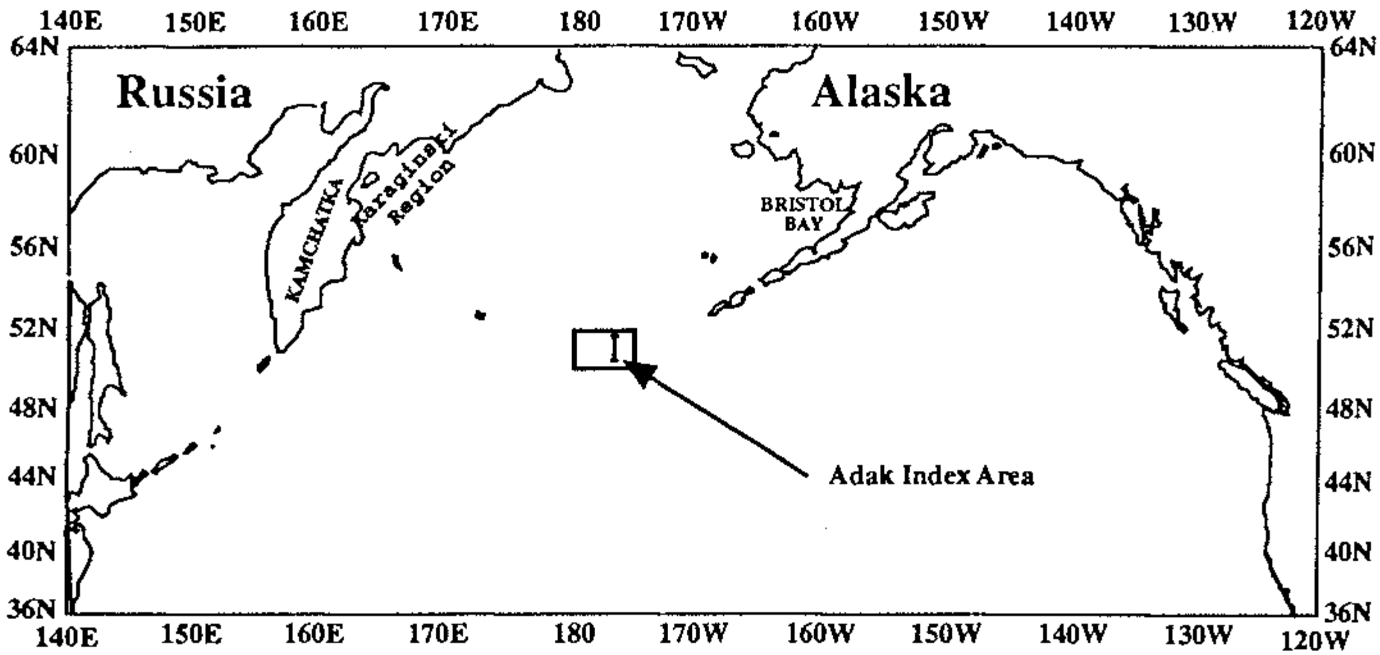

Fig. 1. Map showing the location of International North Pacific Fisheries Commission statistical area W8050 (▭) and Adak Index Area (I).

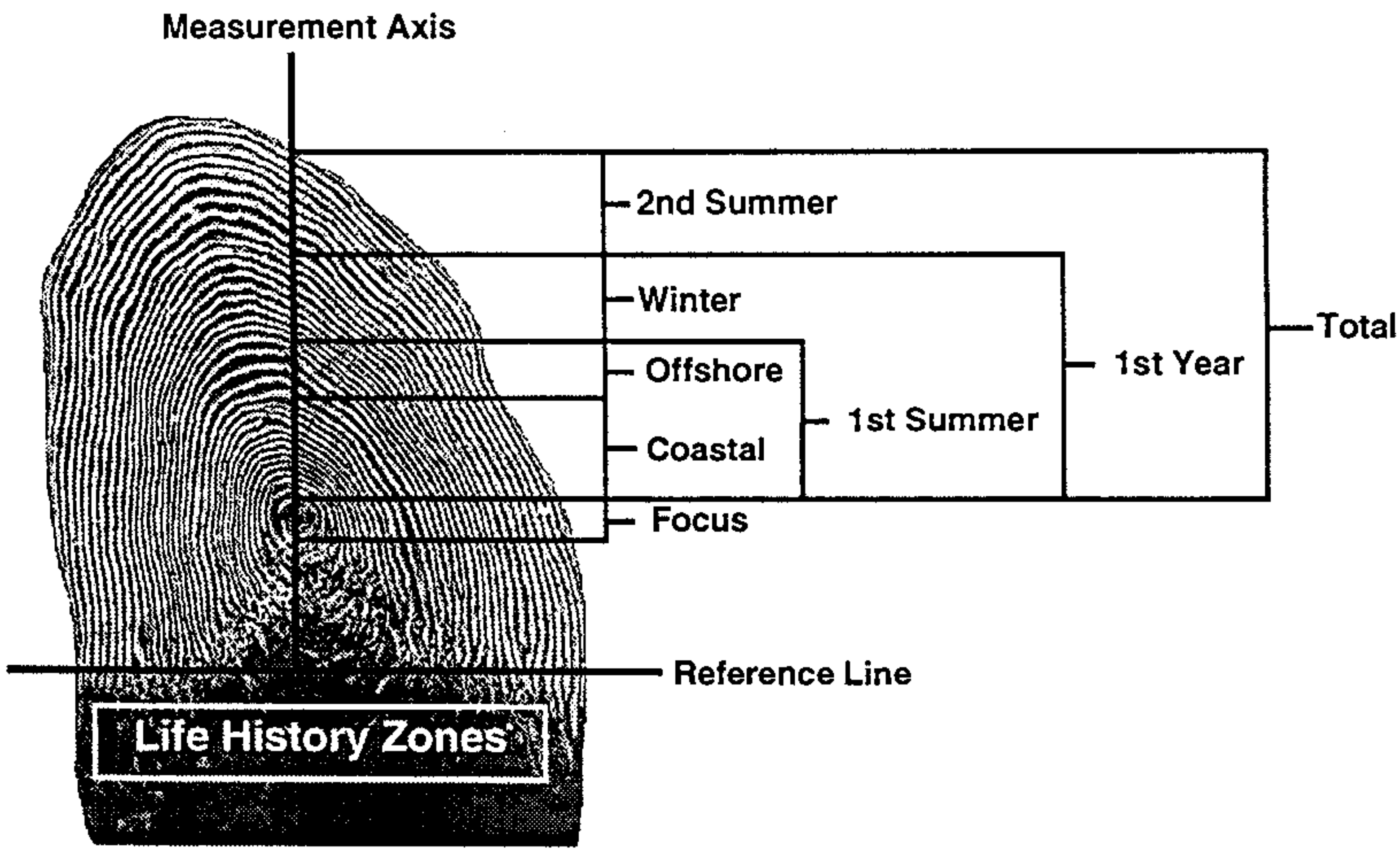

Fig. 2. The scale of a pink salmon caught in July 1978 at International North Pacific Fisheries Commission statistical area W8050 showing the variables used in the scale pattern analysis.

Table 1. The results of unpaired t-tests on fish length and 15 scale variables calculated from radial circulus counts and measurements of maturing odd-year pink salmon caught in July in NPAFC statistical area W8050 in years of low (1971, 1973, and 1975; n = 52 fish) and high (1977; n = 61 fish) abundance. All scale measurements are in microns.

Variable	Group	Mean	Std Dev	Std Error	t-value [a]	Prob. (2-tail)
1. Length of fish (mm)	Low	471.212	35.103	4.868		
	High	464.836	22.766	2.915	1.161	.2481
2. Size of focus	Low	191.788	40.213	5.577		
	High	171.393	32.632	4.178	2.976	.0036 *
3. No. circuli - 1st summer coastal[a]	Low	4.904	3.403	.472		
	High	3.820	2.867	.367	-2.197 [a]	.0281
4. No. circuli - 1st summer offshore	Low	10.442	3.274	.454		
	High	8.066	2.768	.354	4.182	.0001 *
5. No. circuli - total 1st summer	Low	15.346	2.408	.334		
	High	11.885	1.450	.186	9.405	.0001 *
6. No. circuli - winter zone	Low	5.038	1.546	.214		
	High	7.393	1.782	.228	-7.436	.0001 *
7. No. circuli - total 1st year	Low	20.385	2.932	.407		
	High	19.279	1.724	.221	2.486	.0144
8. No. circuli - 2nd summer zone	Low	10.712	2.099	.291		
	High	9.475	1.813	.232	3.359	.0011 *
9. No. circuli - total all zones	Low	32.212	2.546	.353		
	High	29.672	1.720	.220	6.288	.0001 *
10. Size - 1st summer coastal zone[a]	Low	177.865	125.815	17.447		
	High	127.639	100.150	12.823	-2.614 [a]	.0089 *
11. Size - 1st summer offshore zone	Low	463.192	141.614	19.638		
	High	308.869	111.029	14.216	6.489	.0001 *
12. Size - total 1st summer zone	Low	641.058	109.419	15.174		
	High	436.508	82.349	10.544	11.319	.0001 *
13. Size - winter zone	Low	158.712	53.338	7.397		
	High	203.197	57.339	7.342	-4.244	.0001 *
14. Size - total 1st year	Low	799.769	137.254	19.034		
	High	639.705	86.214	11.039	7.533	.0001 *
15. Size - 2nd summer zone	Low	515.712	110.600	15.337		
	High	430.672	85.815	10.988	4.598	.0001 *
16. Size - total all zones	Low	1507.269	174.245	24.163		
	High	1241.770	131.158	16.793	9.226	.0001 *

*=statistically significant difference ($\alpha = .01$)

[a]Variable nos. 3 (no. circuli - 1st summer coastal zone) and 10 (size - 1st summer coastal zone) are not normally distributed because the scales of some fish do not exhibit coastal growth. For these two variables, a non-parametic test (Mann-Whitney U) was used. Z-values (corrected for ties) are shown.

Table 2. The results of unpaired t-tests on fish length and 15 scale variables calculated from radial circulus counts and measurements of maturing even-year pink salmon caught in July in NPAFC statistical area W8050 in years of low (1970 and 1972; n = 46 fish) and high (1978; n = 46 fish) abundance. All scale measurements are in microns.

Variable		Group	Mean	Std Dev	Std Error	t-value [a]	Prob. (2-tail)
1.	Length of fish (mm)	Low	470.978	38.102	5.618		
		High	481.848	28.778	4.243	-1.544	.1261
2.	Size of focus	Low	269.109	70.41	10.381		
		High	255.804	45.026	6.639	1.080	.2832
3.	No. circuli - 1st summer coastal[a]	Low	4.717	3.209	.473		
		High	8.630	2.870	.423	-5.218 [a]	.0001 *
4.	No. circuli - 1st summer offshore	Low	8.848	3.098	.457		
		High	7.000	2.625	.387	3.086	.0027 *
5.	No. circuli - total 1st summer	Low	13.565	2.373	.350		
		High	15.630	2.101	.310	-4.419	.0001 *
6.	No. circuli - winter zone	Low	5.435	2.105	.310		
		High	6.652	2.193	.323	-2.716	.0079 *
7.	No. circuli - total 1st year	Low	19.000	3.183	.469		
		High	22.283	2.518	.371	-5.485	.0001 *
8.	No. circuli - 2nd summer zone	Low	11.435	2.949	.435		
		High	11.217	2.021	.298	.412	.6810
9.	No. circuli - total all zones	Low	31.457	3.038	.448		
		High	34.543	2.354	.347	-5.447	.0001 *
10.	Size - 1st summer coastal zone[a]	Low	230.478	160.139	23.611		
		High	384.370	143.125	21.103	-4.274 [a]	.0001 *
11.	Size - 1st summer offshore zone	Low	548.478	186.330	19.638		
		High	418.304	157.540	14.216	6.489	.0001 *
12.	Size - total 1st summer zone	Low	778.957	150.096	22.130		
		High	802.674	138.760	20.459	-.787	.4334
13.	Size - winter zone	Low	245.000	111.431	16.430		
		High	305.739	110.920	16.354	-2.620	.0100 *
14.	Size - total 1st year	Low	1023.957	198.821	29.314		
		High	1108.413	155.776	22.968	-2.268	.0257
15.	Size - 2nd summer zone	Low	720.826	232.678	34.306		
		High	701.696	141.633	20.883	0.476	.6350
16.	Size - total all zones	Low	1744.783	253.666	37.401		
		High	1810.109	205.516	30.302	-1.357	.1781

*=statistically significant difference ($\alpha = .01$)

[a]Variable nos. 3 (no. circuli - 1st summer coastal zone) and 10 (size - 1st summer coastal zone) are not normally distributed because the scales of some fish do not exhibit coastal growth. For these two variables, a non-parametic test (Mann-Whitney U) was used. Z-values (corrected for ties) are shown.

Table 3. The number of recoveries of maturing pink salmon tagged in International North Pacific Fisheries Commission statistical area W8050 in June and July (1956-1993) by region of origin. Regions: SAKH = Sakhalin Island, WKAM = western Kamchatka, EKAM = eastern Kamchatka, WAK = western Alaska, CAK = central Alaska, SEAK = southeast Alaska.

Odd Years

Period		Region of Origin					
		SAKH	WKAM	EKAM	WAK	CAK	SEAK
JUN	1-10	0	0	12	1	0	0
JUN	11-20	0	0	32	1	0	0
JUN	21-30	1	0	9	0	0	0
JUL	1-10	0	0	1	1	0	0
JUL	11-20	0	0	0	1	0	0
JUL	21-30	0	0	0	0	0	0

Even Years

Period		Region of Origin					
		SAKH	WKAM	EKAM	WAK	CAK	SEAK
JUN	1-10	0	0	6	3	0	0
JUN	11-20	0	0	0	3	0	0
JUN	21-30	0	0	0	5	0	0
JUL	1-10	0	0	0	8	0	0
JUL	11-20	0	0	0	5	0	0
JUL	21-30	0	0	1	5	0	0

Table 4. Total catch (numbers of fish) and catch per seine set of pink salmon at Stations 1-5 south of Adak Island in International North Pacific Fisheries Commission statistical area W8050, July-August 1968-1978. Data from Harris et al. (1980).

Year	Period Fished	No. of seine sets	Catch	Catch/set
1968	July 7-Aug. 12	58	65	1.1
1969	July 3-Aug. 12	89	188	2.1
1970	June 30-Aug. 11	66	51	0.8
1971	July 3-Aug. 9	51	35	0.7
1972	July 4-Aug. 13	74	26	0.4
1973	July 4-Aug. 8	55	12	0.2
1974	July 4-Aug. 15	56	25	0.4
1975	July 5-Aug. 17	70	43	0.6
1976	July 12-Aug. 18	41	35	0.9
1977	July 3-Aug. 25	62	664	10.7
1978	July 3-Aug. 20	63	582	9.2

Table 5. Commercial catches of pink salmon in East Kamchatka, 1970-1980 (weight in thousands of tons). Data from Kazarnovsky (1989).

Year	Catch
1970	0.008
1971	2.530
1972	0.260
1973	2.810
1974	0.710
1975	8.110
1976	5.020
1977	14.220
1978	8.390
1979	27.830
1980	15.250

Table 6. Inshore commercial catch and escapement (numbers of fish) of pink salmon in the Nushagak district, Bristol Bay, in even years from 1970 through 1980. Data from Alaska Dept. Fish & Game (1985).

Year	Catch	Escapement	Total run
1970	417,834	152,580	570,414
1972	67,953	58,536	126,489
1974	413,613	585,516	999,129
1976	739,580	863,434	1,603,024
1978	4,348,336	9,386,477	13,734,813
1980	2,202,545	2,785,196	4,987,741