NPAFC
Doc. 77

A METHOD FOR ESTIMATING GROWTH PATTERN OF HATCHERY REARED CHUM SALMON BY SCALE ANALYSIS AND BACK-CALCULATION

by

Masa-aki Fukuwaka and Masahide Kaeriyama

Hokkaido Salmon Hatchery, Fisheries Agency of Japan
2-2 Nakanoshima, Toyohira-ku, Sapporo 062, Japan

Submitted to the
NORTH PACIFIC ANADROMOUS FISH COMMISSION
by the
JAPAN NATIONAL SECTION

October 1994

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:

Fukuwaka, M., and M. Kaeriyama. 1994. A method for estimating growth pattern of hatchery reared chum salmon by scale analysis and back-calculation. (NPAFC Doc. 77) 11 P. Hokkaido Salmon Hatchery, Fisheries Agency of Japan, Sapporo.

A METHOD FOR ESTIMATING GROWTH PATTERN OF HATCHERY REARED CHUM SALMON BY SCALE ANALYSIS AND BACK-CALCULATION

ABSTRACT

We examined a scale analysis and back-calculation method for estimating individual growth of marked juvenile chum salmon during early ocean life. The spacing of scale circuli decreased during the hatchery-rearing period, and increased during the early-ocean period. A check was formed on the scales immediately after release. The estimation of individual release size, back-calculated from the scale radius of the check, enabled calculation of the individual growth rate of juvenile chum salmon in the ocean. This method could be useful in estimating the individual growth of chum salmon in the first ocean year.

INTRODUCTION

The objective of the North Pacific Anadromous Fish Commission (NPAFC) is to promote the conservation of anadromous stocks in the Convention Area (ARTICLE VIII-2). Anadromous stocks should be conserved as local populations in which individuals interbreed and share a common gene pool. It is fundamentally important to improve the precision of stock identification technology, as scientific research for the conservation of anadromous stocks (Fisheries Agency of Japan 1993). Hard tissue analyses, genetic identification, and tagging experiments also parasites, serology, and morpho metrics have been used to identify stocks of Pacific salmon. The hard tissues, characterized as additive growth, would produce information on life history pattern. The scale patterns of chum salmon during the first ocean year are a key character for stock identification because of variability in their life history patterns owing to differentiation of coastal environments (Tanaka et al. 1969).

Mean growth rates of juvenile chum salmon have been estimated by group-marking and length-frequency analysis. These methods cannot be used to calculate individual growth rate. It is considered that larger juveniles in a population of chum salmon have lower mortality (Healey 1982) and migrate faster than smaller juveniles (Mayama et al. 1982). In the case of size-dependent effects, the frequency distribution of body size does not reflect the mean of actual somatic growth and individual growth patterns in a observed population. We examined a method for estimating individual growth in hatchery reared chum salmon by scale analysis and back-calculation.

METHODS

Samples Juvenile chum salmon were marked by clipping both ventral fins from March 24 to April 5, 1993. Marked juveniles were collected on March 29 and April 5 in Shou River Hatchery of Shou River, which discharges into Toyama Bay in the Japan Sea. Juveniles were released from the hatchery on April 5, 1993. These fish were recaptured in coastal waters of the Japan Sea in northern Honshu. After fixation by 10 % formalin, we measured fork length and collected scales from the body area near the lateral line and between the dorsal and anal fins.

Scale Analysis Radii and circuli spacings of scales mounted with glycerin-jelly were measured along the longest axes. Focus measurements of scales were not used in the analysis. The change in circuli spacing was analyzed by determining the correlation between circuli spacing and circuli number from the center of the scale focus to each circulus. Circuli spacings were smoothed by calculating a moving average.

We defined the release check as the narrowly spaced circulus preceding a more widely spaced circulus (Bilton and Robins 1971). Scale radius at check formation was equal to the sum of the circuli spacings from the center of the focus to the check.

Back-Calculation The relationship between fork length and scale radius was examined by calculation of a geometric mean regression (Ricker 1973). Fork lengths at check formation were back-calculated by a modified Frazer-Lee equation (Ricker 1992):

$$\frac{L_i - L_p}{S_i - S_p} = \frac{L_c - L_p}{S_c - S_p}$$

where L_i is fork length (mm) at check formation, S_i is scale radius (μm) at check formation, L_c is fork length (mm) at recapture, S_c is scale radius (μm) at recapture, L_p and S_p are fork length (mm) and scale radius (μm), which are the original point of proportional back-calculation.

Growth rates of juveniles from release to recapture were calculated by the instantaneous growth rate:

$$g(L) = \frac{\ln L_t - \ln L_0}{T}$$

where L_t is fork length (mm) at recapture, L_0 is fork length (mm) at release, and T is time in days from release to recapture.

RESULTS AND DISCUSSION

Scale Patterns at Release Mean fork length of juveniles at release was 59.2 mm. Size frequency distribution at release had two modes at 53 mm and 67 mm (Fig. 1). Circuli number at release ranged from 3 to 8 and increased with fork length (Fig. 2). Mean radius (84.3 μm) of focus was considerably longer than the other circuli spacings (Fig. 3). Mean circuli spacings of juveniles decreased with circuli number until release (Fig. 3). Table 1 shows the change in the pattern of circuli spacing. The positive and negative signs of the correlation coefficient indicate the tendencies for circuli spacing to increase and decrease, respectively. Correlation coefficients for most juveniles at release were negative. These results indicated that circuli spacings of juveniles decreased continuously until release. Bilton (1975) reported that circuli spacing increased with somatic growth. The decrease in circuli spacing suggests decreased somatic growth in the hatchery.

Scale Patterns of Recaptured Juveniles Table 2 shows the change patterns of circuli spacings of recaptured juveniles. Circuli spacing patterns of most juveniles showed the tendency to decrease. All of juveniles recaptured shorter than 14 days after release showed a decrease in the smoothed circuli spacing.

Eight fishes were recaptured in coastal waters longer than 14 days after release. The scales of these fish showed the following pattern: circuli spacing decreased continuously until release, the check was formed immediately after release, and circuli spacing increased in the early ocean life period.

Marked juveniles migrating into the sea immediately after release encountered changes in the environment from the hatchery to the sea. Bilton and Robins (1971) reported that a check was formed on the scale as a result of changes in environmental factors such as food intake. We, therefore, think that the check on the scales of marked juveniles would be formed immediately after their release. The check formation was not affected with an additional handling at fin–clipping because release checks were observed on the scales of non–marked juveniles.

Back–Calculation The relationship between fork length and scale radius is shown in Fig. 5. The geometric mean regression was calculated:

$$Y=-178.7+7.329X$$

where Y is scale radius (μm) and X is fork length (mm). For the juvenile chum salmon, squamation begins when the fish are 40–50 mm in fork length (Kaeriyama and Bunya 1982). From this equation, the scale radius at squamation was calculated in 114 μm. We used a 40 mm in fork length and a 114 μm in scale radius as the original values for proportional back–calculation.

Back–calculated fork lengths at check formation are shown in Table 3. Circuli numbers at check formation corresponded to those at release (Fig. 2). Back–calculated fork lengths at check formation were in the range of body size at release (Fig. 1). Circuli spacings decreased until release (Table 1), and then increases after check formation (Fig. 4). This evidence also indicates that checks are formed on the scale immediately after release.

Instantaneous growth rates by back–calculation ranged from 0.0106 to 0.0374 (Table 3). Instantaneous growth rates during early ocean life by group–marking of chum salmon have been reported as 0.0055–0.0126 in Japan Sea (Mayama et al. 1982), and 0.0104–0.0116 and 0.0050–0.0118 in Pacific Ocean (Kaeriyama 1986). Calculated instantaneous growth rates in the present study were slightly larger than these.

CONCLUSION

We demonstrated a method of estimating the individual growth of chum salmon during the early ocean life by scale analysis and back–calculation. This method will be useful in clarifying the growth patterns of chum salmon in the first ocean year.

ACKNOWLEDGEMENTS

We thank Katherine W. Myers for critical reviews and useful comments on the manuscript.

REFERENCES

Bilton, H. T. 1975. Factors influencing the formation of scale characters. INPFC Bull. 32: 102–108.

Bilton, H. T., and G. L. Robins. 1971. Effect of feeding level on circulus formation on scales of young sockeye salmon (*Oncorhynchus nerka*). J. Fish. Res. Bd. Canada 28: 861–868.

Fisheries Agency of Japan. 1993. A Japan's view on conception of scientific research for the Committee on Scientific Research and Statistics. (NPAFC Doc. 28). Fisheries Agency of Japan, Ministry of Agriculture, Forestry and Fisheries, Kasumigaseki, Chiyoda-ku, Tokyo 100. 11p.

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.

Kaeriyama, M. 1986. Ecological study on early life of the chum salmon, *Oncorhynchus keta* (Walbaum). Sci. Rep. Hokkaido Salmon Hatchery, (40): 31–92. [In Japanese with English Summary]

Kaeriyama, M., and T. Bunya. 1982. Morphological and ecological characteristics of phasic development from fry to fingerling in the chum salmon. Bull. Japan. Soc. Sci. Fish. 48: 1537–1544. [In Japanese with English Summary]

Mayama, H., M. Kato, J. Seki, and I. Shimizu. 1982. Studies on the chum salmon released in the Ishikari River system–Ⅰ. On the seaward migration and inshore distributions of liberated fry in 1979. Sci. Rep. Hokkaido Salmon Hatchery (36): 1–17. [In Japanese with English Summary]

Ricker, W. E. 1973. Linear regressions in fishery research. J. Fish. Res. Bd. Canada 30: 409–434.

Ricker, W. E. 1992. Back-calculation of fish lengths based on proportionality between scale and length increments. Can. J. Fish. Aquat. Sci. 49: 1018–1026.

Tanaka, S., M. P. Shepard, and H. T. Bilton. 1969. Origin of chum salmon (*Oncorhynchus keta*) in offshore waters of the North Pacific in 1956–1958 as determined from scale studies. INPFC Bull. 26: 57–155.

Table 1. Number of chum salmon by each change pattern of scale circuli spacing at release.

Correlation coefficient	Negative		Positive	
	Simple decrease	Partial decrease	Partial increase	Simple increase
Smoothed	11	4	4	2
Non-smoothed	2	13	6	0

Table 2. Change patterns of scale circuli spacing in recaptured chum salmon.

Correlation coefficient		Negative		Positive	
		Simple decrease	Partial decrease	Partial increase	Simple increase
Smoothed	Number of individuals	17	15	5	0
	Days after release	2-14	2-30	9-23	
Non-smoothed	Number of individuals	6	26	5	0
	Days after release	3-11	4-30	9-23	

Table 3. Scale radii, fork lengths, and growth rates of 8 juvenile chum salmon recaptured more than 14 days after release in 1993.

Sample No.	1	2	3	4	5	6	7	8
Location of recapture	Toyama	Toyama	Yamagata	Niigata	Yamagata	Yamagata	Yamagata	Akita
Date of recapture	Apr. 20	Apr. 21	Apr. 28	May 5	Apr. 20	Apr. 28	Apr. 28	Apr. 20
Days after release	15	16	23	30	15	23	23	15
Recapture								
Fork length (mm)	78	74	81	80	85.1	92.7	76.8	69
Scale radius (μm)	301.7	335.1	321.9	353.9	404.6	455.9	411.9	326.8
Number of circuli	7	7	7	8	8	9	9	8
Check formation								
Number of circuli	3	5	4	4	5	5	6	5
Scale radius (μm)	136.3	244.7	196.9	184.5	302.1	305	277.6	211.3
Back-calculated fork length (mm)	44.5	60.1	56.3	51.8	69.2	69.4	60.2	53.3
Instantaneous growth rate	0.0374	0.0130	0.0158	0.0145	0.0138	0.0126	0.0106	0.0173

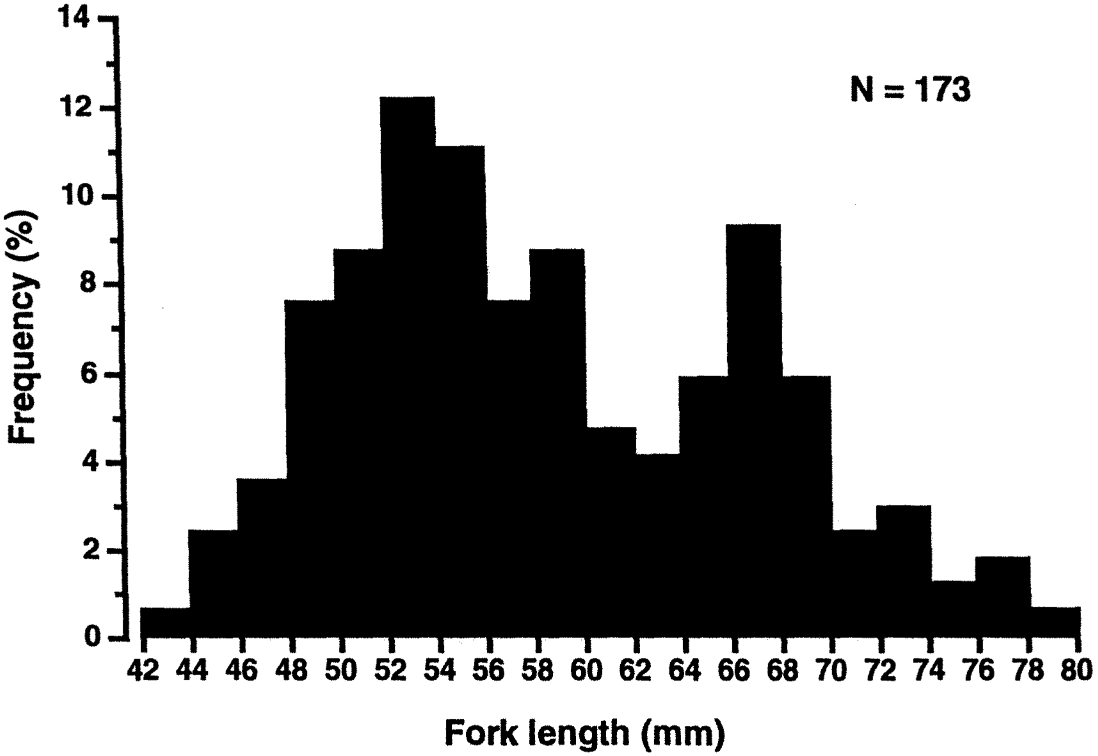

Figure 1. Size frequency distribution of juvenile chum salmon released on April 5,1993.

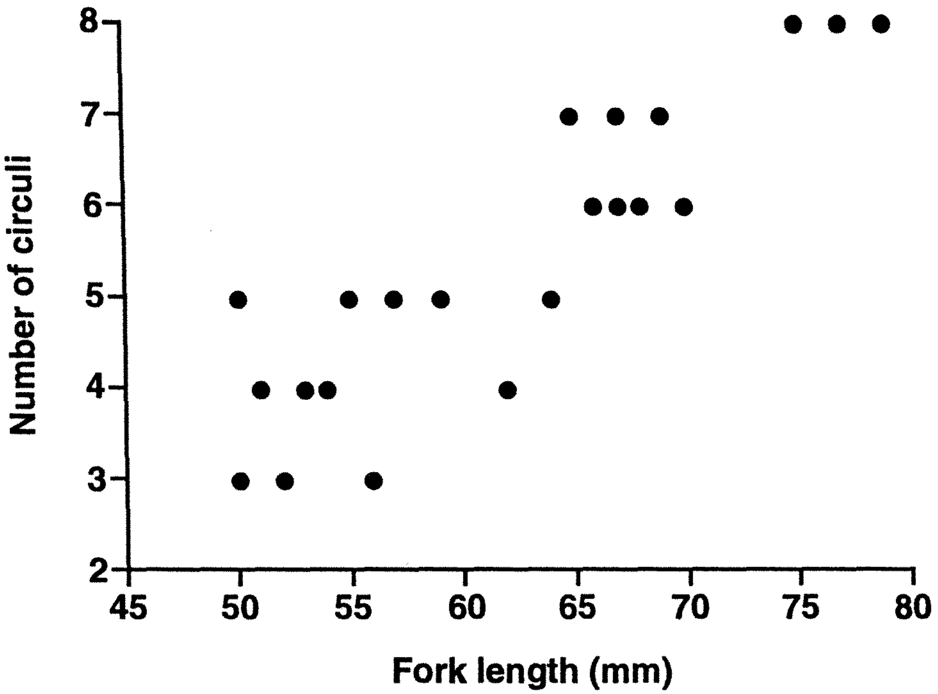

Figure 2. Relationship between fork length and number of scale circuli in juvenile chum salmon at release.

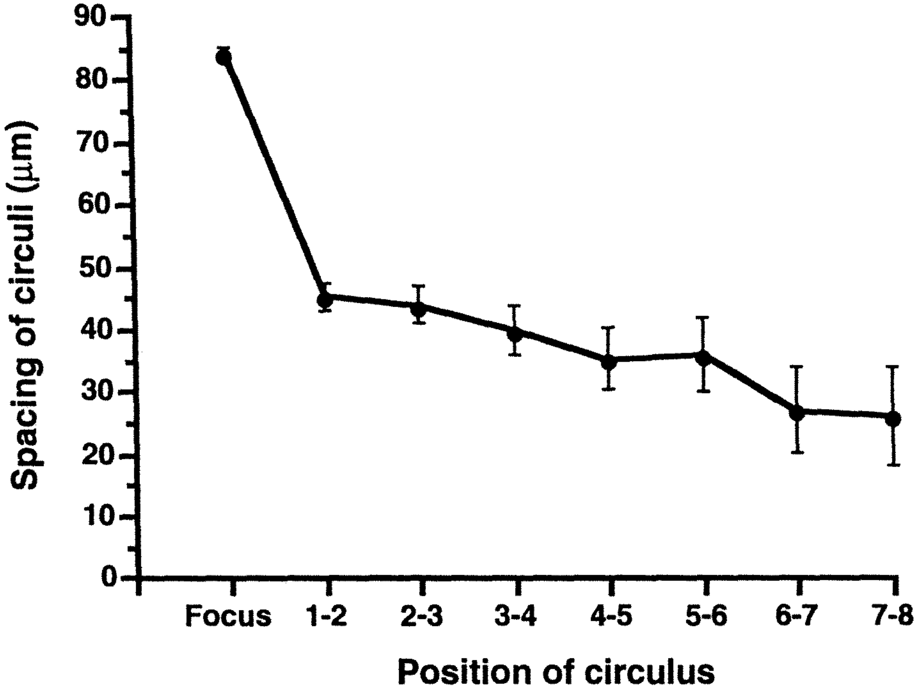

Figure 3. Average spacing of circuli in juvenile chum salmon scale at release. Vertical bars indicate 95% confidence limits.

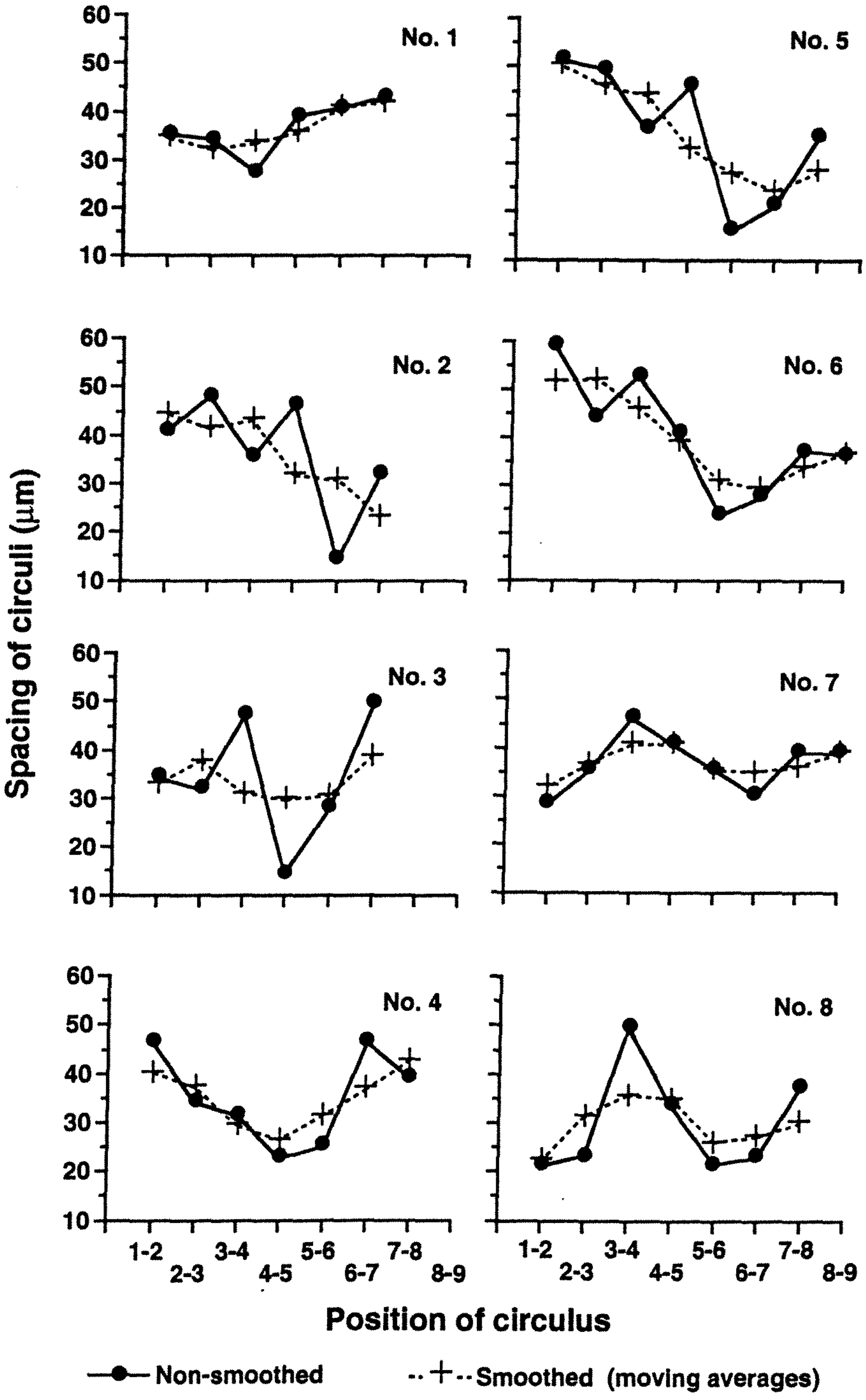

Figure 4. Scale circuli spacing patterns in 8 juvenile chum salmon recaptured in coastal waters longer than 14 days after the release.

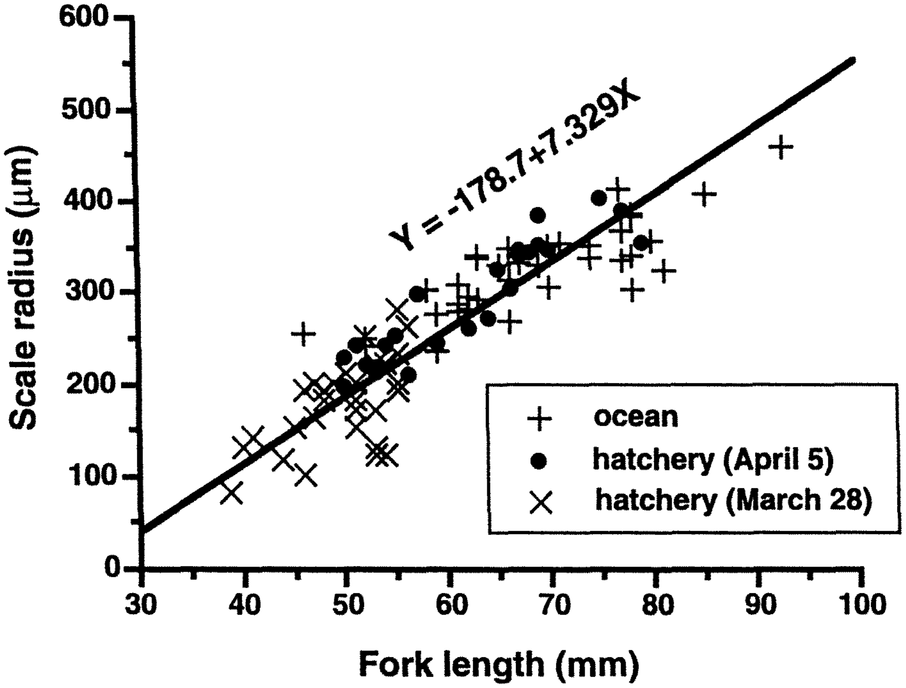

Figure 5. Relationship between fork length and scale radius of juvenile chum salmon. The linear indicates Ricker's (1973) geometric mean regression line.