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Variation of Scale Characteristics of Coho Salmon with Sampling Location on the Body

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ABSTRACT: Scales from coho salmon *(Oncorhynchus kisutch)* were used to determine whether location within a relatively small area of the body above the lateral line between the dorsal and adipose fins would affect the values of five characters of the scales, including total radius, radius of the freshwater zone, and number of circuli in the freshwater zone. Scales taken from two areas an equal distance above the lateral line and a short distance apart did not differ significantly for any of the characters; however, those taken farther above the lateral line had significantly lower values for all five characters. I conclude that substantial error can be introduced into interpretation of scale data if scales from each fish are not sampled from precisely the same area of the body. A well-chosen scrape sample yielded a result as satisfactory as that of a "preferred" or "key" scale.

Scales of Pacific salmon have been used by fishery scientists in seemingly simple studies, such as aging, and in more intricate studies, to separate distinct stocks (Major et al. 1972). In general, biologists have found it beneficial to take scales from standard areas of the fish's body, since scales first form on different areas of their bodies at different times. Scales below and above the lateral line may form at different times and have different measurements throughout the life of the fish. Because the size of scales vary with body area, body-scale relations with different slopes and intercepts may be obtained when scales are taken from different parts of the body (Hile 1970). Similarly, since the time of scale formation varies with body area, the number of circuli formed on a scale during the first year of life varies by area as well.

In the past, the problem of differential scale location characteristics has been reduced by sampling "standard areas" of fish. In salmon, this area has often been above the lateral line, between the dorsal and adipose fins. In separating stocks of salmon, biologists with the International North Pacific Fisheries Commission have often elected to take a "preferred" or "key" scale (Fig. 1), which is the scale between the dorsal and adipose fins two rows above the lateral line scale, along a posteriorly directed diagonal from the posterior insertion of the dorsal fin (Clutter and Whitesel 1956).

The collection of preferred scales poses several problems. Many scales are unusable because they are regenerated. Conditions at sites where samples are taken, such as fish companies or boat docks, are often not conducive to making exact selections. Sampling a preferred scale in the field during adverse weather can be difficult. Yet the area above the lateral line between the dorsal and adipose fins may be too wide to provide the accuracy required in many studies.

My objectives were to determine (1) how scale characteristics of coho salmon *(Oncorhynchus kisutch)* varied within the area above the lateral line between the dorsal and adipose fins, and (2) whether a precisely taken scrape sample of scales could be effectively substituted for the tedious and often impractical sampling of the preferred scale.

Methods

Scales were collected on 18 November 1977 from 30 adult coho salmon that returned to Alsea River Salmon Hatchery, Oregon. All fish were later determined to be age 1.1 (one freshwater and one ocean annulus; fish in its third year of life).

Four distinct samples were taken from the left side of each fish: the preferred scale, and 6 scales from each of three areas (A, B, and C of Fig. 1) above the lateral line and between the dorsal and adipose fins. Area A is a rectangle vertically bounded by and including scale rows 1 and 3 above the lateral line and horizontally bounded by and including the two scales anterior and posterior to the preferred scale. Area B is a rectangle vertically bounded by and including scale rows 1 and 3 above the lateral line and horizontally bounded by and including the two scales anterior and posterior to that scale two rows above the lateral line, which was directly below the posterior insertion of the dorsal fin. Area C is a rectangle vertically bounded by and including scale rows 6 to 12 above the lateral line and bounded horizon-

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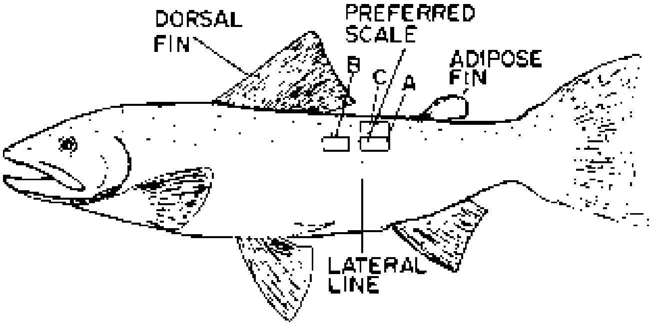

Fig. 1. Location of sampling areas for scales used in this study. The preferred scale is within area A.

tally by the dorsal extension of the boundaries from area A. Area C is thus directly dorsal to area A.

Scales were mounted on gummed cards and impressions of the scales were made on acetate sheets under heat and pressure, by methods similar to those described by Clutter and Whitesel (1956). Scale impressions of the preferred scale and one of the six scales from each of areas A, B, and C for each fish were examined with the aid of a projector at a magnification of 80×. The following measurements were taken: (1) total scale radius, (2) radius of the freshwater zone at 20° ventral to the longest axis, (3) number of circuli in the freshwater zone at 20° ventral to the longest axis, (4) radius of the freshwater zone at 90° ventral to the longest axis, and (5) number of circuli in the freshwater zone at 90° ventral to the longest axis (Fig. 2). From these measurements and counts, two other values were calculated: character 2 divided by character 3 (character 6) and character 4 divided by character 5 (character 7). I designated characters 6 and 7 as distance per circulus at 20° and 90°,

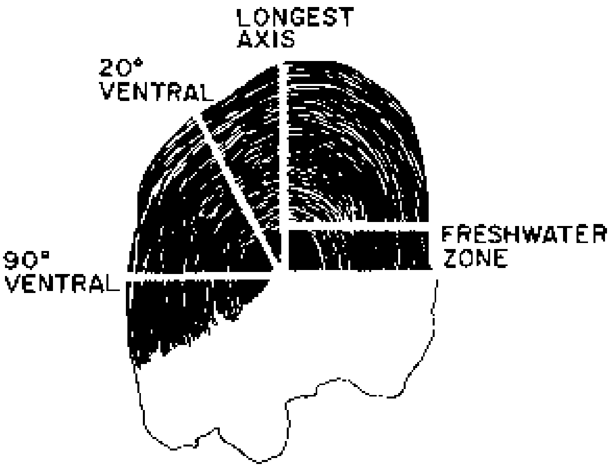

Fig. 2. Scale of salmon, showing lines 20° ventral and 90° ventral to the longest axis

respectively. Comparisons between scale locations were made for characters 1, 2, 3, 6, and 7. For each of these five characters, means and 95% confidence intervals for 30 scales, each from a different fish, were calculated for areas A, B, and C.

Only 18 of the preferred scales were usable; the rest were regenerated. These 18 scales were compared with corresponding samples taken from areas A, B, and C of these same fish. Means and 95% confidence intervals were calculated for areas A, B, and C, and for the preferred scales.

Data were subjected to a one-way analysis of variance. When significant differences between treatment means were found, means were compared by using the method of least significant difference (Snedecor and Cochran 1967).

Results

No statistical differences were found between area A and area B for any of the characters. Scales from area B were statistically different in all five characters from those of area C. Scales from areas A and C were statistically different in all characters except distance per circulus at 20° (Table 1). Scales from area C averaged only 78% of the total radius of scales from area A; the freshwater scale radius at 20° averaged only 69% of that of area A; only 72% as many freshwater circuli were present at 20° as were present in area A; mean distance between circuli at 90° was only 87.6% of that of area A (Table 2).

In the second group of comparisons, in which 18 of the samples were used for comparison with the preferred scales, significant differences between means were found for four of five characters; distance per circulus at 20° was the only character where treatment means were not statistically different (Table 2). None of the means of characters of area A, area B, or the preferred scales were statistically different from each other. Means for area C differed from those of area A, area B, and the preferred scales for four of the five characters. Comparisons of the preferred scales with scales from areas A, B, and C are shown in Table 1.

Discussion

It is evident that, even within the area above the lateral line between the dorsal and adipose fins, significant variations in scale characteristics exist among scales taken from a coho salmon. It is therefore important to specify precisely where on the fish the scales are to be taken. Even in age and growth studies, care in collecting scales can reduce error and lead to more consistent results. It is imperative that the location for taking scales from a fish be precisely defined for studies employing numbers of circuli or freshwater scale radius as characters.

Table 1. Comparisons of means from areas A, B, and C (Fig. 1), and the preferred scales (P) for five characters, showing significant differences between means for one area and those for each other area. Comparisons among areas A, B, and C were made for a sample of 30 fish and those with the preferred scale for 18 fish.

Character	Area comparisons[a] A and B	A and C	B and C	Preferred scale comparisons[a] P and A	P and B	P and C
Total scale radius	NS	**	**	NS	NS	**
Freshwater scale radius at 20°	NS	**	**	NS	NS	**
Number of circuli at 20°	NS	**	**	NS	NS	**
Distance per circulus at 20°	NS	NS	**	NS	NS	NS
Distance per circulus at 90°	NS	**	**	NS	NS	**

[a] NS = not significant; ** = highly significant ($P < 0.01$)

Since spawning salmon reabsorb the outer edges of their scales, measurements of total scale radius in this study are not exact. Nevertheless, the results tend to indicate that body-scale relation can vary substantially within a relatively small scale-sampling area on the fish. Verification of the differences in body-scale relation with area of sampling should be possible if the coho salmon used were caught in the ocean, where their scales are intact.

The results also indicate that a sample of scales taken from the area closely surrounding the preferred scale (area A) yields results similar to those based on the preferred or key scale. Sampling from area B also yields satisfactory scales. A good representative sample can be obtained by following the diagonal scale row from the posterior insertion of the dorsal fin to the lateral line, and taking scales from a row or two above the lateral line. Scales taken from area B also provide an adequate sample. Most errors result from taking scales too far above the lateral line, where part of the early life history of the fish is not recorded on the scale. In general, for coho salmon, scales should be taken close to the lateral line.

Acknowledgments

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Table 2. Means and (in parentheses) 95% confidence intervals of length (cm × 80) or counts for five scale characters from areas A, B, and C (Fig. 1), and preferred scale. Values for the first three columns were calculated from a sample of 30 fish, and values for the last four from a sample of 18 fish.

Character	Area comparisons: Area A	Area B	Area C	Preferred scale comparisons: Preferred scale	Area A	Area B	Area C
Total scale radius	30.02(0.96)	30.65(1.06)	23.53(0.81)	30.21(1.31)	29.98(1.31)	30.29(1.53)	23.64(1.07)
Freshwater scale radius at 20°	7.21(0.32)	7.04(0.34)	5.00(0.34)	7.19(0.50)	7.28(0.48)	7.03(0.50)	5.12(0.49)
Number of circuli at 20°	38.40(1.31)	36.83(1.42)	28.00(1.93)	38.89(1.77)	38.28(1.64)	37.28(1.77)	28.27(2.38)
Distance per circulus at 20°	0.188(0.006)	0.191(0.006)	0.179(0.007)	0.184(0.007)	0.190(0.008)	0.188(0.008)	0.181(0.010)
Distance per circulus at 90°	0.193(0.005)	0.199(0.005)	0.168(0.006)	0.193(0.007)	0.191(0.006)	0.195(0.006)	0.169(0.009)

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Probable Discovery of the Original Pyramid Lake Cutthroat Trout

Salmo clarki henshawi, the cutthroat trout native to the Lahontan basin of Nevada and California, evolved in pluvial Lake Lahontan, a late Pleistocene lake, comparable in size to present day Lake Erie.

As the only larger predator among several potential cyprinid and catostomid forage species, the selective pressures determining the evolutionary divergence of *S. c. henshawi* perhaps resulted in the largest and most highly predacious trout native to western North America (Behnke and Zarn 1976). Only the population in Pyramid Lake, Nevada, continued to coexist with the full array of the Lahontan basin fish fauna after the final dessication of Lake Lahontan about 8000 years ago. Stocks of *S. c. henshawi* persisting in streams of the Lahontan basin evidently were ill adapted by virtue of an evolutionary heritage as a large, lacustrine predator and rapidly disappeared after nonnative trouts were introduced. Only a few small headwater streams isolated by barrier falls still contain *S. c. henshawi*, and two native lacustrine populations still exist in Independence Lake, California, and in Summit Lake, Nevada. Although "*S. c. henshawi*" has been propagated in large numbers since the 1950's, the bulk of hatchery-produced Lahontan cutthroat trout are derived from Heenan Lake, California, from a stock originating from the Carson River, but which is slightly hybridized with rainbow trout (Behnke and Zarn 1976). The taxon *S. c. henshawi* was formerly recognized as an endangered species under the 1973 Endangered Species Act, but its status was changed to "threatened" in 1975 to facilitate management and to allow angling.

The uniqueness of the Pyramid Lake population lies in the fact that this stock persisted in a continuous lake environment for 50,000 to 100,000 years. Pyramid Lake is the only lake in the Lahontan basin that has maintined a direct continuity from pluvial Lake Lahontan with a retention of the original fish fauna. The evolutionary programming associated with a continuous environment endowed the native trout of Pyramid Lake with specialized adaptive features reflected in their behavior and physiology to maximize efficiency of energy conversion and use of the entire environmental resources.

The evolutionary selective factors acting to specialize the Pyramid Lake cutthroat trout for the large-lake environment and to feed on the abundant schools of large forage fish, which attain lengths of 375-450 mm (15-18 in.), were responsible for making this fish the largest trout native to western North America. The official world record cutthroat trout, taken from Pyramid Lake, weighed 18.6 kg (41 lb), but it is a common belief among the older Paiute Indians around Pyramid Lake that much larger trout were once regularly caught by the Indian fishermen. Wheeler (1969) reported a trout of 28.2 kg (62 lb) taken in 1916 in the Indian fishery. Summer (1940), observing the final spawning run of cutthroat trout from Pyramid Lake in 1938, recorded the average weight of the trout in the run as 9.1 kg (20 lb). Since 1955, millions of *S. c. henshawi* of Heenan Lake origin (in more recent years, supplemented by the offspring of Summit Lake trout), have been stocked into Pyramid Lake to support a trophy fishery, but relatively few specimens larger than 9.1 kg have been taken in the last 20 years.

The demise of the original Pyramid Lake trout began in 1906 with the closure of Derby Dam, part of the Newlands Irrigation Project of the Bureau of Reclamation. This dam blocked the Truckee River, the only spawning stream tributary to Pyramid Lake, about 50 km (30 mi) above the lake. In the 1920's, more and more of the Truckee River was diverted at the dam and complete dewatering frequently occurred. Successful spawning became sporadic; the last known run left the lake during the high-water year of 1938. No water was