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Focal Scale Damage among Chum Salmon (*Oncorhynchus keta*) of the Bering Sea and the Gulf of Anadyr, 1966
I. Distribution among physical parameters*

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Abstract

Damage to the osseous scale layer resulting in a hole, or intrusion of the osseous scale layer into the underlying fibrillary plate, was found among chum salmon (*Oncorhynchus keta*) sampled in the Bering Sea and the Gulf of Anadyr during July, 1966. Overall, tests to detect differences in the frequency distribution of these scale traits among physical parameters produced conflicting results. Where sample size exceeded an arbitrary value of 50, results from three Gulf of Anadyr locations, and two central Bering Sea locations suggested that the frequency of these traits increases with age. At one central Bering Sea location, the average fork length of chum salmon classified as possessing focal damage resulting in a hole was significantly larger than those of the other classifications. The opposite was found, however, in an additional case where significant differences in fork lengths were found. No differences were detected for these traits between sexes or sexual maturity indices.

Introduction

Bigler (In Press) reported two characteristics of scales sampled from Hokkaido chum salmon (*Oncorhynchus keta*); intrusion of the osseous (annual ring) scale layer into the underlying fibrillary plate, and removal of scale material such that a hole was formed. Examination of scales indicated that damage to the osseous and fibrillary plate scale layers is confined to the first, and occasionally the second, annual growth zone, and represents a permanent mark. No physical or population parameter was found which could distinguish fish possessing either focal scale trait from those which did not. That study, however, was restricted to samples collected during late spawning migration. The present study was initiated to investigate these phenomena in other chum salmon populations of the North Pacific Ocean, implementing data of wider fork length range and various degrees of sexual maturity. This study will also serve as a preliminary test of these traits as a population identification tool. The present report will discuss analysis of physical data, an additional paper (Bigler, 1988) will discuss the utility of these traits in population identification.

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Materials and Methods

General

The activity responsible for these scale traits found among samples taken in 1966 and those described by Bigler (In Press) are considered the same. Scale traits described here are found only at the focus and are assumed to involve two separate phenomena; extension of the ossified layer into the fibrillary plate, and removal of scale material which invariably results in a hole (Fig. 1A, B, C).

Data collection

With the advent of mounting scales on gum cards and pressing into acetate plastic, few scale collections are available in which these traits can be readily examined. Detection of damage resulting in a hole requires that only one side of the scale be available for inspection. Fibrillary plate damage is only visible if the scale is mounted between glass slides, or if two scales are mounted on gum cards; one with the annual ring side (osseous layer) down. In 1966, a fisheries training ship of Hokkaido University, the Oshoro Maru, sampled chum salmon captured at 31 widely distributed locations within the Bering Sea (Fig. 2). Examination for focal damage is possible because scales were mounted between glass microscope slides.

Gill nets were operated in 31 locations ranging from north of the Aleutian

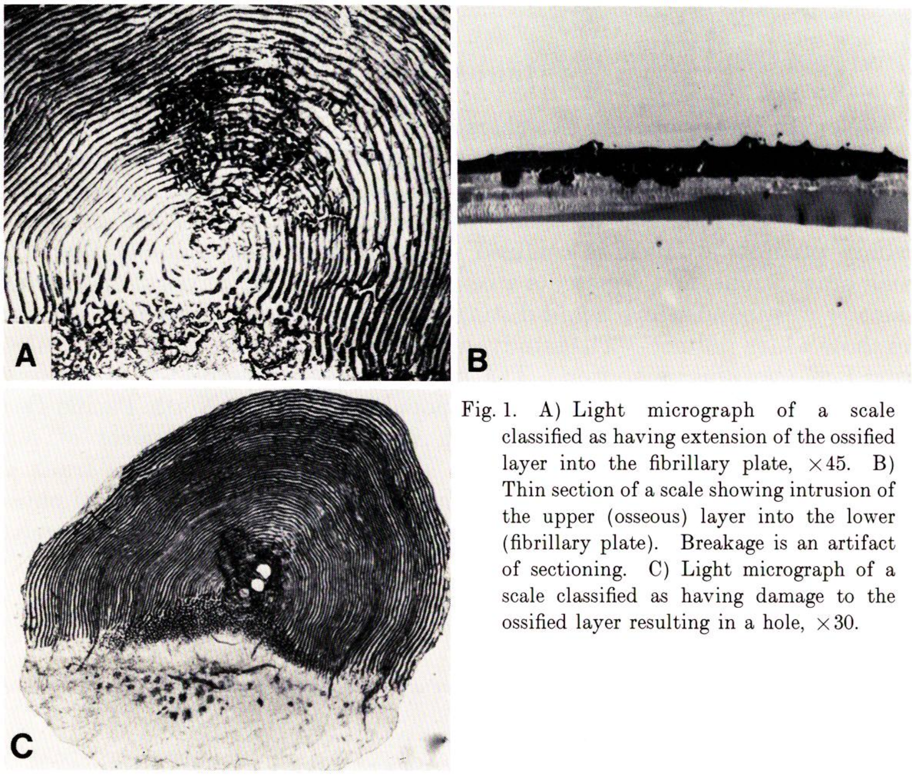

Fig. 1. A) Light micrograph of a scale classified as having extension of the ossified layer into the fibrillary plate, ×45. B) Thin section of a scale showing intrusion of the upper (osseous) layer into the lower (fibrillary plate). Breakage is an artifact of sectioning. C) Light micrograph of a scale classified as having damage to the ossified layer resulting in a hole, ×30.

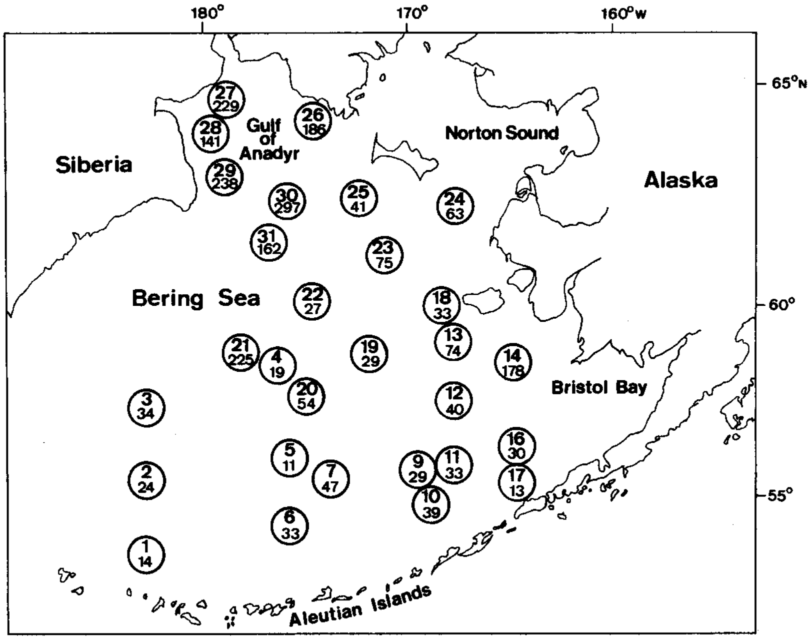

Fig. 2. Locations where chum salmon were sampled in the Bering Sea and Gulf of Anadyr. Numbers in the upper half of circles correspond to the sampling date during July, 1966. Numbers in the lower half indicate the number of chum salmon sampled for age.

Islands, the coast of western Alaska, the central Bering Sea and the Gulf of Anadyr (Fig. 2). Number designations for each of the sampling locations used in this study correspond to the date of collection during the month of July, 1966. (See Hokkaido University Faculty of Fisheries (1967), or Nishiyama et al. (1968a) for a description of net length, mesh sizes, fishing periods, and other associated data.) Fork length in millimeters, body and gonad weight in grams, and several scales, were collected from randomly selected fish at each location. Scales were taken from the area four rows above and below the lateral line between the dorsal and adipose fins (Nishiyama et al., 1968a), placed between glass microscope slides and transported to the Hakodate campus of Hokkaido University.

The catch of chum salmon ranged from 2 at location 8, to 752 at location 30 (Hokkaido University Faculty of Fisheries, 1967). Chum salmon were sampled randomly from catches taken at 29 locations in numbers ranging from 11 (100%) at location 5, to 398 (53%) at location 30. Catches were not sampled at locaitons 8 and 15. Both immature and mature chum salmon were captured at locations in the central Bering Sea. Sample sizes for each location may differ from those reported elsewhere due to missing or incomplete data.

For this paper, a male chum salmon with a testis weight of less than 5 g, and a female with an ovary weight of less than 9 g, are considered immature and highly unlikely to spawn in the year of collection (Ishida et al., 1961). Nishiyama et al., (1968a, b) described several biological and population characteristics of chum salmon taken from the Gulf of Anadyr and surrounding high seas. Minor differences between that work and this study are attributed to differing sexual maturity classifications of male chum salmon.

Scale examination

Age is expressed in European notation where two numerals which precede and follow a decimal point, respectively, indicate the observed number of freshwater and ocean annuli on the scale. Scales were magnified 100 times for age determination (confirmation) and examination for focal damage.

Thin sectioning

Samples collected and placed between glass microscope slides are not suitable for examination by thin sectioning. Several additional samples (not including the surrounding skin tissue) were collected, fixed in 1 percent glutaraldehyde for at least 4 hr, washed with a 0.1 mol phosphate buffer adjusted to pH 7.4, post fixed in a 1% osmic acid solution, dehydrated through an alcohol series to 100 percent, and embedded in epoxy resin. Sections of 0.5-1.5 μm were cut using a glass knife, mounted on microscope slides, and stained with silver nitrate.

Statistical tests

Special attention is drawn to analyses performed on limited sample sizes. Conclusions are drawn only where sample size exceeds an arbitrary value of 50 fish. Locations where less than 50 fish were sampled were not tested. This value is admittedly limited and statistically unacceptable, however, this sample size included: 1) 12 of 28 locations, 2) locations where sexually immature chum salmon had been sampled, and 3) a relatively similar number of sampling locations in the Gulf of Anadyr, central Bering Sea, and near the west coast of Alaska (Fig. 2).

Differences in frequency distributions of each trait among sexes, maturity, and age classes were compared by a log likelihood ratio test, and those among fork lengths were tested using the nonparametric Kruskal-Wallis test with tied ranks (Zar, 1984). To simplify calculations, fork lengths were rounded to the nearest centimeter. Tests for differences between sexual maturity indices were confined to samples collected at location 21 where similar numbers of mature and immature chum salmon were sampled. Statistical significance is judged at the $P=0.05$ probability level.

Results

Distribution between age classes

Significant differences found in the frequency distribution of focal scale damage traits between age classes were isolated to samples collected in the Gulf of Anadyr and the central Bering Sea. Age classes ranged from 0.3 to 0.5 among all locations. Among chum salmon sampled at locations 23 (central Bering Sea), and 26 and 28 (Gulf of Anadyr), the frequency of fibrillary plate damage among younger fish was lower, and that of older fish was higher, than the expected values given a random distribution (Table 1). A similar pattern was responsible where significant differences were found in frequencies of damage resulting in a hole at locations 21 (central Bering Sea) and 29 (Gulf of Anadyr). A higher incidence of focal scale

Table 1. Log likelihood ratio calculations among sampling locations where significant differences were found between observed and expected values of focal scale traits in chum salmon of the Bering Sea, 1966. An asterisk indicates the source of greatest variation from the expected values.

Sampling Location	Age/ Sex	N	Numbers of Fish (1)			Expected Value			Log Likelihood Ratio (2)
			None	F.P.	Hole	None	F.P.	Hole	
21	Age:								
	0.2	147	135	8	4	124.1	9.1	13.7*	
	0.3	64	46	5	13	54.0	4.0	6.0	
	0.4	14	9	1	4	11.8	0.9	1.3	
	Total	225	190	14	21				22.730 P<0.001
23	Age:								
	0.2	21	18	2	1	16.5	3.4*	1.1	
	0.3	49	40	6	3	38.5	7.8	2.6	
	0.4	5	1	4		3.9	0.8	0.3	
	Total	75	59	12	4				11.741 P<0.001
	Sex:								
	Male	45	38	7		35.4	7.2	2.4*	
	Female	30	21	5	4	23.6	4.8	1.6	
	Total	75	59	12	4				7.828 0.025>P>0.01
26	Age:								
	0.2	90	70	20		62.9	26.6*	0.5	
	0.3	83	55	27	1	58.0	24.5	0.4	
	0.4	13	5	8		9.1	3.8	0.1	
	Total	186	130	55	1				10.726 0.05>P>0.025
28	Age:								
	0.2	85	79	5	1	71.7	11.5*	1.8	
	0.3	46	35	10	1	38.8	6.2	1.0	
	0.4	10	5	4	1	8.4	1.3	0.2	
	Total	141	119	19	3				15.183 0.005>P>0.001
29	Age:								
	0.2	156	137	18	1	130.4	19.7	5.9*	
	0.3	67	50	10	7	56.0	8.4	2.5	
	0.4	15	12	2	1	12.5	1.9	0.6	
	Total	238	199	30	9				13.546 0.01>P>0.005

(1) Numbers of fish classified as having each focal damage trait: None, F.P.=Fibrillary plate, Hole.
(2) Calculated according to Zar (1984).

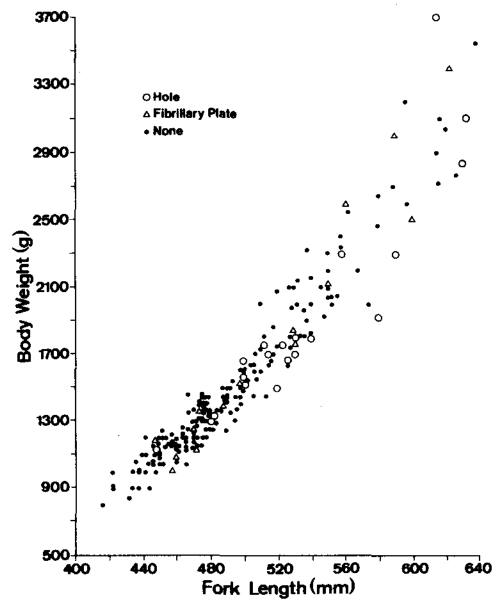

Fig. 3. Fork length and body weight distribution among chum salmon collected from location 21 in the central Bering Sea which were found to have: (○) damage resulting in a hole; (△) damage of the fibrillary plate; and (●) no evidence of damage.

damage may be evident among older fish captured within the Gulf of Anadyr and central Bering Sea.

Distribution among fork lengths

A tendency for larger fish to possess focal damage resulting in a hole was found among samples collected from location 21 where a relatively large number of fish were sampled (n=225) and fork lengths ranged from 40 cm to 63 cm (Fig. 3). Average fork lengths for fish having no damage traits, fibrillary plate damage, and that resulting in a hole were 49.8, 51.0, and 52.8 cm, respectively. Though these values differ, a multiple comparison shows a significant difference only between those with no damage and that resulting in a hole. These results corroborate indications that older (larger) chum salmon sampled at location 21 tend to possess this trait.

Results of this test on samples collected from location 23, however, showed the opposite to be true; fish classified as having focal damage resulting in a hole were of significantly smaller average fork length than those with none, or fibrillary plate damage. Average fork lengths for fish where no damage was detected, and where fibrillary plate, or a hole was found were, 59.0, 61.0, and 56.5 cm, respectively (n=75). No differences were found among these data from other locations.

Distribution between mature and immature chum salmon

No differences in the frequency of focal scale damage was detected between mature or immature chum salmon at location 21, where immature salmon composed 62.9% of the sample. Resorption resulting in a hole among mature and immature fish was strikingly similar at 9.5% and 9.0%, respectively. The frequency of fibrillary plate damage was slightly higher among mature (6.3%) than immature

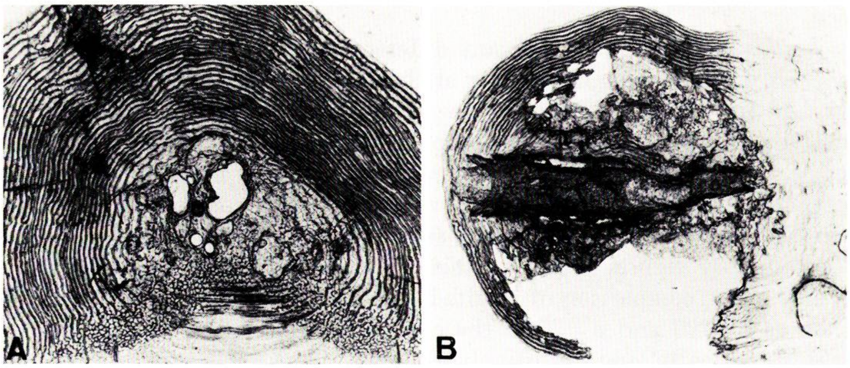

Fig. 4. Scale damage that was noted in (A) regenerated and (B) lateral line scales.

(4.2%) chum salmon, but this difference is not statistically significant. These results are not consistent with other indications that the incidence of focal scale damage at this location increases with fork length and age.

Distribution between sexes

No conclusive differences were found in the frequency distribution of either trait between male and female chum salmon. Significant differences were found between males and females at location 23 (n=75), where fibrillary plate damage was confined to females (Table 1). No differences were detectable in these tests involving other locations.

Occurrence among other scale types

During examination of this scale collection, several examples were found where focal damage occurred among scales other than those intended for age determination. The primary goal for the collection of these data was to describe the distribution of immature chum salmon within the Bering Sea (Nishiyama et al., 1968a). It was noted, however, that lateral line and obviously regenerated scales were occasionally mounted with scales usable for the intended purpose. Some regenerated scales, which were noted to include at least two seasons of normal growth (two annuli) found among fish classified as having focal damage resulting in a hole, also had this trait (Fig. 4A). It is particularly noteworthy that one lateral line scale which was not much more than a fragment due to severe damage, was also included in samples from location 30 (Fig. 4B). Although the occurrence in lateral line and regenerated scales is perhaps uncommon, these observations show that scale damage resulting in a hole occurs in all scale types.

Discussion and Conclusions

Generally, focal damage of the osseous scale layer or damage to the underlying fibrillary plate were found to occur irrespective of sexual maturity and most likely sex. Where samples included a wide range of fork lengths and age classes, a tendency for larger, older, fish to possess either damage trait was suggested. This was contradicted in a similar test where fewer samples, of a more narrow range, were involved.

It is conspicuous that significant differences in the frequency of focal scale damage were found among age classes at three of four locations within the Gulf of Anadyr, and two of four locations in the central Bering Sea. At least two possible explanations for this apparent geographic tendency can be offered: First, the number of samples collected in these areas was relatively high, and the possibility of detecting a subtle tendency increases with sample size. Second, a decrease in the occurrence of these traits over the past several years may be indicated.

Contradictory results found in this work are probably due to sample size. Unless they agree, comparison of results between two locations with diverse sample sizes such as n=225 and n=75 in the case where differences in fork length were found, is statistically and intuitively difficult. The incidence of focal damage resulting in a hole only once exceeded 10% (10.4% at location 30) and that of fibrillary plate damage was below 35%. The accurate detection of differences in these small frequencies requires a larger and more consistent sample size than was available in this study. Additionally, although two central Bering Sea locations included more than 50% immature chum salmon, samples younger than age 0.3 were not found. Future analysis will necessarily include a sampling scheme designed to optimize the detection of these traits among a wider range of ages and at a higher sample size than was used in this study.

This study has suggested that the incidence of these traits may increase with time spent at sea. If this is later proven conclusively, use of these traits for population identification will be limited. Stock differentiation based on the proportion of these two traits among each sampling location in the Bering Sea is discussed in a concurrent study (Bigler, 1988).

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