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Focal Scale Damage among Chum Salmon (*Oncorhynchus keta*) of the Bering Sea and the Gulf of Anadyr, 1966. II. Geographic distribution and stock identification.*

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Abstract

Focal scale damage in the form of perforations through the scale or extension of the osseous 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. These traits may be of use in population separation studies. A cluster analysis was used to demonstrate that the individual frequencies of these characteristics among chum salmon sampled near the coastline of Alaska were substantially different from those sampled in the central Bering Sea and the Gulf of Anadyr. Generally, perforations through the scale were found most frequently among fish taken in waters of the central Bering Sea.

Introduction

In a concurrent study (Bigler, 1988), damage to the osseous scale layer resulting in a hole, or intrusion of the osseous layer into the underlying fibrillary plate was found in the central area of scales among chum salmon (*Oncorhynchus keta*) sampled from several locations within the Bering Sea. These traits were found to occur irrespective of sex or degree of sexual maturity. A tendency for chum salmon of older age, and longer fork length to possess these traits was suggested but not concluded. The present study was initiated to investigate whether these phenomena exist in distinct proportions within geographically separated regions of the Bering Sea to allow conclusions as to stock identification.

Materials and Methods

Data collection

The present study was performed using scales collected throughout the Bering Sea in July, 1966, by the Oshoro Maru, a fisheries training ship of Hokkaido University. Chum salmon were sampled from 31 gill net catches taken from north of the Aleutian Islands, western Alaska, the central Bering Sea and the Gulf of Anadyr (Fig. 1). Number designations for each of the sampling locations used in this study correspond to the date of collection during the month of July, 1966. A

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more detailed description of these samples and the methods used for collection has been described by Hokkaido University Faculty of Fisheries (1967), Nishiyama et al. (1968), and Bigler (1988). Examination for focal scale traits was performed with scales which had been mounted between glass microscope slides.

Extension of the osseous scale layer into the underlying fibrillary plate is treated as a separate phenomenon from damage to th osseous layer which invariably results in a hole (See Bigler, 1988, Fig. 1. This is done because : 1) no evidence has been found that these phenomena are related, and 2) differing percentages of each trait among sampling locations may represent a tendency unique to geographically separated spawning populations.

Cluster analysis

A cluster analysis was performed by means of an unweighted pair-group method using arithmetic averages (UPGMA) on an unstandardized data matrix of the percentage of both traits found at the respective sampling locations. This analysis was confined to sampling locations from which an arbitrary value of at least 50 fish were sampled, and results are presented in terms of Euclidean Distance. The value of 50 samples was selected because the relatively low incidence of these traits creates a risk of erroneous conclusions. Also, this sample size encompassed approximately half (12 of 28) of the locations, and included a similar number of geographically separated areas. Calculations were performed on a programmable hand calculator according to Romesburg (1984).

Results

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. 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 remains as a permanent mark.

Geographic distribution

Damage resulting in a hole was found among none to 33.3%, and fibrillary plate damage was detected in none to 44.8%, among locations where less than 50 samples were collected (Table 1). Where sample sizes exceeded the arbitrary value of 50 fish, fibrillary plate damage was found among 35.1, 34.3, and 28.6%, respectively, of chum salmon sampled near western Alaska at locations 13, 14, and 24. Among chum salmon sampled in the central Bering Sea, (locations 20–21, 23, 30, and 31) the incidence of damage resulting in a hole averaged 8.1% and ranged from 5.3% at location 23, to 10.4% at location 30 ; generally higher than values found elsewhere (Fig. 1).

The proportion of each sample possessing focal scale traits, where sample sizes exceeded 50 fish, was sufficiently unique that differences are discernible which perhaps reflect stock composition. Relatively strong differences were found in the occurrence of these traits between samples collected near the coast of western Alaska and those of the central Bering Sea and Gulf of Anadyr (Fig. 2). Based on a

Table 1. Sample size, and the frequency of each type of scale focal damage type for locations in the Bering Sea and near the coast of western Alaska where less than an arbitrary 50 chum salmon were sampled, 1966. Focal damage is defined as that resulting in a hole (Hole) and extension of the osseous layer into the fibrillary plate (F.P.).

Sampling location	n	Type of focal damage					
		Number			Percent		
		None	F.P.	Hole	None	F.P.	Hole
Central Bering Sea							
1	14	10	1	3	71.5	7.1	21.4
2	24	9	7	8	37.5	29.2	33.3
3	34	30	3	1	88.3	8.8	2.9
4	19	13	6	—	68.4	31.6	—
5	11	10	—	1	90.9	—	9.1
6	33	26	6	1	88.8	18.2	3.0
7	47	37	9	1	88.7	19.1	2.1
9	29	24	5	—	82.8	17.2	—
19	29	16	13	—	55.2	44.8	—
22	27	26	—	1	96.3	—	3.7
25	41	31	10	—	75.6	24.4	—
Alaska							
10	39	34	4	1	81.2	10.3	2.6
11	33	28	5	—	84.8	15.2	—
12	40	27	13	—	67.5	32.5	—
16	30	21	8	1	70.0	26.7	3.3
17	13	13	—	—	100.0	—	—
18	33	26	6	1	78.8	18.2	3.0

Euclidean Distance (ED) of 2.1, the occurrence of these traits among fish collected from the Gulf of Anadyr (locations 27, 28, 29) shows the strongest relative similarity, and are weakly similar (ED=6.3) to those taken from areas of the central Bering Sea (locations 20, 21, 30, 31). Percentages of these characteristics are least similar (ED=15.2) when comparing samples taken from Alaskan waters with those of the central Bering Sea or Gulf of Anadyr (Fig. 2).

Data from two sampling locations showed similarities to samples collected from other geographic locations. Samples from location 26 within the Gulf of Anadyr are most similar to those collected near Alaska. Similarly, the percentage of these traits found among samples from location 23 in the Bering Sea was most similar to other samples collected in the Gulf of Anadyr (the unshaded areas in Fig. 2).

Discussion and Conclusions

As used here, Euclidean Distance represents a relative measurement of focal

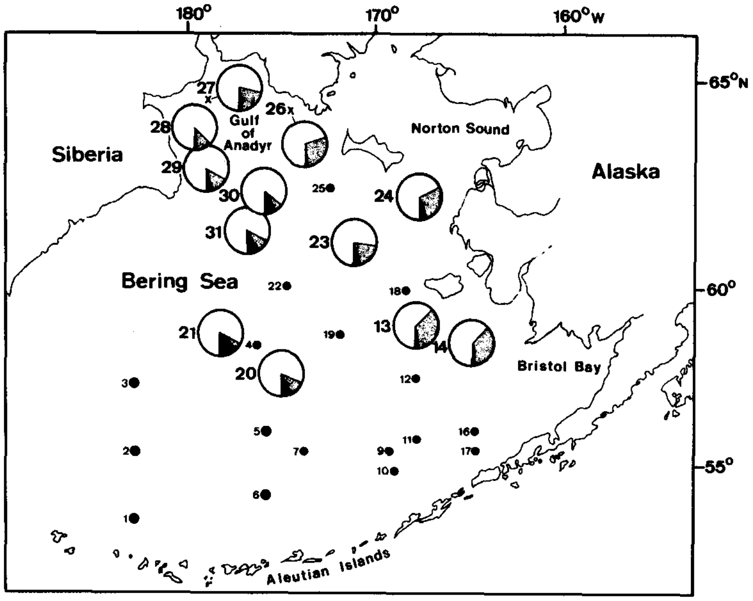

Fig. 1. Locations where chum salmon were sampled in the Bering Sea and Gulf of Anadyr. Location numbers correspond to the sampling date during July, 1966. Pie charts indicate percentage of each trait found at sampling locations where more than 50 chum salmon were sampled. Black areas in pie charts represent the percentage of chum salmon found to have resorption resulting in a hole, mottled areas indicate the percentage with fibrillary plate damage.

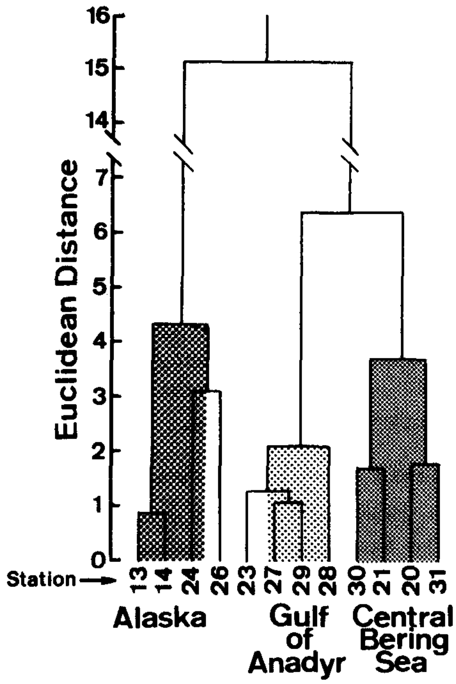

Fig. 2. Dendrogram of Euclidean Distances calculated as a measure of the relative similarity of focal scale trait occurrence between sampling locations where sample size exceeded 50 fish. Shaded areas indicate groupings within geographic regions, unshaded areas (Stations 26 and 23) were found similar to samples taken outside those regions.

scale damage frequency distribution among sampling locations. This measurement suggests that chum salmon taken from the central Bering Sea represent stock(s) which originated from areas outside those sampled, and most likely contain few chum salmon originating from western Alaska. Two previous studies have shown that chum salmon of the central and western Bering Sea are of Russian origin. Shepard et al. (1968) using tagging data, and Tanaka et al. (1968) using scale pattern analysis, concluded that chum salmon (regardless of sexual maturity) in the central Bering Sea during July, most likely originated from spawning grounds of the Soviet Union. Chum salmon taken from a close proximity to the western Alaska coast were determined to have originated from spawning grounds in that region.

In the present study, chum salmon sampled from the central Bering Sea were found to include the highest percentage of fish possessing focal damage resulting in a hole, and relatively low percentages of fibrillary plate damage. The frequency of these traits among chum salmon sampled in waters of western Alaska and the Gulf of Anadyr were exactly opposite of those in the central Bering Sea. Since samples from the Gulf of Anadyr and near the Alaskan coast are in relatively close proximity to major spawning grounds for this species, the dissimilarity found through cluster analysis suggests that central Bering Sea chum salmon originated in areas outside those sampled ; based on the findings of Tanaka et al. (1968), perhaps other areas of the Soviet Union.

Conclusions of stock identity

This study has demonstrated that two recently discovered scale characteristics among chum salmon have a potential use in population identification. Examination of scales indicates that these traits are formed within the first and occasionally the second, year zone of scales, and remain as a permanent mark. A study conducted concurrently with this suggested a higher incidence of damage among older fish (Bigler, 1988). Although this tendency was somewhat geographically isolated to the Gulf of Anadyr and Bering Sea, this may suggest caution in the interpretation these findings which include immature and mature salmon of various age classes. Clear differences in the frequency of occurrence among widely distributed locations in the Bering Sea have been shown, and that these differences probably represent expressions of separate spawning stocks is substantiated by other studies. In the absence of spawning ground samples as standards, however, it is not possible to test the efficacy of these traits for stock identification.

The origin of a single fish is not yet identifiable using these traits. Aside from quantitative testing of these traits, future studies should include a qualitative analysis to determine whether either type of focal scale damage occurs in recognizable patterns on the scales.

Comparison with previous studies of focal scale damage

In 1986, combined focal scale damage was found among 50.0% of chum salmon sampled from Hokkaido, Japan (Bigler, In Press). This percentage is substantially higher than all but locations 1 and 2 from the southern Bering Sea in 1966 (Table 1). This is a very compelling similarity but cannot be reliably tested because of the disparity in sample sizes and the lack of evidence as to whether these traits occur at the same frequency over time. Comparing the overall incidence of these traits among data collected in 1966 with those of 1986, a potential for describing the extent of chum salmon of Japanese origin within the Bering Sea is indicated.

Scale collection methods

With the advent of mounting scales on gum cards and pressing into acetate plastic, few collections exist where focal scale damage can be readily examined. In order to be useful for the study of these traits, future scale collections should include more than one scale from each fish mounted on gum cards and pressed into plastic; one scale mounted with the annual ring side up, and at least one additional scale mounted with the fibrillary plate side up.

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