

SCALE FEATURES OF SOCKEYE SALMON FROM ASIAN AND NORTH AMERICAN COASTAL REGIONS

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ABSTRACT

Photographic plates of sections of sockeye salmon scales, with descriptions, and frequency tables of the number of circuli in the freshwater and first ocean zones illustrate the variations in scale features of fish over the range of the species in coastal regions of Asia and North America. Suggestions are also given for using these data to determine the geographical origin of sockeye salmon taken in offshore areas of the North Pacific Ocean and adjacent waters.

Sockeye salmon (*Oncorhynchus nerka*) are valuable food fish of the Bering Sea and the northern part of the North Pacific Ocean. They spawn in coastal streams of Asia and North America but spend a portion of their lives feeding in oceanic areas. Upon the onset of sexual maturity, they migrate from the ocean, enter their natal streams, spawn, and then die. Because sockeye return to natal streams to spawn, the species is divided into hundreds of individual populations (each from its own geographical area), which are self-reproducing units or "stocks."

A major goal in fisheries research and management of the sockeye salmon resource is to obtain enough spawning fish within each stream to provide the maximum catch to the fishery and to insure the perpetuation of each stock. This goal is difficult to attain in fishing areas where management agencies are uncertain of the geographic area of origin of the stocks of fish that are being caught. Consequently, methods for determining the area of origin of sockeye salmon taken beyond their natal streams are needed.

A number of methods have been used to determine the area of origin of sockeye salmon taken in offshore and coastal areas. These include morphological studies (Fukuhara et al., 1962; Landrum and Dark, 1968), parasitological studies (Margolis, 1963), serological studies

(Ridgway, Klontz, and Matsumoto, 1962), tagging studies (Hartt, 1962, 1966; Kondo et al., 1965), and scale studies (Krogius, 1958; Kubo, 1958²; Kubo and Kosaka, 1959³; Henry, 1961; Mosher, Anas, and Liscom, 1961; and Mosher, 1963, 1968). Scale studies have become one of the most popular and successful methods; scale features, for example, are routinely used by investigators of the International Pacific Salmon Fisheries Commission as one element in a technique to determine the natal streams of sockeye taken near the mouth of the Fraser River and are also routinely used by investigators of the National Marine Fisheries Service (NMFS, formerly the Bureau of Commercial Fisheries) to determine continent of origin of sockeye salmon taken in the Bering Sea and the central North Pacific Ocean.

No detailed information, however, has been published on the variations in scale features among fish from different spawning regions along the Asian and North American coasts. Krogius (1958) specifically mentioned the need for an atlas illustrating scales from different

² Kubo, T. 1958. Study of sockeye salmon stocks by means of the growth pattern of scales (preliminary report). Fac. Fish., Hokkaido Univ. (Hakodate). Part I - 15 p. of Japanese text; Part II - 2 pl., 16 fig. in English. (Transl. of Part I, Int. North Pac. Fish. Comm. Doc. 206), 9 p. (Processed.)

³ Kubo, T., and J. Kosaka. 1959. A study of 5₃ age group red salmon stocks by scale growth formula [in Japanese with English abstr., headings, tables, and fig. legends.] Suisan cho (Fisheries Agency of Japan), (Int. North Pac. Fish. Comm. Doc. 326), 27 p. (Processed.)

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areas and included in her paper were many pictures of scales of sockeye salmon of Asian stocks. A photographic atlas of sockeye salmon scales (Mosher, 1968) was the first step in determining racial origins, and it should be available for reference when the present paper is studied.

The purpose of this paper is to show variations in age and scale characteristics among adult fish from various coastal areas over the range of the species so that workers planning to collect and analyze scale data to determine origin of sockeye taken at sea and in coastal waters are informed about scale features that are linked to various geographic localities.

This report consists of two principal parts. The first comprises (1) photographs of sections of scales of adult sockeye salmon, as plates, for each freshwater age group from various areas over the range of the species; (2) frequency tables of the number of circuli in the freshwater and first ocean zones for fish taken from the various areas; and (3) descriptions of the scales of sockeye salmon from the various areas. The second part is concerned with the selection of scale features for the determination of the origin of fish taken in offshore waters.

METHODS AND MATERIALS

In the preparation of this paper I was concerned with (1) the selection of scale samples of fish from various geographical areas, (2) the selection of scale features that are linked to various stocks or geographical areas, and (3) the method of preparation of plates from photographs of selected sockeye scales. I have discussed each of these items separately.

SELECTION OF SCALE SAMPLES OF FISH FROM VARIOUS GEOGRAPHICAL AREAS

An important consideration in deciding which stocks of sockeye salmon to include in this paper was the relative number of fish produced in the various localities over the range of the species shown in Figure 1. Study of catch data seems to be the best way to determine the most abun-

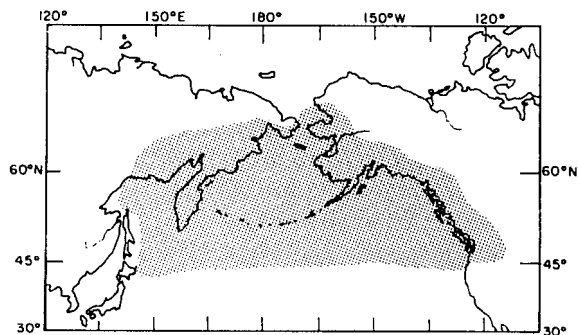


FIGURE 1.—Approximate range of sockeye salmon in and around the North Pacific Ocean and adjacent seas. The distribution in the northern Bering and Chukchi Seas was estimated to include the northernmost spawning streams on both continents. Sockeye salmon may be found in many streams within the range shown, but in only a few streams in some areas. Atkinson et al. (1967) shows detailed maps of streams where sockeye salmon have been known in the United States. The distribution at sea varies within and between years, depending on many factors, Manzer et al. (1965), Hartt (1962, 1966), and Kondo et al. (1965). In addition to the above references, Hanamura (1966, 1967) and Aro and Shepard (1967) were also sources of data for this figure.

dant stocks because the catch is roughly proportional to the production of fish in an area. Table 1 shows the average catch for the 3 years, 1966-68, the statistics for which are complete for Asia

TABLE 1.—Sockeye salmon catch, average of 1966-68.

Area	Thousands of fish	Metric tons
Total all areas	27,297.2	70,387.0
Asia	9,512.6	20,972.6
Japan ¹	8,527.0	17,988.6
USSR	985.6	2,984.0
North America	17,784.6	49,414.4
Canada (British Columbia)	5,676.4	
United States	12,108.2	
North of Bristol Bay	2.8	
Bristol Bay ²	5,715.0	
Alaska Peninsula ³	1,625.5	
Cook Inlet	1,465.7	
Copper River area ⁴	832.2	
Southeastern Alaska ⁵	952.1	
Washington and Oregon ⁶	1,514.9	

¹ Japan has no stocks of sockeye salmon.

² Includes north side of Alaska Peninsula.

³ Includes Aleutian Islands, south side of Alaska Peninsula, Chignik, and Kodiak Island.

⁴ Includes Resurrection Bay, Prince William Sound, Copper and Bering Rivers.

⁵ Includes Yakutat.

⁶ Includes the Columbia River (32.2 thousand fish).

Source of data: International North Pacific Fisheries Commission, 1966, 1967, and 1968; and supplemental catch statistics supplied to the INPFC by the USSR.

and North America from International North Pacific Fisheries Commission (INPFC) sources. The approximate ranking on each continent of the importance of the coastal areas is as follows:

<i>Asia (from Hanamura, 1966 and Krogius, 1958)</i>		<i>North America (from catch data of Table 1)</i>	
Ozernaya River	1	Bristol Bay	1
Kamchatka River	2	British Columbia	2
Bolshaya River	3	Alaska Peninsula	3
Paratunka River	4	Washington and	
Apuka River	5	Oregon	4
Okhota and		Cook Inlet	5
Kukhtuy Rivers	6	Southeastern Alaska	6
		Copper River area	7
		Columbia River	8
		North of Bristol	
		Bay	9

The abundance and catch of sockeye salmon in most areas can fluctuate widely between years, however. Some of these variations in catch are revealed in Appendix Table 1 of the catch of the 5 years, 1964-68, which series includes one high production year in Bristol Bay—1965.

The distribution of spawning streams in Asia extends from approximately lat 66° N near the Anadyr River southward to the tip of the Kamchatka Peninsula and the Kurile Islands, and westward to the Okhota and Kukhtuy Rivers on the northern coast of the Okhotsk Sea (Hanamura, 1966, 1967). Berg (1948) indicated that the species was very rare in northern Hokkaido Island. Krogius and Krokhin (1956) concluded that approximately 90% of the total sockeye catch along the Far Eastern Coast of the USSR was produced in the Ozernaya and Kamchatka Rivers of the Kamchatka Peninsula.

The distribution of North American spawning streams extends from the Noatak River of Kotzebue Sound in Northern Alaska, southward to the Columbia River of Oregon and Washington (Aro and Shepard, 1967; Atkinson et al., 1967). The streams can be conveniently grouped into three major geographical areas for study: (1) the Columbia River to and including British Columbia; (2) Bristol Bay, Alaska, and areas north of Bristol Bay; and (3) the area between Bristol Bay and British Columbia. In many years each area contributes about one-third of the North American catch. Normally, the catch of sockeye salmon north of Bristol Bay is insignificant

in relation to the number of fish taken in the Bay, but consumption and barter of salmon is substantial, especially by residents along the Kuskokwim River.

Thus, plates of representative scales of fish from southern Kamchatka, Bristol Bay, and the areas north of Bristol Bay, central and southeastern Alaska, British Columbia, and the Columbia River (the coastal areas listed in Table 1) are included in the first part of this paper.

The scale samples used in a previous study (Mosher, 1968) with a few samples, which have recently become available from additional areas, were used for this study.⁴ The areas from which these samples were collected are listed in Table 2. Figure 2 shows the approximate location of the areas mentioned in the text and on the plates.

SELECTION OF SCALE FEATURES LINKED TO VARIOUS STOCKS OR AREAS

My previous paper (Mosher, 1968) shows in detail the features of sockeye salmon scales and the range of variations in many characters. This paper continues the study of sockeye salmon scales to show the relation of many of the variations to locality and how these variations in scale characters can be used to identify the mainland origin of sockeye salmon taken in offshore waters.

A number of age groups have been found in all populations of sockeye salmon that have been studied. These age groups are based on the number of years the fish lived in fresh water and in the ocean. Over the geographical range of the species, individuals with scales showing freshwater ages from 0. to 4., ocean ages from .1 to .4, and total ages of 0.1 to

⁴ Contributions of the following agencies to the salmon scale sampling program are gratefully acknowledged: The Alaska Department of Fish and Game, Juneau, Alaska; the Fisheries Research Board of Canada, Nanaimo, B.C.; the Fisheries Agency of Japan, Tokyo, Japan; and the Fish Commission of Oregon, Portland, Ore. In addition, special thanks are given to Dr. I. Lagunov of the Pacific Institute of Fisheries Research and Oceanography (TINRO), Petropavlovsk, Kamchatka, USSR, who kindly supplied a series of samples from USSR streams.

TABLE 2.—Geographical areas where scales were taken from sockeye salmon. (Scales are available at the National Marine Fisheries Service, Northwest Fisheries Center, Seattle, Wash.)

Asia	11. Alaska Peninsula area ²	16. Ketchikan area ²
1. Kamchatka River	A. King Cove	A. Portland Canal
2. Paratunka River	B. Chignik	B. Moira Sound
A. Dalnee Lake	C. Kodiak Island	(1) North Arm
B. Blizhnee Lake	(1) Karluk	(2) Kegan Creek
3. Bolshaya River	(2) Red River	C. Karta Bay
4. Ozernaya River	(3) Frazer River	D. Dolomi Lake and Stream
5. Okhtosk Sea	12. Cook Inlet area ²	E. Hugh Smith Stream
6. North Pacific Ocean and Bering Sea from areas near the Kamchatka Peninsula	A. Cook Inlet Fishery	F. Clarence Strait
	B. Kenai River	G. Eek Bay
	C. Susitna River	H. Hetta Bay
North America	(1) Fish Creek	I. Nicholas Bay
7. Nome area	(2) Judd Lake	J. Nichols Bay
A. Salmon Lake	(3) Alexander Creek	K. Klawock Creek
B. Unalakleet River	D. Kasilof River	L. Klakas Lake
8. Kuskokwim River	E. Fish Creek, Knik Arm, Kenai Peninsula	M. Deweyville
9. Bristol Bay	F. Skilak Lake	17. British Columbia
A. Togiak River	G. Tustamina Lake (Bear Creek)	A. Nass River
B. Nushagak-Wood River System ¹	H. Upper Russian Lake	B. Skeena River
C. Kvichak River ¹	13. Copper River ²	C. Rivers Inlet
D. Naknek River ²	A. Haley Creek	D. Smith Inlet
(1) Brooks Lake	14. Yakutat	E. Alert Bay
(2) Branch River	A. Situk River	F. Nimpkish River
E. Egegik River ¹	15. Petersburg area ²	G. Fraser River
F. Ugashik River ¹	A. Kasheets	18. Columbia River
G. Bear River	B. Stikine River	A. Main stem
10. Aleutian Islands	C. Salmon Bay	B. Wenatchee River
A. Attu	D. Tahlton Lake	C. Okanogan River
B. Adak	E. Red Bay	
C. Unalaska	F. Port Houghton	

¹ Samples from the five major Bristol Bay rivers were taken each year since 1954. There are samples for most other areas for a number of years, but there is only one sample for some of the less important areas.

² Additional samples were taken, but numbers of scales were small.

³ 4 occur, but in most localities most fish are in age groups 1.2, 1.3, 2.2, and 2.3.

The number of years spent in fresh water varies within and between many spawning areas and influences many of the scale characters (Mosher, 1963, 1968). Only a few adult fish of age 0. or 4. are found, some fish of age 3. are found in a few areas, but fish of age 1. and 2. are present in substantial numbers in most areas. Table 3 shows the percentage freshwater age composition of sockeye salmon in stream samples (except as noted) from areas around the North Pacific Ocean available at the NMFS Northwest Fisheries Center.

Many features of sockeye salmon scales can be used in racial studies. Scientists at the NMFS Northwest Fisheries Center in Seattle have examined about 50 different features

such as counts of circuli, measurement of zones and portions of zones, and various ratios based on these counts and measurements; but only scale characteristics with the greatest difference between Kamchatkan and Bristol Bay stocks have been described in our publications (Mosher et al., 1961; Mosher, 1963, 1968; Anas, 1964; Anas and Murai, 1969). In all of our studies—published and unpublished—the best features for racial studies have been in the freshwater and first ocean zones of the scale.

Because of the large number of Asian and North American spawning areas and the large number of age groups in some areas, it is evident that space is not available for examples of scales representative of each area and age group over the geographic range of the species. Scales from numerous areas are similar in many characters; consequently I will group together scales from fish of more than one stock or spawning area that have a relatively similar appearance.

The number of circuli in the freshwater and first ocean zones (counted as indicated on p. 36

⁵ Age designation follows the European system, Koo (1962a): the number of winters the fish spent in fresh water since hatching, a decimal point, and the number of winters the fish spent in the ocean (see Mosher, 1968, p. 259 and 262).

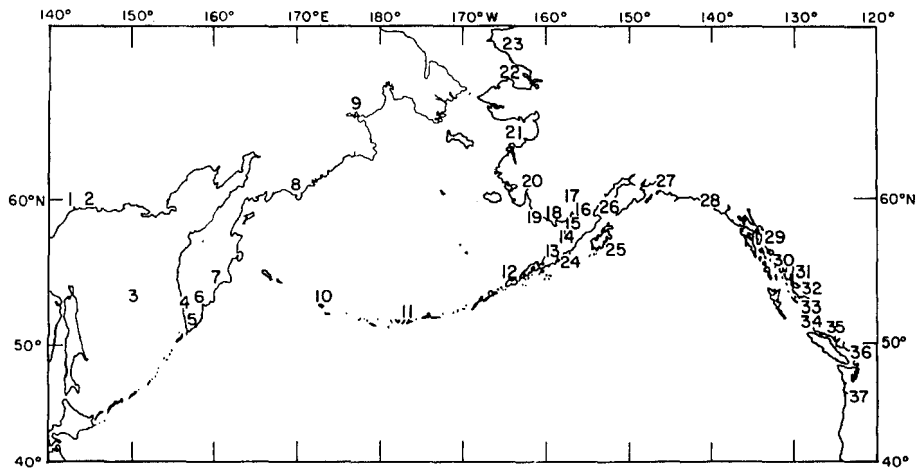


FIGURE 2.—Approximate location of areas mentioned in the text and on the plates.

- | | | |
|---------------------|---------------------------|-----------------------|
| 1. Okhota River | 13. Bear and Sandy Rivers | 25. Kodiak Island |
| 2. Kukhtuy River | 14. Ugashik River | 26. Cook Inlet |
| 3. Okhotsk Sea | 15. Egegik River | 27. Copper River area |
| 4. Bolshaya River | 16. Naknek River | 28. Yakutat Bay |
| 5. Ozernaya River | 17. Kvichak River | 29. Petersburg area |
| 6. Paratunka River | 18. Nushagak-Wood River | 30. Ketchikan area |
| (Dalnee and | system | 31. Nass River |
| Blizhnee Lakes) | 19. Togiak Bay | 32. Skeena River |
| 7. Kamchatka River | 20. Kuskokwim River | 33. Rivers Inlet |
| 8. Apuka River | 21. Norton Sound- | 34. Smith Inlet |
| 9. Anadyr River | Yukon River | 35. Nimpkish River |
| 10. Attu Island | 22. Kotzebue Sound | 36. Fraser River |
| 11. Adak Island | 23. Noatak River | 37. Columbia River |
| 12. Unalaska Island | 24. Chignik Bay | |

and 37 of Mosher, 1963) are shown for the various areas as frequency tabulations in Tables 4 and 5 for the age 1. fish; in Tables 6 and 7 for the age 2. fish; and in Table 8 for the age 3. fish. Inspection of Tables 4 and 6 shows that the mean number of circuli in the freshwater zone varies among some geographical areas, but that in the first ocean zone (Tables 5 and 7) there is a cline in number of circuli from least in the Adak Island fish to most in the central British Columbia areas of Rivers and Smith Inlets and the Nimpkish River. A decrease in the mean number of circuli among stocks from central British Columbia southward to the Columbia River is also found. The Asian fish and those north of Bristol Bay have slightly more circuli, on the average, than those of Adak Island and Bristol Bay.

The scales from sockeye taken from certain geographic areas have similar frequency distributions of circuli in the freshwater or first ocean zone. These similarities are the basis for dividing the coast of North America into certain broad areas. When I discuss the various geographic areas, reference will be made to the appropriate frequency table.

PREPARATION OF PLATES

The scale plates for the report were made as follows: (1) The scale images produced by a scale projector like the one I described (Mosher, 1950), at 82 \times magnification, were photographed with a 35-mm single lens reflex camera on medium speed, fine grained film and processed to accentuate the contrast by minimum exposure

TABLE 3.—Percentage freshwater age composition of samples of sockeye salmon from geographical areas of the North Pacific Ocean from those listed in Table 2.

Locality	Year ¹	Freshwater age					Number in sample
		0.	1.	2.	3.	4.	
		----- Percent -----					
Asia²							
Ozernaya R.	1959	--	0.8	53.3	45.1	0.8	124
Bolshaya R.	1964	1.2	94.1	3.5	1.2	--	84
Kamchatka R.	1964	2.2	90.2	6.5	1.1	--	92
Paratunka R.:							
Dalnee Lake	1964	--	2.9	44.3	52.8	--	70
Blizhnee Lake	1958	--	0.6	78.5	20.3	0.6	172
Okhotsk Sea	1957	--	51.5	42.1	6.4	--	501
Off S.E. Kamchatka	1965	--	21.9	59.2	16.9	2.0	201
North America:							
Kuskokwim	1959	--	70.5	28.7	0.8	--	122
Bristol Bay:							
Ugashik R.	1966	--	39.6	60.4	--	--	318
Egegik R.	1966	--	5.9	86.9	7.2	--	305
Naknek R.	1966	--	32.0	67.2	0.8	--	356
Kvichak R.	1966	--	4.0	95.7	0.3	--	351
Nushagak R.	1966	--	94.7	5.3	--	--	322
Togiak R.	1955	3.3	80.1	16.6	--	--	307
Bear R.	1959	--	1.6	95.0	3.4	--	119
Aleutian Islands:							
Aitu Isl.	1956	1.3	38.8	52.9	6.6	0.4	227
Adak Isl.	1956	--	30.6	60.5	8.0	0.9	213
Unalaska Isl.	1956	--	38.9	37.5	22.9	0.7	144
Alaska Peninsula:							
King Cove	1957	--	45.7	52.7	1.6	--	182
Chignik R.	1957	--	40.0	59.3	1.7	--	175
Karluk R.	1959	--	--	48.1	47.2	4.7	106
Red River	1959	--	--	85.1	14.9	--	107
Cook Inlet	1959	--	83.9	16.1	--	--	118
Cook Inlet Fish Cr.	1959	--	98.3	1.7	--	--	120
Southeastern Alaska:							
Copper R.	1959	--	87.7	12.3	--	--	122
Yakutat R.	1958	--	31.5	65.6	2.9	--	105
Petersburg	1964	4.6	81.8	13.0	0.6	--	323
Ketchikan	1964	0.3	84.1	15.6	--	--	352
British Columbia:							
Nass R.	1964	--	35.0	65.0	--	--	320
Skeena R.	1964	--	98.7	1.3	--	--	297
Rivers Inlet	1961	--	98.0	2.0	--	--	248
Smith Inlet	1961	--	100.0	--	--	--	255
Nimpkish R.	1967	--	64.5	30.4	5.1	--	79
Fraser R.	1964	0.7	98.0	1.3	--	--	153
Columbia River	1964	0.2	88.1	11.7	--	--	416

¹ The year selected is the most complete for that area, is in a series with adjacent areas, or is the only year a sample is available in our series (Table 2).

² Historical data on age composition of samples from Ozernaya, Bolshaya, and Kamchatka Rivers, and Lake Dalnee for a number of years from 1931 to 1960 are available in Hanamura (1966).

and maximum development (Adams, 1952; Mortensen, 1947). (2) Positive prints of sections that showed the important features of the anterior field of the scales were made from these negatives on high contrast enlarging paper. (3) The positive prints of the scale sections were assembled by area groups on mounting sheets and photographed to provide the plates. The scales were all photographed at the same magnification. Consequently, the relative size of the scale features on the plates

reflects the relative size of the scale features themselves.

As indicated in my previous paper (Mosher, 1968), the texture, contrast, and distinctness of circuli vary greatly both on individual scales and between the scales of the same and different fish. Some scales can be photographed to show the features clearly; other scales, especially from some localities with many closely spaced and broken circuli, do not provide clear photographs of all features.

TABLE 4.—Percentage frequency distribution¹ of circuli in the total freshwater zone from age 1, sockeye salmon collected in various years from 1956 to 1967.

Number of circuli	Asia					Alaska										British Columbia						
	Kam-chatka River ²	Bol-shaya River ²	Dolnea Lake ³	Far North ⁴	Bristol Bay ⁵	Attu Island ⁶	Adak Island ⁶	Un-alaska Island ⁶	Chignik ⁷	Cook Inlet ⁸	Fish Creek ⁷	Copper River ⁹	Yaku-tat ⁵	Peters-burg ²	Ketch-ikan ²	Nass River ⁸	Skeena River ⁹	Rivers Inlet ⁹	Smith Inlet ⁹	Nimp-kish River ¹⁰	Fraser River ⁹	Col-umbia River ⁷
	Percent																					
5	1.9	1.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.5	--	--	--	--
6	5.6	6.5	--	--	--	--	--	--	--	--	1.1	--	2.2	0.5	--	--	--	1.9	1.0	--	--	--
7	7.4	12.0	--	--	--	0.7	--	--	--	0.5	--	3.8	0.5	6.5	1.5	--	--	4.8	4.5	--	--	--
8	9.6	14.7	--	0.4	--	2.8	--	--	--	1.5	--	4.7	3.1	11.2	2.5	--	--	10.5	8.5	0.5	--	--
9	13.3	16.4*	--	0.9	--	7.0	--	--	0.6	2.0	--	4.9	6.6	15.9*	2.5	0.5	--	18.3	12.5	0.9	--	--
10	16.7	14.0	--	1.3	--	13.0	--	--	2.8	2.0	--	6.7	9.2	15.9*	2.5	3.0	0.5	23.3*	20.0	3.9	--	--
1	18.2*	9.9	--	3.0	--	16.9*	--	--	6.0	4.0	--	9.6	11.2	12.5	7.0	5.5	2.5	20.0	23.5*	9.3	--	--
2	13.9	8.6	--	4.3	0.1	14.8*	--	--	8.5	10.5	--	14.2	12.8	10.8	14.5	4.5	6.5	11.7	15.5	9.8	0.6	0.3
3	7.4	6.2	--	3.0	1.9	9.5	--	--	12.5	18.5	--	16.9*	14.8	8.6	21.0	5.5	10.0	6.0	6.0	6.4	1.7	0.6
4	3.1	3.1	0.5	0.9	6.5	7.0	--	--	17.0*	20.5*	--	16.3	18.4*	6.5	22.5*	13.0	13.5	2.6	3.5	5.4	2.8	0.3
5	1.2	1.7	2.7	2.2	11.3	7.0	--	0.5	16.2	16.0	--	12.2	15.8	5.2	15.0	21.0*	21.0	0.5	3.5	4.9	5.6	0.6
6	1.2	1.4	5.5	7.8	15.1	5.6	--	3.7	11.1	11.5	--	5.8	6.1	3.0	6.0	21.0*	23.5*	--	1.5	3.4	10.1	1.8
7	0.6	1.4	5.5	12.4	18.6	3.5	0.8	7.9	8.0	7.5	--	2.3	1.0	1.3	2.0	13.5	15.0	--	--	4.9	14.6	2.1
8	--	1.0	7.3	19.8	19.5*	3.2	4.0	7.9	7.1	3.5	--	1.1	0.5	0.4	1.0	7.0	6.0	--	--	10.3	16.6*	4.3
9	--	0.7	14.1	22.8*	15.5	3.2	8.5	6.5	5.4	1.5	0.3	0.3	--	--	1.0	3.5	1.5	--	--	13.7*	13.5	10.1
20	--	0.7	17.7*	13.8	8.7	2.1	10.9	6.5	2.6	0.5	0.9	--	--	--	0.5	1.5	--	--	--	9.8	10.4	14.3
1	--	0.3	15.5	5.2	2.6	0.7	11.3	5.6	1.1	--	5.2	--	--	--	--	0.5	--	--	--	5.4	10.1	16.8
2	--	--	14.1	1.7	0.1	0.4	11.3	4.2	0.9	--	14.3	--	--	--	--	--	--	--	--	4.4	8.4	17.1*
3	--	--	11.4	--	--	0.7	11.7	5.1	0.3	--	21.0	--	--	--	--	--	--	--	--	2.5	4.5	14.3
4	--	--	4.1	--	--	0.7	12.5*	9.2	--	--	22.6*	--	--	--	--	--	--	--	--	0.9	1.1	10.7
5	--	--	0.5	--	--	0.7	10.5	13.0*	--	--	18.9	--	--	--	--	--	--	--	--	0.9	--	5.2
6	--	--	0.9	--	--	0.4	6.0	11.1	--	--	11.0	--	--	--	--	--	--	--	--	0.5	--	1.2
7	--	--	0.5	--	--	--	3.6	6.9	--	--	4.6	--	--	--	--	--	--	--	--	0.5	--	0.3
8	--	--	--	--	--	--	3.6	5.6	--	--	1.2	--	--	--	--	--	--	--	--	0.9	--	--
9	--	--	--	--	--	--	3.6	4.2	--	--	--	--	--	--	--	--	--	--	--	0.5	--	--
30	--	--	--	--	--	--	1.6	1.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1	--	--	--	--	--	--	--	0.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Number of fish	81	73	55	58	181	71	62	54	88	50	82	86	49	58	50	50	50	105	50	51	89	82

¹ Actual frequencies smoothed according to Henry (1961).² 1964.³ 1958.⁴ 1957.⁵ 1966.⁶ 1956.⁷ 1963.⁸ 1965.⁹ 1961.¹⁰ 1967.

* Indicates modes.

TABLE 5.—Percentage frequency distribution¹ of circuli in the first ocean zone of age 1, sockeye salmon collected in various years from 1956 to 1967.

Number of circuli	Asia				Alaska										British Columbia								
	Kam-chatka River ²	Bol-shaya River ²	Dalnee Lake ³	Far North ⁴	Bristol Bay ⁵	Attu Island ⁶	Adak Island ⁶	Un-alaska Island ⁶	Chignik ⁷	Cook Inlet ⁸	Fish Creek ⁷	Copper River ⁹	Yaku-tat ²	Peters-burg ²	Ketch-ikon ²	Nass River ⁸	Skeena River ⁸	Rivers Inlet ⁹	Smith Inlet ⁹	Nimp-kish River ¹⁰	Fraser River ⁹	Colum-bia River ⁷	
	Percent																						
10	--	--	--	--	--	--	0.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11	--	--	--	--	--	--	0.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	2.7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3	--	--	--	--	0.1	0.1	5.9	0.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4	--	--	--	--	0.4	0.4	10.0	1.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
5	--	--	--	--	1.1	0.8	12.6	3.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
6	--	--	--	0.4	3.9	1.2	13.3*	5.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7	--	0.3	1.4	2.2	8.6	2.6	13.2*	7.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
8	1.2	0.7	3.2	5.2	12.3	5.1	10.8	9.6	0.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--
9	3.1	0.7	3.6	9.1	16.7	7.3	8.4	13.7	1.4	2.0	0.9	--	--	--	--	--	--	--	--	--	--	--	--
20	3.7	1.0	5.9	11.2	21.0*	12.6	7.4	14.8*	2.3	6.5	2.7	0.3	--	--	--	--	--	--	--	--	--	0.3	--
1	6.8	4.5	12.3	15.5	18.1	16.9*	5.8	11.2	4.5	11.0	5.5	0.9	--	1.3	--	0.5	--	--	--	--	--	0.6	0.9
2	12.3	12.3	19.1	21.1*	10.5	14.9	3.8	9.5	8.5	13.5	11.0	2.0	--	3.0	0.5	1.5	0.5	--	--	--	1.4	4.0	
3	17.6	19.5	20.0*	17.2	5.0	13.2	2.3	8.9	14.2	17.0	17.4	4.1	1.0	2.5	2.0	3.0	3.0	--	--	--	5.1	7.3	
4	20.7*	21.2*	15.5	10.3	1.9	11.5	1.5	6.4	17.3*	20.0*	18.9*	6.4	4.1	2.2	3.0	4.5	10.5	--	--	--	9.8	9.8	
5	17.2	18.1	10.5	6.0	0.4	6.7	0.7	3.9	15.6	14.5	16.2	9.9	12.2	6.0	5.5	6.5	16.0	0.5	0.5	--	12.6	14.0	
6	10.5	12.0	5.9	1.7	--	2.7	0.2	2.0	13.4	7.5	13.4	14.5	23.0*	13.4	13.0	11.5	13.5	1.4	1.5	--	13.5*	18.0*	
7	4.9	5.8	2.3	--	--	1.4	0.2	1.2	9.9	5.0	8.8	16.3*	23.0*	17.7*	18.0*	15.5*	13.5	1.7	4.0	1.5	12.4	16.8	
8	1.5	2.7	0.5	--	--	1.3	0.1	1.1	6.0	2.5	3.3	14.8	14.8	16.4	16.0	14.0	16.5*	1.4	6.5	3.9	11.5	12.2	
9	0.3	1.0	--	--	--	0.9	--	0.4	3.7	0.5	0.9	11.9	11.2	13.8	13.5	9.5	14.0	2.9	8.0	7.4	11.5	8.2	
30	--	--	--	--	--	0.3	--	--	2.0	--	0.6	7.0	8.2	10.8	11.5	7.5	7.0	6.2	9.0	11.8	9.3	5.2	
1	--	--	--	--	--	--	--	--	0.6	--	0.3	4.1	2.6	5.6	7.5	10.0*	2.5	8.8	7.5	11.8	6.2	2.4	
2	--	--	--	--	--	--	--	--	--	--	--	3.2	--	2.2	4.5	10.0*	2.0	11.2	7.0	10.8	3.9	0.9	
3	--	--	--	--	--	--	--	--	--	--	--	1.7	--	1.7	3.5	5.0	1.0	13.8	8.0	13.7	1.7	0.3	
4	--	--	--	--	--	--	--	--	--	--	--	1.5	--	1.7	1.5	1.0	--	14.0*	8.5	14.7*	0.3	--	
5	--	--	--	--	--	--	--	--	--	--	--	1.1	--	1.3	--	--	--	12.1	10.5	11.8	--	--	
6	--	--	--	--	--	--	--	--	--	--	--	0.3	--	0.4	--	--	--	8.8	12.5*	7.4	--	--	
7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6.2	10.0	3.4	--	--	
8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4.8	4.5	1.5	--	--	
9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.9	1.5	0.5	--	--	
40	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.9	0.5	--	--	--	
1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.2	--	--	--	--	
2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.2	--	--	--	--	
Number of fish	81	73	55	58	181	181	203	140	88	50	82	86	49	58	50	50	50	105	50	51	89	82	

¹ Actual frequencies smoothed according to Henry (1961).² 1964.³ 1958.⁴ 1957.⁵ 1966.⁶ 1956, ages 1. and 2. combined.⁷ 1963.⁸ 1965.⁹ 1961.¹⁰ 1967.

* Indicates modes.

TABLE 6.—Percentage frequency distribution¹ of circuli in the total freshwater zone of age 2, sockeye salmon collected in various years from 1956 to 1967.

Number of circuli	Asia				Alaska							British Columbia			
	Ozernaya River ²	Blizhnee Lake ³	Dalnee Lake ³	Far North ⁴	Bristol Bay ⁵	Attu Island ⁶	Adak Island ⁶	Unalaska Island ⁶	Chignik ⁷	Cook Inlet ⁸	Karluk River ⁹	Yakutat ⁸	Ketchikan ¹⁰	Nass River ⁸	Nimpkish River ¹¹
	Percent														
9	--	0.5	--	--	--	0.4	--	--	--	--	--	--	--	--	--
10	--	2.9	--	--	--	2.4	--	--	1.2	--	--	--	--	--	--
1	--	10.3	--	--	--	5.5	--	--	8.5	--	--	2.4	--	--	--
2	0.3	18.6	--	--	--	9.3	--	--	16.1*	--	--	6.0	--	--	--
3	0.7	20.1*	--	1.2	--	12.9	--	--	13.3	0.3	--	11.9	--	--	--
4	0.7	16.2	--	4.5	0.2	14.0*	--	--	7.7	3.0	--	20.2*	0.5	--	--
5	2.4	11.3	--	8.2	1.9	12.1	--	0.9	7.3	6.9	--	19.0	4.0	--	--
6	5.6	6.9	--	12.7	4.4	8.8	--	3.7	9.7	10.2	0.5	13.1	8.5	1.1	--
7	9.4	4.4	--	16.4*	6.8	7.9	0.2	6.9	12.5	11.8*	4.0	11.9	11.5	5.7	--
8	14.6	3.9	--	16.4*	10.0	7.4	0.4	7.9	12.1	11.5	10.0	8.3	15.5	10.2	1.0
9	16.3*	2.9	--	13.9	11.9	4.8	0.9	7.9	7.3	10.2	12.5	3.6	16.5*	13.6	3.1
20	14.6	1.5	--	9.4	13.1	3.3	2.5	10.2*	2.4	11.5	12.0	2.4	13.5	19.3*	5.2
1	13.2	0.5	--	7.0	14.8*	2.6	5.8	10.2*	0.4	11.8*	15.0	1.2	11.5	18.2	5.2
2	9.7	--	--	6.6	14.1	2.4	9.7	6.9	--	10.5	18.5*	--	9.5	10.2	3.1
3	5.9	--	--	3.3	11.3	2.6	13.1	6.9	0.4	5.9	14.5	--	5.5	8.0	2.1
4	4.2	--	--	0.4	7.4	1.4	15.5*	9.2	0.8	2.6	7.0	--	1.5	8.0	2.1
5	2.1	--	--	--	3.0	0.7	15.3	9.7	0.4	1.3	3.5	--	--	4.5	2.1
6	0.3	--	--	--	0.8	0.9	13.3	7.9	--	0.3	2.0	--	0.5	1.1	3.1
7	--	--	0.7	--	0.2	0.4	10.2	5.1	--	0.3	0.5	--	1.0	--	5.2
8	--	--	5.3	--	--	--	6.5	2.8	--	0.7	--	--	0.5	--	4.2
9	--	--	10.5	--	--	--	3.2	1.9	--	0.3	--	--	--	--	2.1
30	--	--	11.2	--	--	--	1.3	1.4	--	--	--	--	--	--	3.1
1	--	--	12.5	--	--	--	0.7	0.5	--	--	--	--	--	--	4.2
2	--	--	16.4*	--	--	--	0.5	--	--	--	--	--	--	--	7.3
3	--	--	16.4*	--	--	--	0.4	--	--	--	--	--	--	--	12.5*
4	--	--	10.5	--	--	--	0.4	--	--	--	--	--	--	--	11.5
5	--	--	5.9	--	--	--	0.2	--	--	--	--	--	--	--	6.2
6	--	--	5.3	--	--	--	--	--	--	--	--	--	--	--	4.2
7	--	--	3.9	--	--	--	--	--	--	--	--	--	--	--	5.2
8	--	--	1.3	--	--	--	--	--	--	--	--	--	--	--	5.2
9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.1
Number of fish	72	51	38	61	216	105	139	54	62	76	50	21	50	22	24

¹ Actual frequencies smoothed according to Henry (1961).² 1959.³ 1958.⁴ 1957.⁵ 1966.⁶ 1956.⁷ 1961.⁸ 1963.⁹ 1965.¹⁰ 1964.¹¹ 1967.

* Indicates modes.

DESCRIPTION OF SCALES FROM FISH OF VARIOUS AREAS

The scale photographs are shown in three major series: ages 1., 2., and 3. Representative scales from each broad coastal area with relatively similar scales (including specific scale types from some areas of small production, when necessary) are shown on one plate. Two exceptions to this grouping are made: (1) distinctive scales from age 1. fish from North American areas are shown on two plates and those for

age 2. fish on one plate; and (2) scales from fish from North American areas north of Bristol Bay of ages 1., 2., and 3. are shown on the same plate. Scales of age 0. fish from all areas are shown on one plate, and those of age 4. fish from all areas are shown on another plate.

A reference to the appropriate frequency tables of the number of circuli in the freshwater and first ocean zones (Tables 4 to 8) is made for each area group. These tables should be referred to as scales from each group are discussed.

TABLE 7.—Percentage frequency distribution¹ of circuli in the first ocean zone of age 2. sockeye salmon collected in various years from 1956 to 1967.

Number of circuli	Asia			Alaska								British Columbia			
	Ozernaya River ²	Blizhnee Lake ³	Dalnee Lake ³	Far North ⁴	Bristol Bay ⁵	Attu Island ⁶	Adak Island ⁶	Unalaska Island ⁶	Chignik ⁷	Cook Inlet ⁸	Korluk River ⁹	Yakutat ⁶	Ketchikan ¹⁰	Nass River ⁶	Nimpkish River ¹¹
	Percent														
11	--	--	--	--	--	--	0.9	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	2.7	--	--	--	--	--	--	--	--
3	--	--	--	--	--	0.1	5.9	0.2	--	--	--	--	--	--	--
4	--	--	--	--	0.3	0.4	10.0	1.2	--	--	--	--	--	--	--
5	--	--	--	--	1.2	0.8	12.6	3.4	--	--	--	--	--	--	--
6	--	--	--	--	3.4	1.2	13.3*	5.4	--	--	--	--	--	--	--
7	--	--	2.0	2.0	8.0	2.6	13.2	7.0	--	--	--	--	--	--	--
8	--	--	5.3	7.0	13.1	5.1	10.8	9.6	--	--	--	--	--	--	--
9	0.3	--	7.9	9.8	17.9	7.3	8.4	13.7	--	0.7	0.5	--	--	--	--
20	1.7	1.0	13.8	12.7	20.9*	12.6	7.4	14.8*	0.4	3.0	1.5	--	--	--	--
1	3.1	5.9	21.1*	16.4*	17.8	16.9*	5.8	11.2	4.0	6.9	4.5	--	0.5	--	--
2	6.6	11.8	21.1*	15.6	10.5	14.9	3.8	9.5	8.1	9.5	7.5	--	2.0	--	--
3	16.0	13.2	13.8	13.5	4.5	13.2	2.3	8.9	8.9	10.9	8.5	2.4	3.5	--	--
4	24.0*	14.7	7.9	10.7	1.5	11.5	1.5	6.4	11.3	15.5	12.5	14.3	5.0	1.1	1.0
5	22.2	18.6*	5.3	6.6	0.5	6.7	0.7	3.9	14.5	18.4*	15.0	25.0*	10.0	3.4	3.1
6	14.2	16.7	2.0	3.7	0.2	2.7	0.2	2.0	16.1	13.8	14.5	21.4	15.0*	8.0	5.2
7	7.3	9.3	--	1.6	0.1	1.4	0.2	1.2	16.9*	9.2	16.5*	16.7	14.5	20.5	6.2
8	3.5	4.9	--	0.4	--	1.3	0.1	1.1	13.3	6.9	13.5	13.1	13.0	29.5*	8.3
9	1.0	2.5	--	--	--	0.9	--	0.4	5.6	3.3	5.0	6.0	12.5	21.6	16.7
30	--	1.0	--	--	--	0.3	--	--	0.8	1.3	0.5	1.2	10.0	9.1	22.9*
1	--	0.5	--	--	--	--	--	--	--	0.7	--	--	6.5	2.3	16.7
2	--	--	--	--	--	--	--	--	--	--	--	--	4.5	--	8.3
3	--	--	--	--	--	--	--	--	--	--	--	--	2.5	1.1	5.2
4	--	--	--	--	--	--	--	--	--	--	--	--	0.5	2.3	2.1
5	--	--	--	--	--	--	--	--	--	--	--	--	--	1.1	1.0
6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.1
7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.0
Number of fish	72	51	38	61	216	191	203	140	62	76	50	21	50	22	24

¹ Actual frequencies smoothed according to Henry (1961).

² 1959.

³ 1958.

⁴ 1957.

⁵ 1966.

⁶ 1956, ages 1 and 2 combined.

⁷ 1961.

⁸ 1963.

⁹ 1956.

¹⁰ 1964.

¹¹ 1967.

* Indicates modes.

KEY TO THE PLATES

To compensate for the reduction of the original scale photographs to fit the printed page, use a 3 to 5× reading or magnifying glass to study them.

The area enclosed by the first or central circulus is the focus or central platelet of the scale.

The long black pointers near the focus indicate winter marks in the freshwater growth zone.

A black stub pointer, if present, indicates the end of plus or transitional growth. If plus growth is present, the circuli between the outermost long black pointer and the black stub pointer are plus growth circuli. If no plus growth is present, the outermost black pointer indicates

the end of freshwater growth as well as the last winter in fresh water.

The white pointers bordered by black indicate the first winter mark in the ocean growth. The circuli between the end of the freshwater growth (or plus growth, if present) and this pointer are ocean-growth circuli and record the first year's growth in the ocean (the first ocean growth zone). The more widely spread circuli of this zone were deposited from May or June to September or October (the summer growth), whereas the more closely spaced circuli near the pointer were deposited during the autumn, winter, and early spring months (the winter growth).

If a small white pointer is present, it indicates an adventitious check in the first ocean growth

TABLE 8.—Percentage frequency distribution¹ of circuli (A) in the total freshwater zone and (B) in the first ocean zone of age 3. sockeye salmon collected in various years from 1955 to 1964.

Number of circuli	(A)					(B)				
	Asia			North America		Asia			North America	
	Asia ²	Blizhnee Lake ³	Dalnee Lake ⁴	Bristol Bay ⁵	Karluk River ⁶	Asia ²	Blizhnee Lake ³	Dalnee Lake ⁴	Bristol Bay ⁵	Karluk River ⁶
	----- Percent -----									
12	--	0.6	--	--	--	--	--	--	--	--
3	--	4.1	--	--	--	--	--	--	--	--
4	--	9.9	--	--	--	--	--	--	0.4	--
5	0.5	15.1	--	--	--	--	--	--	1.2	--
6	2.9	19.2*	--	--	--	--	--	--	3.3	--
7	8.8	17.4	--	--	--	--	--	--	7.1	--
8	15.9	11.6	--	--	--	--	--	2.7	12.1	--
9	18.1*	9.9	--	1.0	--	1.0	--	8.1	17.9	0.3
20	16.9	8.1	--	2.0	--	2.9	--	10.1	19.6*	1.9
1	14.5	3.5	--	4.0	1.0	5.9	--	11.5	15.4	4.8
2	7.8	0.6	--	10.0	3.2	10.8	1.2	16.9	10.8	7.6
3	2.2	--	--	12.0	6.6	16.4	5.8	18.9*	6.7	13.0
4	1.2	--	--	13.0	9.5	20.1*	12.2	15.5	2.9	20.2
5	1.5	--	--	19.0*	11.4	19.1	15.1	10.8	1.7	20.9*
6	1.2	--	--	17.0	13.3	13.5	16.3	4.7	0.8	14.8
7	1.7	--	--	10.0	12.7	6.4	18.0*	0.7	--	8.6
8	2.5	--	0.7	6.0	12.1	2.2	16.3	--	--	3.8
9	2.0	--	4.1	3.0	14.2*	1.2	10.5	--	--	1.9
30	1.2	--	8.1	2.0	10.2	0.5	4.1	--	--	1.6
1	0.7	--	8.1	1.0	4.1	--	0.6	--	--	0.6
2	0.2	--	6.1	--	1.2	--	--	--	--	--
3	--	--	8.1	--	0.3	--	--	--	--	--
4	--	--	11.5*	--	--	--	--	--	--	--
5	--	--	8.1	--	--	--	--	--	--	--
6	--	--	6.8	--	--	--	--	--	--	--
7	--	--	11.5*	--	--	--	--	--	--	--
8	--	--	11.5*	--	--	--	--	--	--	--
9	--	--	8.1	--	--	--	--	--	--	--
40	--	--	4.1	--	--	--	--	--	--	--
1	--	--	0.7	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--	--	--
6	--	--	0.7	--	--	--	--	--	--	--
7	--	--	1.4	--	--	--	--	--	--	--
8	--	--	0.7	--	--	--	--	--	--	--
Number of fish	102	43	37	25	79	102	43	37	25	79

¹ Actual frequencies smoothed according to Henry (1961).² 1962, from an area off southeast Kamchatka.³ 1958.⁴ 1964.⁵ 1955 and 1957 combined.⁶ 1961.

* Indicates modes.

zone. Adventitious checks in other zones are not noted.

AGE 0., ALL AREAS (Plate 1)

As noted previously, age 0. sockeye salmon are not common anywhere since fish of this species normally live for one or more years in a lake before migrating to the sea. Consequently,

it was not possible to assemble frequency distributions of the number of circuli in the first ocean zone for age 0. fish. It appears, however, that usually there are a few more circuli in the first ocean zone of scales of age 0. than on scales from fish of the same geographical area that have lived one or more years in fresh water.

A few individuals of this age have been found at some time in almost every locality. Gilbert



KAMCHATKA R.



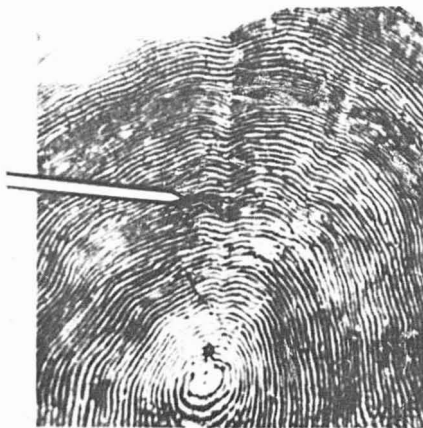
NUSHAGAK R.



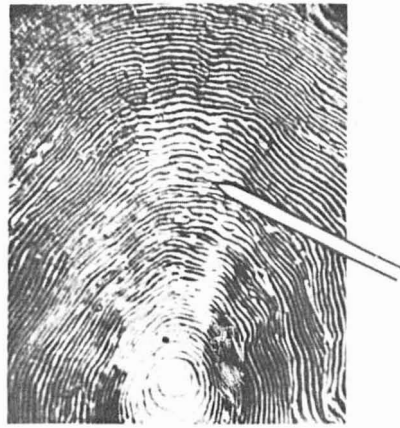
COPPER R.



PETERSBURG



NASS R.



SMITH INLET

PLATE 1.—Age 0., all areas.

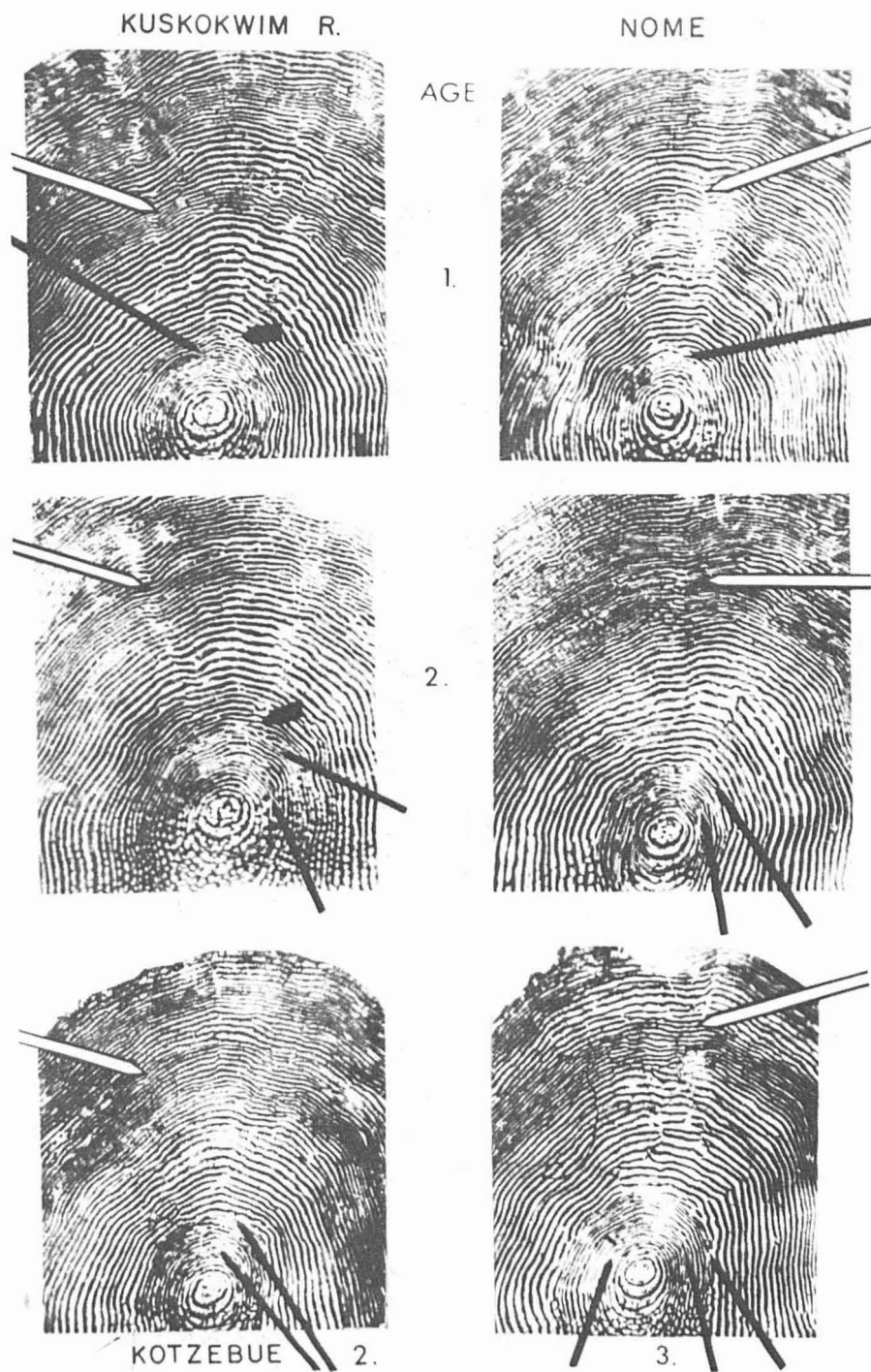
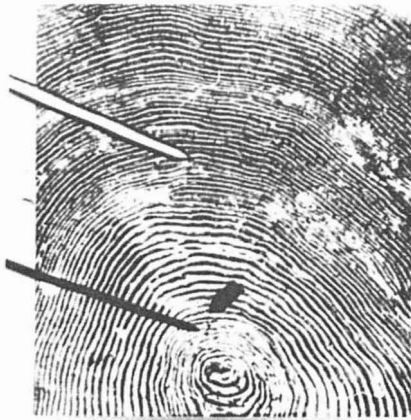


PLATE 2.—Ages 1, 2, and 3., Alaskan areas north of Bristol Bay.



KAMCHATKA R.



OZERNAYA R.



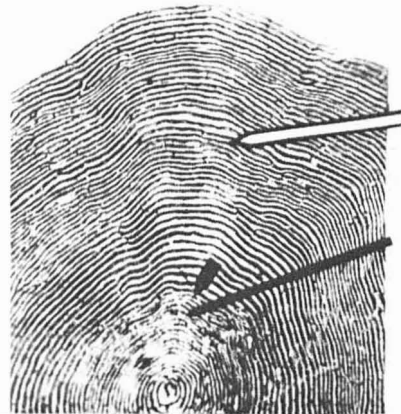
BOLSHAYA R.



OKHOTSK SEA



LAKE BLIZHNEE



LAKE DALNEE

PLATE 3.—Age 1., Asia.



UGASHIK R.



EGEK R.



NAKNEK R.



KVICHAK R.



NUSHAGAK R.



TOGIAK BAY

PLATE 4.—Age 1., Bristol Bay.



ATTU ISLAND



UNALASKA



CHIGNIK R.



RED R.



KARLUK R.

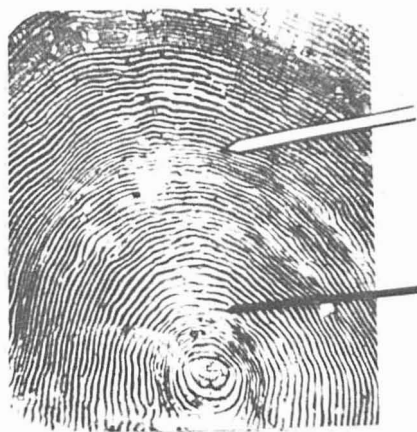


COOK INLET

PLATE 5.—Age 1., Aleutian Islands to Cook Inlet.



COPPER R.

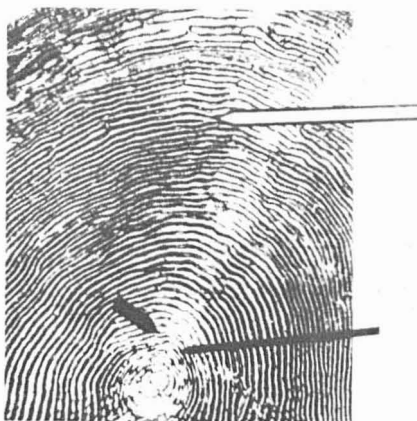


YAKUTAT



A

PETERSBURG



B



A

KETCHIKAN



B

PLATE 6.—Age 1., Copper River to southeastern Alaska.



NASS R.



SKEENA R.



A

FRASER R.



B



A

COLUMBIA R.



B

PLATE 7.—Age 1., British Columbia and the Columbia River.

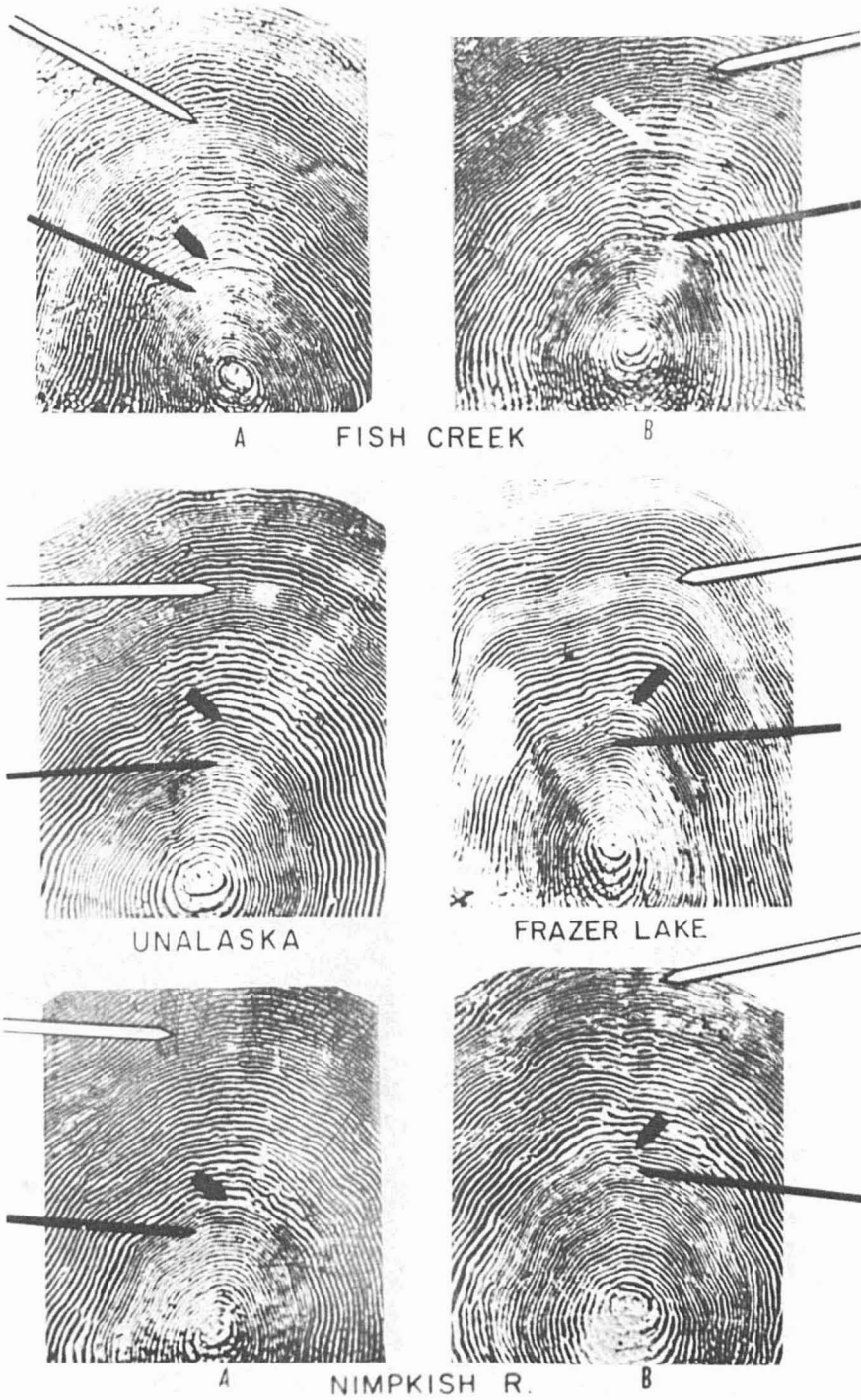


PLATE 8.—Age 1, North American areas with distinctive scales, Fish Creek type.

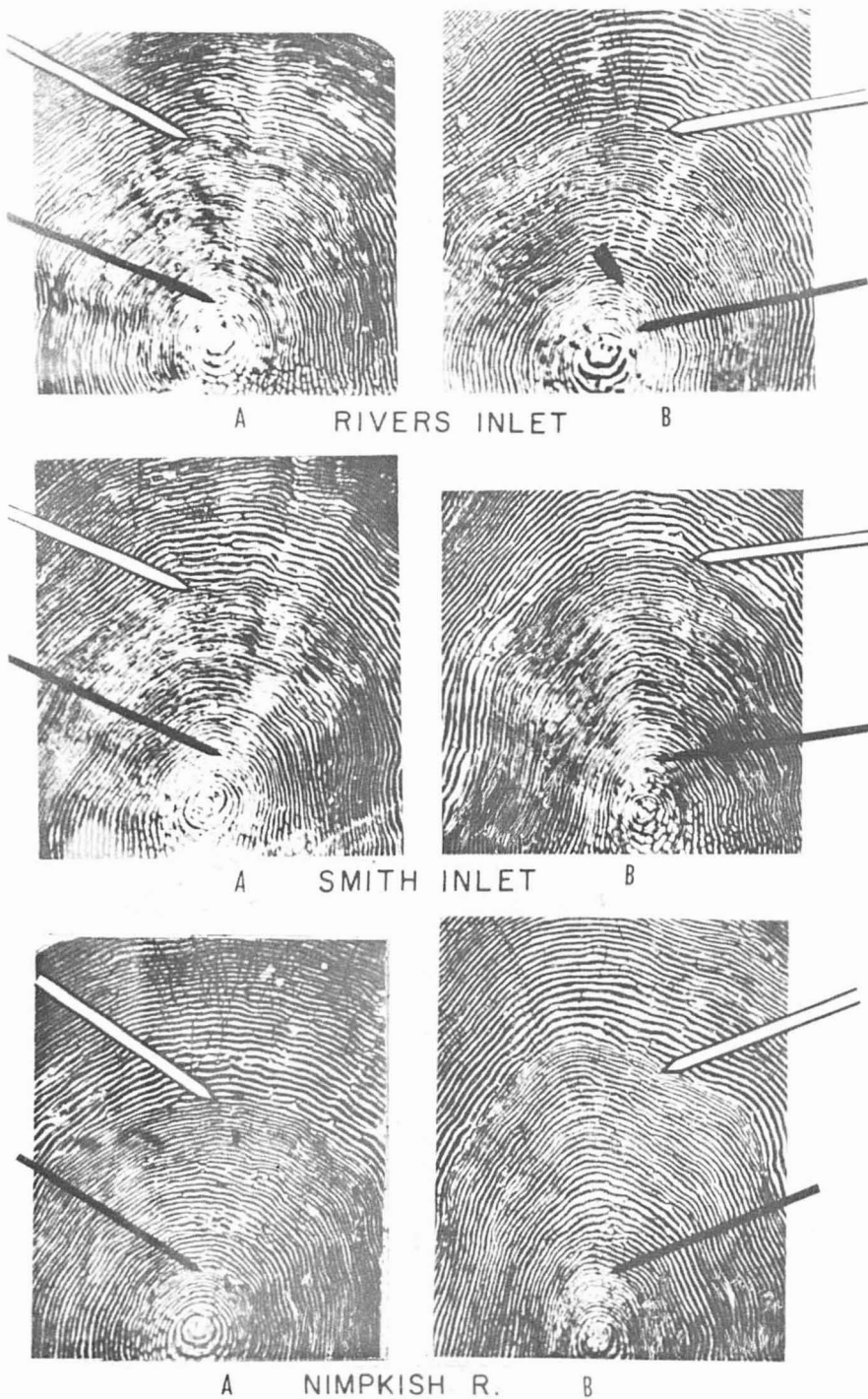


PLATE 9.—Age 1, North American areas with distinctive scales, Rivers Inlet type.



KAMCHATKA R.



OZERNAYA R.



BOLSHAYA R.



OKHOTSK SEA



LAKE BLIZHNEE



LAKE DALNEE

PLATE 10.—Age 2., Asia.



UGASHIK R.



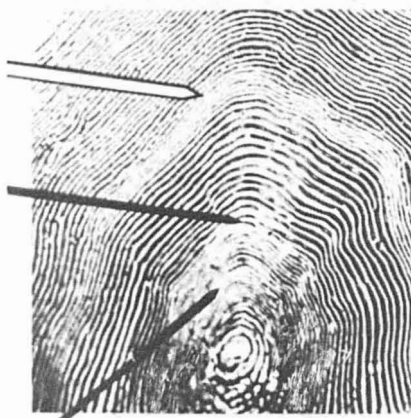
EGEGIK R.



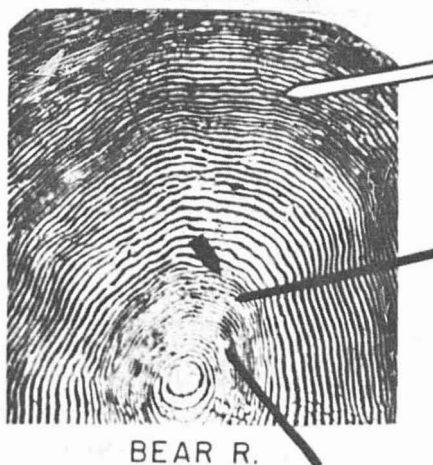
NAKNEK R.



KVICHAK R.



NUSHAGAK R.



BEAR R.

PLATE 11.—Age 2., Bristol Bay.

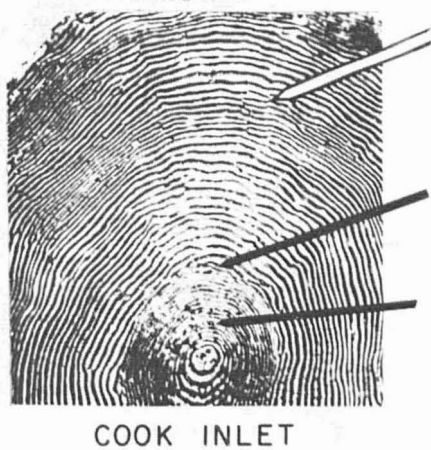
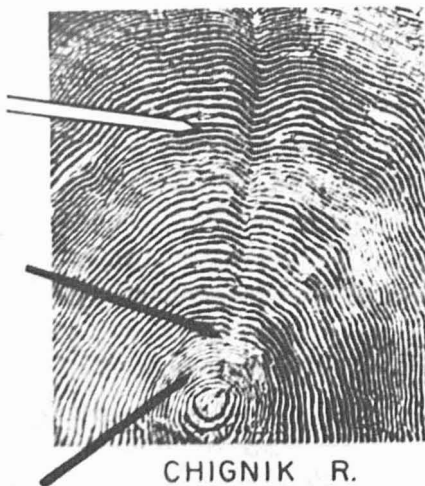


PLATE 12.—Age 2., Aleutian Islands to Cook Inlet.



COPPER R.



YAKUTAT



PETERSBURG



NASS R.



NIMPKISH R.



COLUMBIA R.

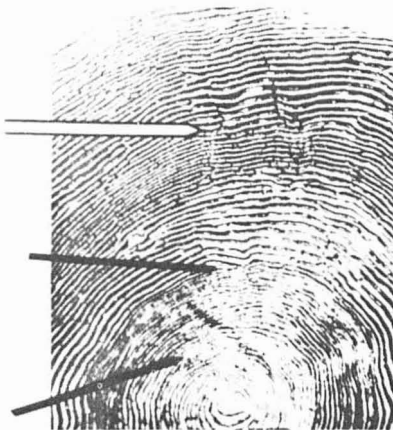
PLATE 13.—Age 2, Copper River to the Columbia River.



FRAZER LAKE



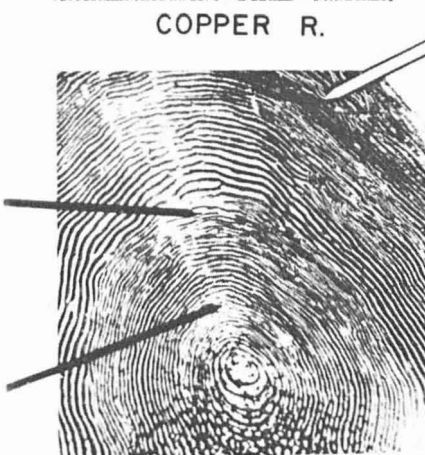
FISH CREEK



COPPER R.



NIMPKISH R.



COLUMBIA R.



RIVERS INLET

PLATE 14.—Age 2., North American areas with some distinctive scales.



OZERNAYA R.



BOLSHAYA R.



A OKHOTSK SEA



B

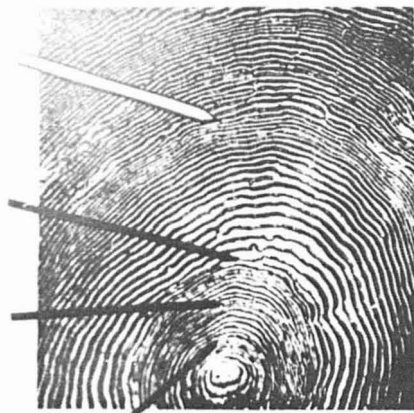


LAKE BLIZHNEE



LAKE DALNEE

PLATE 1b.—Age 3., Asia.



EGEGIK R.



FRAZER LAKE



CHIGNIK R.



KARLUK R.



PETERSBURG



NIMPKISH R.

PLATE 16.—Age 3., North America, all areas.



LAKE BLIZHNEE



LAKE DALNEE



EGEGIK R.



ADAK ISLAND



KARLUK R.



FRAZER LAKE

PLATE 17.—Age 4., all areas.

(1919) reported a stock spawning in the Harrison River, B.C., near its junction with the Fraser, B.C., and Krogius (1958) noted that they occurred in the Kamchatka, Bolshaya, and Paratunka Rivers, USSR. The Nushagak River, Bristol Bay, Alaska, had more than the usual number of individuals of this age in 1961 (Koo, 1962b) but not enough fish from which to take scales to furnish a frequency distribution.

Except for the Rivers Inlet, B.C., fish, there is little difference between areas in the features of the scales of this freshwater age. Scales from individuals taken from the Copper River, Alaska, southward to the Fraser River, however, tend to have a few more circuli in the first ocean zone than those from Bristol Bay, Alaska.

Fish of this age from Rivers Inlet and Smith Inlet, B.C., can be identified to that geographical area because the first ocean zone has the fine-textured circuli typical of most fish from these areas regardless of the freshwater age of the fish (see Plates 9 and 14).

AGE 1., 2., and 3., ALASKAN AREAS
NORTH OF BRISTOL BAY (Plate 2;
Tables 4, 5, 6, and 7)

Production of sockeye salmon north of Bristol Bay is small. The Kuskokwim River is the largest producer in the area. In the Norton Sound (Nome) and Kotzebue areas, few sockeye salmon are found. However, they are heavily exploited when present along with the other species—by local residents for food and barter—and thus are important in the local economy, especially in some years.

Very little is known of the migrations and ocean distribution of sockeye salmon originating in areas north of Bristol Bay. Of the many thousands of sockeye tagged by Japanese and United States scientists near the central Aleutian Islands, only two tagged near Attu Island in 1958 and one tagged near Kiska Island in 1960 have been returned from the area north of Bristol Bay. All three were recaptured in the Kuskokwim River (Hartt, 1966).

Presently it is not possible to identify the origin of most of the sockeye salmon from this area that are caught in offshore waters because

the scales resemble those from many fish from Asia and Alaska Peninsula.

All freshwater age groups of sockeye salmon from north of Bristol Bay have small freshwater zones with few, often broken and irregular circuli in each zone. Some scales show plus growth (see Mosher, 1968, p. 251-254).

Circuli of the first ocean zone are widely and evenly spaced as in scales from Asian fish or those from the Alaska Peninsula. The widest spacing of circuli is usually some distance from the freshwater zone. The number of circuli varies from few, like fish from Bristol Bay, to somewhat more, like fish from Asia or Alaska Peninsula areas.

AGE 1., ASIA (Plate 3; Tables 4 and 5)

Scales from fish from the Kamchatka, Ozernaya, and Bolshaya Rivers do not differ much between rivers. The freshwater zone is relatively small with few, often broken and irregular circuli. Often adventitious checks (false winter marks, see p. 275, Mosher, 1968) occur in the freshwater zone of these scales. Scales that I have examined from fish captured in the Okhotsk Sea (which, according to Hanamura, 1966, may be a mixture of runs from the Ozernaya and Bolshaya Rivers and, at times, small numbers of fish from the Okhota and the Kukhtuy Rivers on the northern coast of the Okhotsk Sea and from other small producing streams of southeastern Kamchatka and the Kurile Islands) do not differ much from those of the Ozernaya and Bolshaya Rivers. Krogius (1958) reported that the scales of fish from the Kukhtuy River are similar to those of the Ozernaya River. Very few fish of this freshwater age are found in the Ozernaya River.

Scales from fish from the Paratunka River show two distinct types of freshwater growth; those from Lake Blizhnee have a very small freshwater zone with only a few, mostly broken, irregular circuli; those from Lake Dalnee have a moderately large to large freshwater zone with numerous regular, unbroken circuli. Krogius (1958) reported the favorable conditions for growth of the fish in Lake Dalnee and the much poorer conditions in Lake Blizhnee.

TABLE 9.—Freshwater scale characters of Asian stocks of sockeye salmon (from Krogius, 1958).

Item	Area and number of years in fresh water											
	1 year				2 years				3 years			
	Kamchatka River	Bolshaya River	Dalnee Lake	Blizhnee Lake	Kamchatka River	Ozernaya River	Dalnee Lake	Blizhnee Lake	Kamchatka River	Ozernaya River	Dalnee Lake	
Type of circuli	Regular	Irregular	Regular	Irregular	Regular	Irregular	Regular	Irregular	Regular	Irregular	Regular	
Years fresh water	<i>Number of circuli</i>											
1	10-16	5-10	12-23	9-15	5-10	5-8	6-23	9-13	5-8	5-8	5-15	
2	--	--	--	--	10-24	9-13	10-24	5-9	5-8	5-8	5-15	
3	--	--	--	--	--	--	--	--	5-8	5-8	5-15	

The circuli of the first ocean zone of the scales from the Asian fish are average (some broken, some regular, see p. 255, Mosher, 1968) and more or less uniformly spaced. If there are a few more widely spaced circuli in the zone, they are usually some distance from the freshwater growth.

As can be seen from Table 3, my samples of scales from the Asian areas are quite small. Krogius (1958) reported on some of the scale characteristics of the Asian spawning stocks. Table 9 summarizes the pertinent material from her paper. My scale data generally agree with those she reported.

AGE 1, NORTH AMERICA

Bristol Bay (Plate 4; Tables 4 and 5)

The number and proportion of fish of this freshwater age group varies from year to year in the Bristol Bay rivers, but age 1. fish predominate each year in the Nushagak area as either the 1.2 or 1.3 age groups (Burgner, 1964).^o Thus this is an important freshwater age group every year in Bristol Bay.

The bulk of the Bristol Bay sockeye salmon are produced in the Ugashik, Egegik, Naknek, Kvichak (including the Branch River), and Nushagak-Wood River systems. The relative importance of each river varies somewhat from year to year, but the Naknek-Kvichak area produces the largest number of fish, especially in the "big" years (see 1965 catch statistics in Appendix Table 1). In addition to these five

river systems, there are a few other areas that provide some fish to Bristol Bay. Streams emptying into Togiak Bay and the Bear and Sandy Rivers on the north side of the Alaska Peninsula produce substantial numbers of sockeye salmon in some years. The Togiak area fish are usually of age 1., whereas those of the Bear River are of age 2. generally. The catches of the various areas of Bristol Bay for 1966, as an example, were as follows (International North Pacific Fisheries Commission, 1966):

<i>Area</i>	<i>Thousands of fish</i>
Naknek-Kvichak	5,397.6
Egegik	2,101.2
Nushagak-Wood River	1,170.3
Ugashik	445.4
Togiak	119.8
Bear and Sandy Rivers	151.3

Scales from fish of this age from Bristol Bay are quite similar between streams with only minor variations from year to year. Most scales have distinct freshwater and ocean zones with well-marked circuli. The freshwater growth is moderately large with well-spaced, regular, mostly unbroken circuli. Plus growth is sometimes present, especially in the Togiak, Nushagak, Kvichak, and Ugashik Rivers. In most cases it is easily identified on the scales.

The first ocean zone has relatively few circuli. The summer growth circuli are broad and widely spaced, predominantly regular, and unbroken. An area of widely spaced circuli is usually present near the freshwater zone. The ocean zones of scales of Bristol Bay fish have a more "open" appearance than those of fish from any other geographical area. This is the result of (1) a distinct winter zone of a number of closely spaced circuli, sometimes so close that the zone appears like a broad line around the scale (see winter

^o Burgner, R. L. 1964. Age composition of Nushagak red salmon runs, 1946-63. Univ. Wash., Fish. Res. Inst. Circ. 219, 62 p. (Processed.)

marks labelled "1" on p. 260 of Mosher, 1968); (2) a relatively small number of circuli in the ocean zones; and (3) a wider spacing of the circuli usually near the freshwater zone.

In the other geographical areas, except Adak Island, there are more circuli, on the average, in the first ocean zone on the scales, and the winter zone may be diffuse (see winter marks labelled "3" on p. 260 of Mosher, 1968). These features result in a more even spacing of ocean circuli and a smaller average width per circulus producing a less "open" appearance. The effect of this characteristic is reflected in the size of the widest five adjacent circuli in the first ocean zone in the frequency tabulations shown in Table 10. This table shows that Bristol Bay scales, on the average, have five adjacent circuli that are substantially wider than on scales from fish of other geographical areas. This feature is found on scales of Bristol Bay salmon of all freshwater ages. Krogius and Krokhin (1956) also have noted variation in spacing of circuli.

Aleutian Islands to Cook Inlet (Plate 5; Tables 4 and 5)

The area from Chignik to Cook Inlet is an area of high production of Alaskan sockeye salmon, usually second to that of Bristol Bay. To provide a comparison with other areas, the commercial catch in 1966 of sockeye salmon in the subsections of this geographic area are shown below (International North Pacific Fisheries Commission, 1966):

<i>Area</i>	<i>Thousands of fish</i>
Aleutian Islands	1.0
South side Alaska Peninsula	606.2
Chignik	222.1
Kodiak Island	631.6
Cook Inlet	1,866.5

Commercial fishing operations in the Aleutian Islands and along the south side of the Alaska Peninsula take both transient fish migrating to Bristol Bay and local stocks (Atkinson, 1955). My samples from the Aleutian Islands, obtained for INPFC purposes, are of local stocks.

TABLE 10.—Frequency tabulations of the width of the widest five adjacent circuli in the first ocean zone of age 1 sockeye salmon from representative areas.¹ (Asterisks indicate modes.)

Width ²	Asia ³	Bristol Bay	Chignik	Cook Inlet	Fish Creek	Ketchikan	Skeena River	Rivers Inlet	Fraser River	Columbia River
13	--	--	--	--	--	--	--	1.5	--	--
14	--	--	--	--	--	0.5	--	5.9	0.3	--
15	--	--	--	0.3	--	1.5	0.9	12.4	2.8	0.3
16	--	--	0.3	0.9	0.3	6.5	5.4	20.6	8.3	1.5
17	--	--	1.4	2.9	2.7	16.5	12.2	25.9*	13.2	4.9
18	0.9	--	4.0	7.6	6.1	23.0*	16.8	20.0	16.7	11.0
19	3.2	0.2	9.1	13.1	9.1	20.0	19.0	8.8	18.4*	14.6
20	6.0	0.6	16.8	17.7	13.7	12.5	19.3*	2.9	16.7	15.2
21	8.8	2.0	21.3*	20.1*	18.0	8.5	15.1	0.9	12.1	16.8*
22	12.5	4.7	18.5	17.7	18.6*	5.5	7.1	0.3	6.6	15.5
23	15.7	7.8	12.5	10.8	14.0	2.0	2.3	0.6	2.8	11.3
24	16.7*	12.0	7.7	4.4	7.9	1.5	1.4	0.3	1.1	6.1
25	16.2	15.7	4.8	2.0	4.3	1.5	0.6	--	0.6	1.8
26	12.0	17.3*	2.8	1.2	2.7	0.5	--	--	0.3	0.6
27	5.6	15.7	0.9	0.6	1.8	--	--	--	--	0.3
28	1.9	10.9	--	0.6	0.6	--	--	--	--	--
29	0.5	6.3	--	0.3	--	--	--	--	--	--
30	--	3.5	--	--	--	--	--	--	--	--
31	--	1.8	--	--	--	--	--	--	--	--
32	--	1.1	--	--	--	--	--	--	--	--
33	--	0.4	--	--	--	--	--	--	--	--
No. in sample	54	281	88	80	82	50	88	85	87	82

¹ All samples from 1963 except Ketchikan, 1964.

² Millimeters of projected image, magnification 82X.

³ Asian samples from an area near Southeastern Kamchatka coast where Asian fish are present almost exclusively (Margolis, Cleaver, Fukuda, and Godfrey, 1966). Data smoothed according to Henry (1961).

In the Aleutian Islands a number of scale types may be found. One type from Attu Island is similar to that of Asian fish: a small freshwater zone with few, often broken and irregular circuli. The first ocean zone of these Attu fish has evenly spaced, often broken circuli, but usually fewer circuli than the Asian fish. Another type, found in Unalaska Island samples in some years, has a larger freshwater zone with more circuli, like Bristol Bay fish (see submode at 17-18 circuli in column 8 of Table 4). A third type in both Adak and Unalaska Islands (see column 7 and primary mode in column 8 of Table 4) samples, has a large freshwater zone with numerous circuli like the Fish Creek sockeye salmon (these are pictured in Plate 8). Fish from Adak Island tend to have fewer circuli in the first ocean zone than fish from other areas. As noted above, the numbers of fish produced in the Aleutian Islands are very small, consequently these scale types are included here only to provide a complete series of age 1. scales.

Scales from Chignik, Kodiak Island, and most streams in Cook Inlet have moderately small freshwater zones with relatively few circuli (except those from Fish Creek, Plate 8), often with plus growth. Generally most of the fish from Kodiak Island are of ages 2. and 3. The first ocean zone of the fish from Chignik to Cook Inlet has a few more circuli on the average than do scales from Bristol Bay fish; moreover, the circuli are closer together and more uniformly spaced. The position of the widest circuli, if present, varies considerably in fish of this area group but often is near the following winter zone like many of the Asian fish.

Copper River to Southeastern Alaska (Plate 6; Tables 4 and 5)

The Copper River is the only river of significant production of sockeye salmon in this large geographical area; however, there are many streams that provide small numbers of fish to make a substantial total. The commercial catch for 1966 for subdivisions of this area follow (International North Pacific Fisheries Commission, 1966):

<i>Area</i>	<i>Thousands of fish</i>
Copper River	1,005.6
Yakutat	184.4
Southeastern Alaska	868.7

Fish of age 1. predominate here every year. Most fish from these areas are quite similar in both freshwater and first ocean circuli. The freshwater zone is small with few circuli. The freshwater zone of many fish taken near Petersburg and Ketchikan is very small with very few circuli, similar to that of the Rivers Inlet fish, but there are differences in the first ocean zone that distinguish Rivers Inlet scales. Most freshwater circuli of all fish of these areas are broken, irregular, crowded together, and poorly marked. Some scales show plus growth.

The first ocean zone of fish from these areas has a few more circuli on the average than do scales from Chignik or Cook Inlet. Circuli are usually irregular but evenly spaced; generally there is no area of wider circuli but sometimes there are a few wider circuli in two or more places in the first ocean zone. Adventitious checks (false winter marks) may also be present in the ocean zones. Thus some of these scales may be difficult to use for determination of age and racial origin.

British Columbia and the Columbia River (Plate 7, Tables 4 and 5)

This is also an area of high production of sockeye salmon. The yearly total for British Columbia varies, but it is either first or second to Bristol Bay in the total for North America. Average catches (from Aro and Shepard, 1967) for the major areas of British Columbia are as follows:

<i>Area</i>	<i>Millions of fish</i>
Nass River (average 1951-1963)	0.21
Skeena River (average 1951-1963)	0.49
Rivers and Smith Inlets (average 1951-1963)	1.06
Fraser River (average 1938-1963):	
1901 cycle	2.87
1902 cycle	6.12
1903 cycle	1.73
1904 cycle	1.92

Relatively few sockeye salmon are produced in the Columbia River (see Table 1). Fish of age 1.

predominated in all sections of this geographical area; however, in some years age 2. fish may be abundant in the Nass River.

Most scales of fish from the rivers identified in this plate do not differ much between areas. (Scales from sockeye salmon from Rivers and Smith Inlets and some from the Nimpkish River are distinct and are shown on Plate 9.) Freshwater zones on the scales of fish from the Nass and Skeena Rivers tend to have slightly fewer circuli, and those from the Columbia River slightly more circuli than those from the Nimpkish and Fraser Rivers. (Scales from sockeye salmon from the Nimpkish River which are represented by the primary mode in column 20 of Table 4 are not pictured here as they are similar to the scales of Fraser River fish.) The freshwater circuli of scales from fish of these areas are mostly regular and unbroken. These characters give the freshwater zone a clear-cut appearance. Plus growth is often present.

The first ocean zone is usually distinct and well marked. There are numerous circuli in this zone, and even if some of them are irregular or broken, the zone usually has a clear-cut appearance. The spacing of circuli tends to be uniform, but a few wider spaced circuli may occur at any position within the zone. Scales from the Nimpkish River tend to have the most circuli of any of these areas. Adventitious marks are common in the ocean zones, but in spite of these irregularities, the circuli and winter marks are generally distinct and easy to count and measure.

Geographical Areas with Distinctive Scale Types (Plates 8 and 9)

There are two types of scales showing this freshwater age which are distinctive:

1. The "Fish Creek" type (Plate 8), so called because it was first observed in Fish Creek, Knik Arm, Cook Inlet, but later also found in small numbers in some other streams as noted below.
2. The "Rivers Inlet" type (Plate 9), so called because it was first observed in Rivers Inlet, B.C., but later found in some other areas, also noted below.

Fish Creek Type (Plate 8; Tables 4 and 5).—Fish Creek type scales are on most sockeye salmon from Fish Creek. A few were also found in the samples from Adak and Unalaska Islands and in the recently available samples from Fraser Lake (Kodiak Island) and the Nimpkish River (fish with more than 20 circuli in column 20, Table 4).

Fish Creek type scales are characterized by a large freshwater zone with many well-marked circuli. There is often a check or winter mark about 18 or 20 circuli from the center of the scale, followed by a few circuli of plus growth.

The circuli of the first ocean zone are also well marked, and in most cases, well separated, sometimes with an area of wider spaced circuli near the freshwater zone like most of the Bristol Bay fish. The numbers of circuli in this zone tend to vary with the locality from which the fish came: Adak and Unalaska Island, less than 22 circuli; Fish Creek and Kodiak Island, 22-27 circuli; and the Nimpkish River, over 27 circuli.

The annual number of adult fish with this scale type from all areas is relatively small (perhaps in the neighborhood of 100,000 fish as a maximum), but the scales have been observed in offshore samples because of their distinctive appearance (Mosher et al., 1961).

Rivers Inlet Type (Plate 9; Tables 4 and 5).—Gilbert (1914) first noted that scales of sockeye salmon from Rivers Inlet and later from Smith Inlet were different from those of other areas. Recently, samples from the Nimpkish River (on Vancouver Island, which empties into the northern end of Johnstone Straits near Rivers and Smith Inlets) became available. Some of these scales were also of the Rivers Inlet type.

These scales are characterized by a small, diffuse freshwater zone with very few circuli. Usually the circuli are broken, irregular, crowded together and difficult to count. The transition from freshwater to ocean growth is usually diffuse and difficult to distinguish.

The first ocean zone, the distinctive feature of these scales, has many uniformly spaced circuli, usually with no area of wider spacing. This first ocean zone often looks like freshwater

growth of scales from other areas (compare these photographs with those of the Fish Creek type on Plate 8). The second ocean zone is of typical ocean growth—heavy textured, well-spaced circuli. This zone, unlike that on scales from other areas, is usually wider than the first ocean zone. Often the winter check between the first and the second ocean zones is diffuse and indistinct.

The whole scale shows two large areas of contrasting texture: the freshwater and first ocean zones of fine-textured circuli and the second and subsequent ocean zones with coarse-textured circuli of typical ocean growth. On the scales from fish of other areas there is a difference in texture, but the zone of fine texture, the freshwater growth, is relatively small; and the coarse-textured portion of the scale, the entire ocean growth, is the major portion of the scale.

In the Nimpkish River, some of the fish of this age have scales of Rivers Inlet type (secondary mode at 12 circuli in column 20 of Table 4). These fish generally have a few more circuli in both the freshwater and first ocean zones than the fish from Rivers Inlet, and the circuli are also usually less broken and irregular than those from Rivers Inlet. The difference in texture, however, between the first and second ocean zone is typical of Rivers Inlet type scales.

Most of the fish from Rivers and Smith Inlets have scales of this type. In representative samples the following typical Rivers Inlet scales were found:

<i>(Area and year)</i>	<i>Percentage of Rivers Inlet type</i>
Rivers Inlet, 1958	126 of 156 fish (76.2%) (Manzer, Bilton, and Mosher, 1960) ⁷
Rivers Inlet, 1963	374 of 377 fish (98.4%)
Smith Inlet, 1960	123 of 132 fish (93.2%)
Smith Inlet, 1961	246 of 270 fish (91.1%)

These percentages approximate the range of typical Rivers Inlet type scales in this area. The

⁷ Manzer, J. I., T. H. Bilton, and K. H. Mosher. 1960. The ocean distribution of sockeye salmon originating in Rivers and Smith Inlets. Fish. Res. Board Can. (Nanaimo, B.C.) and Bur. Commer. Fish. (Seattle, Wash.) (INPFC Doc. 407), 5 p. (Processed.)

few scales that are not typical of fish of these areas usually resemble scales of the Skeena or Nass Rivers; consequently they still are in British Columbia.

Only an occasional scale from the other areas (Cook Inlet to the Fraser River) has the appearance of a Rivers Inlet scale. In these few cases, the number of circuli in the first ocean zone is usually less than that of the Rivers Inlet fish.⁸

In a test of 300 unlabeled scales from many areas over the range of the species set up by an assistant, I correctly identified 63 out of 64 Rivers Inlet scales. This indicates that these scales are indeed distinct and can be identified from their appearance with a high degree of accuracy.

The Rivers Inlet area is a good producer of sockeye salmon. In most years more than 1 million fish are caught there. The Nimpkish River is a small producer, but escapements of 150,000 and 70,000 fish were recorded in 1957 and 1958, respectively (Henry, 1961).

Rivers Inlet type scales have been observed widely in offshore samples (Manzer et al., see footnote 7; Mosher et al., 1961).

AGE 2., ASIA (Plate 10; Tables 6 and 7)

Representative scales of sockeye salmon from the Kamchatka, Ozernaya, and Bolshaya Rivers, the Okhotsk Sea, and Lakes Blizhnee and Dalnee are shown on this plate. Like those of age 1., scales from these fish, except Lakes Blizhnee and Dalnee, do not differ much between areas. The freshwater zone is of moderate size, sometimes with plus growth. The circuli are close together and many are broken or irregular. (See Table 9 for a summary of freshwater scale characters of Asian sockeye salmon from Krogius, 1958.)

The first ocean zone of scales from these fish also do not differ significantly and are similar to the same zone of the scales of the age 1. fish from the same areas. Usually the circuli are evenly and moderately closely spaced and lack the open

⁸ From this point on, the term "Rivers Inlet" also includes Smith Inlet and the Rivers Inlet type scales of fish from the Nimpkish River.

appearance of the Bristol Bay scales. An area of wider spaced circuli may often be found at any position in the first ocean zone, but usually it is near the middle of the zone or the following winter zone. Plus growth is sometimes present.

Scales of many fish from Lake Blizhnee are distinctive. They have a very small freshwater zone with few circuli in each year's growth. Circuli are irregular and the zone is difficult to interpret because of the broken and closely spaced circuli. The first ocean zone is similar to that of the other Asian fish of the Ozernaya, Bolshaya, and Kamchatka Rivers.

Scales from Lake Dalnee fish have large to very large freshwater zones. The freshwater growth makes up a larger portion of these scales than those from any other locality over the range of the species. The circuli of both the freshwater and ocean zones are usually regular and well marked. Sometimes there are fewer circuli in the first ocean zone than on scales from other Asian areas. Scales of fish of this freshwater age can be easily identified as being from Lake Dalnee when they are encountered in samples of fish taken from the North Pacific and Bering Sea because of the unusually large freshwater zone (Mosher et al., 1961).

AGE 2., NORTH AMERICA

Bristol Bay (Plate 11; Tables 6 and 7)

The number of fish of this freshwater age varies from year to year in the different rivers, but few are ever found in the Nushagak and Togiak areas. In some years of large production in Bristol Bay most of the fish are of age group 2.2.

As was true of age 1. fish from Bristol Bay (Plate 4), most scales from these fish, including Bear River, do not differ much between streams. Freshwater and ocean circuli are regular and clear cut. The freshwater zone is moderately large to large, and well marked; the circuli are generally well separated, and plus growth is often present. There are relatively few, well-separated circuli in the first ocean zone. In most cases the winter marks are distinct. Usually the widest circuli are near the freshwater zone. Be-

cause the first 5 or 10 circuli of each ocean growth zone usually are widely separated and the winter marks are well marked and compact, the scales have a more open appearance than scales of fish from other geographical areas. Taken as a whole, scales from Bristol Bay fish are easier to interpret than sockeye scales from other geographical areas.

Aleutian Islands to Cook Inlet (Plate 12; Tables 6 and 7)

Fish of age 2. are usually abundant in this area. Diverse types are present. Aleutian Islands (typified by Attu Island) and Chignik River fish have a small freshwater zone with irregular circuli much like the Asian sockeye salmon. Fish from Unalaska Island (not pictured), Red River (Kodiak Island), and Cook Inlet have moderate-sized freshwater zones with more irregular and broken circuli on their scales than Bristol Bay fish, but fewer than the Asian fish. Adak Island and Karluk River (Kodiak Island) fish have large, usually clear-cut, freshwater zones on their scales, also with more irregular circuli than those from Bristol Bay.

As is true with the age 1. fish, Adak Island sockeye salmon have the fewest circuli in the first ocean zone of their scales; those from Unalaska Island have about the same distribution of circuli as the Bristol Bay fish; and those from Attu Island and from the Alaska Peninsula to Cook Inlet have somewhat more circuli than fish from Bristol Bay. The circuli in the first ocean zone are generally closer together than on scales from Bristol Bay fish. The area of widest circuli, if present, may occur at any position within the growth zone, but it is often near the following winter ring, such as occurs with many Asian fish. Many of the scales from this area, especially from the Aleutian Islands and Chignik, are difficult to interpret with confidence.

Copper River to Columbia River (Plate 13; Tables 6 and 7)

In this large area relatively few age 2. sockeye salmon are produced. In fact only in some years in the Nass River are there substantial numbers.

There are, however, a number of different scale types among those that do occur.

Most fish from the Copper River, Yakutat, and Petersburg areas have scales much like those of Chignik and Cook Inlet. The scales are characterized by small- to medium-sized freshwater zones in which most of the circuli are broken or irregular. The first ocean zone of these scales averages slightly more circuli than those of the Cook Inlet area, however, and the circuli are more closely and evenly spaced.

A second type of scale from this area has a large freshwater zone with numerous circuli. These scales are found in small numbers in various areas from the Copper River to the Columbia River and are shown in Plate 14.

Scales showing this freshwater age from the Nass, Skeena, and Fraser Rivers and some from the Nimpkish River (the British Columbia fish) usually have moderately large, well-marked freshwater zones. Usually the broken circuli are confined to the winter checks. In the first ocean zone, fish from the Nimpkish River have more numerous, regular, evenly spaced circuli than those from any other area. Scales of these British Columbia fish are relatively easy to interpret and often differ from Bristol Bay scales only in having, on the average, a few more circuli and more evenly spaced circuli in the first ocean zone. The scales tend to have a less open appearance than those of Bristol Bay fish.

The few scales of this age group of sockeye salmon from the Ketchikan area occur in at least three types: (1) scales like those of the Copper River-Petersburg area, like the one pictured on this plate from a fish taken near Petersburg, (2) scales with a larger freshwater zone like those from Nass River fish, and (3) very few scales with very large freshwater zones like the one pictured from the Copper River on Plate 14. In the Ketchikan area there are many small streams that produce some sockeye salmon. In addition, many channels and bays serve as waterways through which fish migrate to other areas. Thus it is possible that many of the Petersburg and Nass type scales taken in this area may actually be from fish migrating to the Petersburg area or the Nass River.

Most fish of this age found in the Columbia

River have large freshwater zones varying from those like the one pictured on this plate to ones with very large freshwater zones, shown on Plate 14. On all of these Columbia River scales, the freshwater circuli are well marked and well separated, even if many are broken or irregular. The circuli of the first ocean zone of these scales are also usually well marked; they are evenly and widely spaced. The zone averages somewhat fewer circuli than on scales from the Nimpkish, Nass, Skeena, and Fraser Rivers but more than on the scales from Bristol Bay fish. An area of wider spaced circuli may occur at any position within the first ocean zone, but the difference between the widely spaced and the closely spaced circuli is not as great as in the Bristol Bay scales.

Fish of this freshwater age are rare in Rivers Inlet. These scales can be identified as typical Rivers Inlet type from their appearance (see Plate 14).

Areas with Some Distinctive Scales (Plate 14)

In most years a number of areas from Kodiak Island to the Columbia River have some fish with very large freshwater zones on their scales, but except for the Nimpkish River, there were not enough fish to provide data for frequencies of the number of circuli. Only slight differences in the freshwater zone of the fish from the various areas can be found.

In some years, scales from some Bristol Bay and Aleutian Island fish may also have these very large freshwater zones.⁹ These are not pictured on this plate because they resemble the ones shown from the Copper River to the Columbia River, and they do not occur in most years.

Differences in the number and character of the circuli in the first ocean zone of the scales from fish of the different areas, however, offer an indication of the locality from which the fish came. The largest number of circuli in this zone tends to be on scales of the Nimpkish River sockeye salmon; fewer circuli (and more broken

⁹ A number were observed in Bristol Bay samples for 1970.

circuli) are found on the scales from Ketchikan, Petersburg, Copper River, and Columbia River fish; even fewer circuli (and fewer broken circuli) are found on the Fish Creek and Kodiak Island fish, whereas the least number of circuli (and the most complete and regular circuli) are found on the scales from Aleutian Island and Bristol Bay fish.

The reasons for some of the fish from these areas having such a large freshwater growth zone is a subject for future research. The numerous streams and tributaries of the larger river systems encompass a wide range of environmental conditions. It is likely that these fish are spawned and grow in nursery areas with excellent conditions for freshwater growth. In some years the growth conditions in certain streams may be better than in other streams, contributing to the year to year variation in numbers of fish with this scale type.

In Rivers Inlet, sockeye salmon with scales showing this age are rare. The scales of the few fish that have been found, however, are of typical Rivers Inlet appearance: a small freshwater zone with only a few (mostly broken) circuli in each year's growth, a fine-textured first ocean zone with numerous circuli, and a second (and subsequent) ocean zone of typical ocean type circuli. Thus the scales show the two large areas of contrasting texture, like those of Rivers Inlet scales of other ages—Plates 1 and 9. (Note how much the scale area to the end of the first ocean zone, white arrow, resembles the freshwater zone of the Columbia River scale on this plate.)

AGE 3., ASIA (Plate 15; Tables 8a and b)

Usually fish of this freshwater age are in substantial numbers only in the Asian areas and in Kodiak Island streams, but a few are also found each year in Bristol Bay, especially in the Egegik and Naknek Rivers.

On the Asian side of the Pacific Ocean, scales from fish of the Ozernaya, Bolshaya, and Kamchatka Rivers and the Okhotsk Sea do not differ much (column 1 of Table 8 shows data from fish taken off the southeast coast of the Kamchatka Peninsula where a number of Asian stocks inter-

mingle). The scales of most Asian fish, except those from Lakes Blizhnee and Dalnee, have relatively small freshwater zones with only a few circuli in each year's growth. Many of the circuli are irregular, broken, and closely spaced. The first ocean zone of these scales is like that of the age 1. and 2. fish from the same geographical areas. There are a few more circuli present on the scales of these fish than on those from Bristol Bay, and the circuli are generally uniformly spaced. An area of wider spaced circuli may be present in the first ocean zone, but it generally is less pronounced than on scales from Bristol Bay fish.

Fish of this age are also found in Lake Blizhnee. The scales have a very small freshwater zone with very few circuli in each year's growth. The first ocean zone of these Lake Blizhnee fish is also like that of the other Asian fish except those from Lake Dalnee.

Fish of this freshwater age are relatively common in Lake Dalnee. The scales are distinctive: a very large freshwater zone with numerous, usually clear-cut circuli. The freshwater zone makes up a larger portion of the scales of fish from Lake Dalnee than of fish from any other area in Asia or North America. As in age 2. and 4. fish, the first ocean zone often had fewer circuli than usual for Asian fish—sometimes even fewer than on scales from Bristol Bay or Adak Island fish.

AGE 3., NORTH AMERICA (Plate 16; Tables 8a and b)

As noted above, Kodiak Island has the most sockeye salmon of age 3. on the American side of the Pacific Ocean. In some years a major portion of the run to the Karluk River may be of individuals of this freshwater age with 2 or 3 winters in the ocean (the 3.2 and 3.3 ages). In most years substantial numbers of age 3. fish are found. The freshwater zone of the scales of these fish is relatively large; the circuli are well separated and usually well marked, although more of the circuli may be irregular or broken than on most Bristol Bay scales. The first ocean zone is also well marked; the circuli are distinct and often widest near the freshwater zone as in

the scales of fish from Bristol Bay. Usually a few more circuli are found than on Bristol Bay or Asian scales.

Bristol Bay scales of this age (Egegik River shown) look like Bristol Bay scales of age 2. with an additional freshwater winter mark. The freshwater zone is moderately large and distinct; the circuli are well marked. Circuli of the first ocean zone are also distinct and are fewer in number than on scales from fish of other North American areas except Adak Island. The circuli are usually widely separated near the freshwater zone. These scales, like those from fish of the other Bristol Bay age groups, are usually easy to interpret.

Fish of this age are rarely found in other North American areas. Scales from these age 3. sockeye salmon resemble those of age 2. from the same area but have an additional winter mark in the freshwater zone. Thus, usually the freshwater zone is large (Nimpkish River shown). In Chignik and southeastern Alaska (Petersburg shown) where small freshwater zones predominate, occasionally a fish with a very small freshwater zone with three distinct winter marks may be found.

Among fish of this age, the number of circuli in the first ocean zone is similar to that of age 1. and 2. fish from the same area; thus the number of circuli in the first ocean zone can indicate the area of origin of the fish.

AGE 4., ALL AREAS (Plate 17)

Scales that show this age are rare from Asia to Cook Inlet, Alaska, and are almost never observed in areas southeast of Cook Inlet. Insufficient numbers of fish of this age group have been obtained to assemble frequency distributions of the number of circuli on the scales of fish from any area. While it is possible that some of these scales may be younger with accessory checks, the spacing and appearance of the markings suggests that most of them are actually age 4.

It appears from the scales which I have seen that the freshwater and ocean zones are similar to those found on scales of fish of age 2. and 3. from the same geographical areas, with addi-

tional winter marks in freshwater, and consequently somewhat larger freshwater zones. For instance, the scales of fish from Lake Dalnee have an enormous freshwater zone, and relatively few circuli in the first ocean zone. The Lake Blizhnee fish of this age, on the other hand, have scales with a small freshwater zone with relatively few circuli in each year's growth and with approximately the same number of circuli in the first ocean zone as would be found in most Asian fish of age 2. or 3.

Fish of the Aleutian Islands show two different types of scales. One type (similar to Lake Blizhnee scales) has an extremely small freshwater zone with few circuli in each year's growth. Scales of this type have broken and irregular circuli in both the freshwater and ocean zones, as on the scales of many Asian fish. They average fewer circuli in the first ocean zone than Asian fish, however, and often average fewer circuli than on scales from Bristol Bay fish. The second type, illustrated by a scale from Adak Island, is similar to scales of fish of the same age in Bristol Bay (Egegik River shown). The freshwater zone is moderately large with numerous circuli, some of which are irregular or broken. The first ocean zone has circuli like scales of age 2. fish from the same locality. Generally the circuli are well marked and more widely spaced near the freshwater zone.

Scales from Kodiak Island (illustrated by scales from Karluk River and Frazer Lake) have freshwater zones that vary from large to extremely large.

DETERMINATION OF ORIGIN OF SOCKEYE SALMON TAKEN IN OFFSHORE WATERS

This section is not a formal key for classifying sockeye salmon by stock or geographic origin. The purpose of this section is to show how age and scale characteristics illustrated in the previous section of the paper can be used by experienced workers to assist in identifying the most probable area of origin of many sockeye salmon taken in offshore waters.

Scales of fish from different offshore areas re-

quire different considerations for study. The following discussion is divided into two parts for purposes of racial identification of the fish:

1. The area westward of long 175° W in the North Pacific Ocean and Bering Sea.
2. The eastern North Pacific Ocean and Gulf of Alaska.

WESTERN AND CENTRAL NORTH PACIFIC AND BERING SEA

Studies of the distribution of sockeye salmon stocks in central North Pacific and Bering Sea for the INPFC, including the morphological, parasitological, and tagging reports noted in the introduction, as well as the scale studies of Mosher (1963) and Mason (1966, 1967a, 1967b) have shown intermingling of stocks primarily from Asia and Bristol Bay over most of the offshore area westward of long 175° W to between 160° and 170° E, depending on the latitude (see Figure 74 of Margolis et al., 1966).

When examining scales of fish from this area, occasionally a scale with a very large freshwater zone may be seen. These scales usually stand out distinctly from others and are most likely from Lake Dalnee fish (Plates 3, 10, 15, and 17). A few scales, however, may be seen with unusually small freshwater zones. These scales are most likely from fish from Lake Blizhnee (Plates 3, 10, 15, and 17).

Aside from these scales with unusually large or small freshwater zones, nearly all of the scales are of two types: (1) Bristol Bay type scales (Plates 4, 11, 16, and 17)—well-marked scales with regular circuli in all growth zones and a moderately large freshwater zone, usually with less than 23 circuli in the first ocean zone. The widest spacing of circuli in the first ocean zone (and often the other ocean zones as well) is usually near the freshwater zone. The ocean portion of these scales has an open appearance. (2) Asian type scales (Plates 3, 10, 15, and 17)—relatively small freshwater zones with many broken or irregular circuli. The first ocean zone usually has 23 to 26 circuli which are widely spaced over the whole summer growth portion but lack the open appearance of the Bristol Bay

scales. The ocean zone of these fish often has three and sometimes four winter marks.

EASTERN NORTH PACIFIC OCEAN AND GULF OF ALASKA

When we examine scales of fish taken eastward of long 175° W and in the Gulf of Alaska, many types may be encountered. At the present state of knowledge, I believe that determination of origin is extremely difficult or impossible if separation by each individual stream or river within the area is required. If, however, determination by general locality of origin and certain areas is the immediate goal, age and scale characteristics can be used to classify many, if not most, of the fish.

No sockeye salmon tagged in the Gulf of Alaska has ever been returned from Asian coastal streams.¹⁰ Numerous sockeye tagged in other areas and other species tagged in the Gulf of Alaska have been returned from Asian coastal rivers. Considering that many thousand sockeye salmon have been tagged in the Gulf of Alaska, at least a few should have been recaptured from Asian waters if any Asian fish were present there during the time of tagging.

Thus, the Asian stocks need not be considered when dealing with fish taken in the Gulf area. Some of the scales of fish taken from the Alaska Peninsula eastward to southeastern Alaska resemble Asian fish in some characters at least. This similarity to Asian fish in scale characters has been noted by Oseko (1961),¹¹ and in morphological characters, by Fukuhara et al. (1962). Consequently any scales encountered in the Gulf of Alaska samples that resemble those from

¹⁰ One fish tagged at 48°29' N, 159°10' W in the area south of the Gulf of Alaska in 1961 was recovered the same year off the Kamchatka coast at 50°47' N, 162°29' E. Kondo et al. (1965) concluded that it was not possible to draw any definite conclusions from the recovery. Margolis et al. (1966), however, considered it a Kamchatka sockeye salmon.

¹¹ Oseko, M. 1961. Certain characteristics of the growth pattern of scales as a means of discriminating between sockeye salmon from various streams of Alaska and the Kamchatka Peninsula. [In Japanese.] Hokkaido Reg. Fish. Res. Lab. (INPFC Doc. 479), 38 p. of Japanese text; 5 p. of preliminary English translation. (Processed.)

Asian fish can be considered of North American origin and classified accordingly.

In the area east of long 175° W into the Gulf of Alaska, the number of circuli and the general appearance of the freshwater and first ocean zones of most scales of age 1. fish can be evaluated and the most probable area of origin can be determined by comparison with the scales in Plates 4 to 7.

Rivers Inlet scales can be identified easily by their appearance. They stand out distinctly from the scales of other areas in all freshwater ages because of the fine-textured circuli of the freshwater and first ocean zones (Plates 1, 9, and 14).

Some scales may be found that have large freshwater zones. In age 1. these are most likely from Unalaska or Kodiak Island, Fish Creek, or the Nimpkish River (Plate 8). In age 2., they may be from Kodiak Island, Fish Creek, Copper River, the Ketchikan area, the Nimpkish, Fraser, or Columbia Rivers (Plate 14). None of these stocks are abundant in these ages, but some are taken at times. The number of circuli in the first ocean zone may assist in determining from which specific area the fish originated.

Migration routes to the various streams have not yet been determined for most stocks, but certain indications are given by tagging studies. Research by the Canadians for the INPFC (Fisheries Research Board of Canada, 1967a, 1967b) shows that fish recovered in the Rivers Inlet-Fraser River area tend to have been tagged farther southward in the Gulf of Alaska in spring and summer than those recovered from the Cook Inlet and Copper River areas. Fish recovered from Bristol Bay tend to have been tagged farther westward than those recovered from the Rivers Inlet-Fraser River areas. Hartt (1962, 1966) and Kondo et al. (1965) indicated that many Bristol Bay fish move westward along the south side of the Alaska Peninsula and the Aleutian Islands, turn north through the passes, and then migrate eastward into Bristol Bay.

Thus if the scale (age 2.) under study has a large freshwater zone and a large number of circuli in the first ocean zone (over 27 circuli) and was taken in the southern part of the Gulf of Alaska, it would be most likely from the Nimp-

kish River (Plate 14). If the scale had 23 to 27 circuli in the first ocean zone and was taken in the northern part of the Gulf, it would probably be from Cook Inlet, Kodiak Island, or Fish Creek; if it had 28 to 30 circuli, it would probably be from the Copper River or southeastern Alaska (Plate 14); and if it had less than 23 circuli, it would probably be from a Bristol Bay fish (Plate 11), or possibly from a spawning stream on Adak or Unalaska Island (Plate 12)) if caught near the Aleutian Islands.

In age 3. sockeye salmon, a scale with a large freshwater zone and about 26 circuli in the first ocean zone indicates most likely a Kodiak Island fish; less than 23 circuli, Bristol Bay or Unalaska Island origin; and over 30 circuli, Nimpkish River origin (Plate 16). A scale with a very small freshwater zone and 25 to 28 circuli in the first ocean zone indicates a fish probably from the Copper River or southeastern Alaska (Plate 16).

In age 0. fish, aside from the Rivers Inlet fish which are distinguishable by their compact, fine-textured first ocean zone (Plate 1), the number of circuli in the first zone offers the best indication of area of origin: a few circuli (20 to 25), Bristol Bay; a large number (over 34), southeastern Alaska southward; or an intermediate number (26 to 34), the area from Bristol Bay to southeastern Alaska (Plate 1).

In age 4., any fish found in the Gulf of Alaska will most likely be from Kodiak Island (Plate 17). If the scale is from a fish taken near the Aleutian Islands and has relatively few circuli in the first ocean zone, it may be from a stream on Attu or Adak Island (Plate 17) or from Bristol Bay.

South of lat 50° N in the southern Gulf of Alaska, the intermingling of stocks may be complex. Very few fish have been tagged in this area; catches are very small as a rule, and consequently little is known about these fish. Study of their scales offers the best means of identifying their origin and determining other features of their life history.

Evidence from fishing by United States, Japanese, and Canadian research vessels south of lat 50° N in the late autumn, winter, and early spring indicated that sockeye salmon of many stocks may be present over a wider area to the

southward than during May and June when most fishing has been carried on.¹²

Kondo et al. (1965) show the estimated area of distribution of sockeye salmon in May and June. In the area between long 165° and 175° W, they show only Bristol Bay and Gulf of Alaska stocks (not quite to 170° W). Thus in the area between long 170° and 175° W, probably only Bristol Bay (Plates 1, 4, 11, 16, and 17), Alaska Peninsula, and Aleutian Island stocks (Plates 5, 12, 16, and 17) will be present in most years.

These procedures have been the result of intensive study of sockeye salmon scales from 1954 to 1971. In addition I have examined collections taken before 1954 (Bristol Bay, from the early 1920's; Karluk River, from the mid-1940's; Copper River, from the mid-1930's; the Petersburg area, from the late 1940's; and the Columbia River, selected years from 1910 to 1922) and have verified the scale characters pictured and described here. Although there are minor differences from year to year, within and between areas, the characters have been relatively stable over a long period of time. The pictures of Rivers Inlet scales shown in Gilbert (1914) resemble the Rivers Inlet sockeye salmon scales of recent samples. Thus the pictures and descriptions shown in this report are representative of scales from fish of these areas and can be used as guides in determining the racial origins of fish taken in offshore areas of the North Pacific and adjacent seas.¹³

¹² I have examined the few scale samples available from the area south of lat 50° N and eastward of long 175° W and have observed many diverse scale types. This leads me to believe that fish from many sources intermingle there: some fish from Bristol Bay, the mainland areas around the Gulf of Alaska, and even from Asia.

¹³ Study of salmon scales, in common with other fish scales, is a specialized branch of fishery biology. It requires a person with a special temperament: one who can sit in a darkened room, often for hours at a time, involved in routine counting and measuring of scale features. It requires a person who can evaluate the subtle differences between scales and not be overcome by them. Consequently, a sympathetic approach and a certain amount of experience with fish scale study is required to be able to use scale characteristics to determine the racial origins of sockeye salmon. When a scientist has obtained this experience and can evaluate the differences among scales, he will find that the information available through study of the scales can be applied toward answering many questions of the life history of the individual fish in addition to its age and racial origin.

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APPENDIX TABLE 1.—Commercial catch of sockeye salmon, 1964 to 1968.

Area	1964	1965	1966	1967	1968
	<i>Thousands of fish</i>				
Asia	8,143.5	13,677.2	8,817.5	10,753.6	8,966.7
Japan	7,175.0	12,171.0	7,667.0	9,783.0	8,131.0
USSR	968.5	1,506.2	1,150.5	970.6	835.7
North America	14,135.7	34,115.8	20,496.8	17,513.6	15,343.4
Canada (B.C.)	3,619.0	3,019.4	4,020.3	6,743.0	6,266.0
United States	10,517.7	31,096.4	16,476.5	10,770.6	9,007.4
North of Bristol Bay	13.4	12.9	1.1	1.3	5.9
Bristol Bay	5,825.7	24,718.7	9,559.5	4,555.4	3,030.0
Alaska Peninsula	1,427.3	1,857.2	1,460.9	1,074.0	2,341.7
Cook Inlet	990.7	1,424.4	1,866.5	1,406.6	1,124.1
Copper River Area	780.0	946.0	1,131.1	568.2	797.2
Southeastern Alaska	923.9	1,085.3	1,054.1	971.5	830.8
Washington & Oregon	556.7	1,050.9	1,403.3	2,193.6	947.7

Source of data: International North Pacific Fisheries Commission, 1964-68, and from Supplemental data provided to the INPFC by the USSR.