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CHUM SALMON POPULATION IN THE GULF OF ANADYR AND THE ADJACENT HIGH SEAS IN LATE JULY 1966*

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Since 1955, research vessels participating in studies for the International North Pacific Fisheries Commission have contributed to our knowledge of the distribution and migration of Pacific salmon in the Bering Sea. In the centeral Bering Sea, it has been found that from the middle of July to early August, immature chum salmon are distributed from southeast to northwest along the edge of the continental shelf in the Bering Sea. This is the same distribution reported for immature chum salmon during late summer by Manzer, Ishida, Peterson and Hanavan (1965). From late July to early August in 1964 and 1965, the *Oshoro Maru*, a fisheries training ship of Hokkaido University, undertook a survey of salmon in the Bering Sea—particularly in the northwestern part. The results not only confirmed that immature chum salmon were concentrated in the central Bering Sea but also provided evidence that the distribution of chum salmon extended from the continental shelf at 180° longitude northeasterly into the Gulf of Anadyr west of St. Lawrence Island (Fac. Fish. Hokkaido Univ., 1965, 1966).

To clarify the distribution of immature chum salmon in northern waters, the *Oshoro Maru* in late July 1966 fished for salmon with gillnets in the Gulf of Anadyr and waters adjacent to St. Lawrence Island. Results of this study showed that immature chum salmon did not migrate into the Gulf but, instead, only mature chum salmon were found in this area — a phenomenon peculiar to the Gulf of Anadyr.

This paper reports on the biological characteristics of immature and mature chum salmon distribution both in the Gulf of Anadyr and in the adjacent sea.

The authors wish to express their gratitude to Dr. M. Kanamori, the former Director of the Research Institute of North Pacific Fisheries, Hokkaido University, for his invaluable advice and encouragement in the course of the work. Thanks are due to Messrs. Y. Kanno, A. Koyama and K. Sasaki for their generous assistance in obtaining biological measurements of chum salmon on board ship. We are also indebted to all the crew members and the cadets of the *Oshoro Maru* for their kind assistance. The writers wish to acknowledge with gratitude to Mr. C.E.

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Atkinson, Fisheries Attaché of American Embassy to Japan, for his kind introduction of a reference.

Materials and methods

1. Date and location of exploratory fishing

From July 19 to 31 in 1966, thirteen exploratory sets were made in the northwestern Bering Sea between Cape Navarin, the Gulf of Anadyr, and waters southwest and west of St. Lawrence Island. This report is restricted to the seven fishing locations where relatively large catches of salmon were obtained; the geographical positions of each fishing location are given in Table 1 and Fig. 1. The number assigned each fishing location in this study, F21–F31, corresponds to the date of hauling the gillnet (i.e. a net hauled on July 21 is designated as F21, etc.).

Exploratory fishing was conducted near the coast of Cape Yakkum (F26), near the Anadyr Bay (F27 and F28), and east of Cape Navarin (F29) — all in the Gulf of Anadyr. Two sets were made in the area off the Gulf of Anadyr (F30 and F31), and a third was made further south off Cape Navarin (F21).

2. Fishing gear and fishing procedure

Information on fishing operations in Table 1 is reproduced in part from another publication (Fac. Fish. Hokkaido Univ., 1967). Both mesh size and amount of nets used are shown in Table 2. At all locations, the nets were identical consisting of five mesh sizes, i.e. 90, 115, 121, 130 and 136 mm stretched measure. Most of the nets were 115, 121 and 130 mm in mesh size.

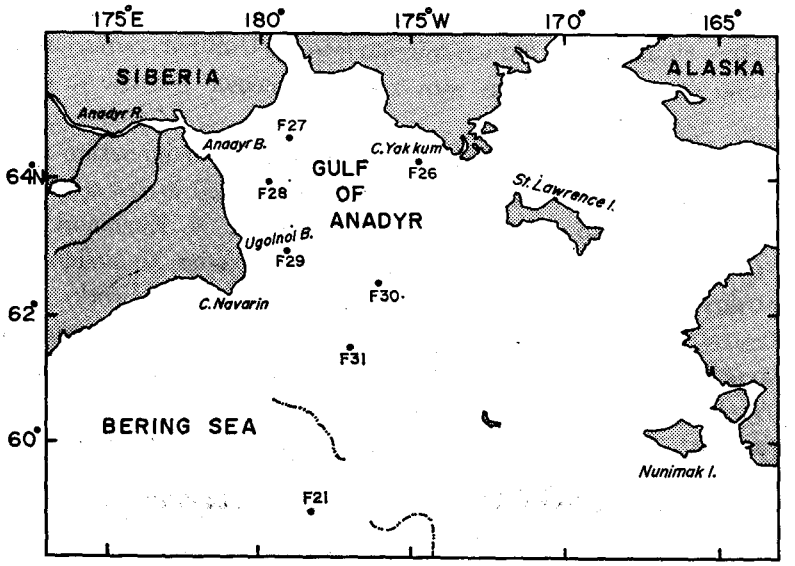

Fig. 1. Fishing stations of the *Oshoro Maru* in late July, 1966

Table 1. Salmon gillnet fishing carried out by the *Oshoro Maru* in the sea within and outside the Gulf of Anadyr, and off Cape Navarin, late July, 1966

Fishing location	Position of net set		Date and ship's time				Direction of drift	Depth (m)
			Net set		Net haul			
	Latitude (N)	Longitude (W)	Date	Time	Date	Time		
F 21	58°49′	178°24′	July 20	1915	July 21	0630	45° & 315°	
F 26	64°17′	174°45′	25	1825	26	0651	50°	75
F 27	64°37′	179°00′	26	1850	27	0708	350°	64
F 28	64°00′	179°41′	27	1911	28	0625	270° & 315°	53
F 29	63°00′	178°54′	28	1830	29	0635	280° & 190°	88
F 30	62°29′	176°00′	29	1811	30	0631	160° & 70°	88
F 31	61°31′	176°51′	30	1905	31	0602	125°	112

Following the same procedure used by Japanese commercial fishing boats, the salmon gillnets were set at sunset and hauled at dawn. The length of time of the nets remained in the water ("soaking time") was eleven to twelve and a half hours a night at all fishing locations. The relation between the length of time the nets were in the water and the catch is not discussed in this paper.

Table 2. Mesh size and amount of salmon gillnets set in the areas within and outside the Gulf of Anadyr and off Cape Navarin, late July, 1966

Mesh size (mm)	91	115	121	130	136	Total
Number of tan	4	23	39	28	8	102
Percentage	3.9	22.6	38.2	27.5	7.8	100.0

3. Number of samples and biological characteristics

Prior to taking samples, the fork length of all individual of fish was measured. Then, a number of fish was sampled at random from the catch made by each mesh size. As shown in Table 3, the number and proportion sampled of the catch ranged from 164 to 283 in number or 26 to 97 percent of the total catch. An exception was relatively small number sampled at location F27.

The body and gonad weights were then taken and scale samples removed for determination of age. The scales were selected from an area four rows above and below the lateral line and between the posterior edge of the dorsal fin and the anterior edge of the adipose fin.

The selectivity of mesh size is not taken into account here and no attempt has been made to adjust the data to provide a more precise estimate of population size.

Table 3. Catch of chum salmon, the number of samples taken and the relation of sample size to total catch for each of five sizes of mesh used at the seven fishing locations (off Cape Navarin —F21, in the Gulf of Anadyr —F26-F29 and off the Gulf of Anadyr —F30 and F31), late July, 1966

Location	Mesh size (mm)	Catch		Sample		$\frac{\text{Sample}}{\text{Catch}} \times 100$
		No.	%	No.	%	
F 21	91	35	10.5	35	16.2	100.0
	115	109	32.8	95	43.6	87.2
	121	127	38.3	65	29.8	51.2
	130	46	13.9	23	10.6	50.0
	136	15	4.5	0	0	0
	Total	332	100.0	218	100.0	65.7
F 26	91	0	0	0	0	0
	115	22	11.6	8	4.9	36.4
	121	77	40.5	76	46.3	98.7
	130	77	40.5	71	43.3	92.2
	136	14	7.4	9	5.5	64.3
	Total	190	100.0	164	100.0	86.3
F 27	91	1	0.2	0	0	0
	115	54	11.5	4	6.9	7.4
	121	237	50.6	10	17.2	4.2
	130	142	30.3	44	75.9	31.0
	136	34	7.4	0	0	0
	Total	468	100.0	58	100.0	12.4
F 28	91	0	0	0	0	0
	115	49	21.5	45	20.4	91.8
	121	75	32.9	72	32.7	96.0
	130	91	39.9	91	41.4	100.0
	136	13	5.7	12	5.5	92.3
	Total	228	100.0	220	100.0	96.5
F 29	91	0	0	0	0	0
	115	20	6.8	20	8.8	100.0
	121	164	56.2	127	56.2	77.4
	130	87	29.8	60	26.5	69.0
	136	21	7.2	19	8.4	90.5
	Total	292	100.0	226	100.0	77.4
F 30	91	15	2.3	15	5.3	100.0
	115	125	19.3	84	29.6	67.2
	121	359	55.3	146	51.6	40.7
	130	121	18.6	20	7.1	16.5
	136	29	4.5	18	6.4	62.1
	Total	649	100.0	283	100.0	43.6
F 31	91	18	2.3	18	9.0	100.0
	115	212	27.0	49	24.5	23.1
	121	379	48.3	76	38.0	20.1
	130	141	18.0	44	22.0	31.2
	136	34	4.3	13	6.5	38.2
	Total	784	100.0	200	100.0	25.5

Results

1. Relative population abundance

The relative abundance of salmon at the seven fishing locations was estimated from the catch per unit tan for each mesh size (Table 4). It was found that at four locations, F26 to F29, the catch per tan was between 2 and 4 fish, at F21

Table 4. Catch of chum salmon per unit tan for each mesh size used at the seven fishing locations (off Cape Navarin —F21, in the Gulf of Anadyr —F26-F29 and off the Gulf of Anadyr —F30 and F31), late July, 1966

Location	Mesh size (mm)				
	91	115	121	130	136
F 21	8.8	4.7	3.3	1.6	1.9
F 26	0	1.0	2.0	2.8	1.8
F 27	0.3	2.3	6.1	5.1	4.3
F 28	0	2.1	1.9	3.3	1.6
F 29	0	0.9	4.2	3.1	2.6
F 30	3.8	5.4	9.2	4.3	3.6
F 31	4.5	9.2	9.7	5.0	4.3

the catch per tan was 3; at F30 and F31 values of 4 to 7 were obtained. It is also seen that the larger catches at locations F26 to F29 were taken in the larger sized mesh while at F21, F30 and F31, the larger catches were made by nets of smaller mesh. In brief, we may assume that larger fish were dominant in the Gulf of Anadyr, while smaller fish occurred in the areas off Cape Navarin and outside the Gulf of Anadyr.

As shown in Table 1, two nets were used at each of four locations, F21, F28, F29 and F30, with each net set in a different direction. The catch of salmon even at the same location differed considerably according to the direction of setting the net. The results of the study are given by Fujii, Yamamoto, Masuda, Kobayashi and Nishiyama (1968).

2. Frequency distribution of fork length

Fork length frequencies for almost all of the individuals taken at the seven locations are plotted in Fig. 2. The size of fish taken at each location varies widely but one easily recognizes three patterns of distribution. The ranges of sizes of fish from locations F26 to F29 are between 48 and 71 cm and the distribution pattern appears to be quite similar. At F21, F30 and F31, the fish were smaller ranging from 40 to 67 cm in length – the mode, however, for fish taken at location F21 is less than for those taken at F30 or F31. Thus, the first group is from locations F26 to F29, the second from F30 and F31, and a third from F21. It is assumed that the fork length frequency distribution of each group is related to differences in age composition.

3. Age composition

Table 5 shows the age composition — in numbers and percentages — of samples taken at the seven locations. It is clearly seen that the three-year fish predominate (50 to 69%) in F26 to F29, next the four-year fish (28 to 45%) and finally the five-year fish (3 to 5%). In contrast, at the fish from F30 and F31 were four-year fish

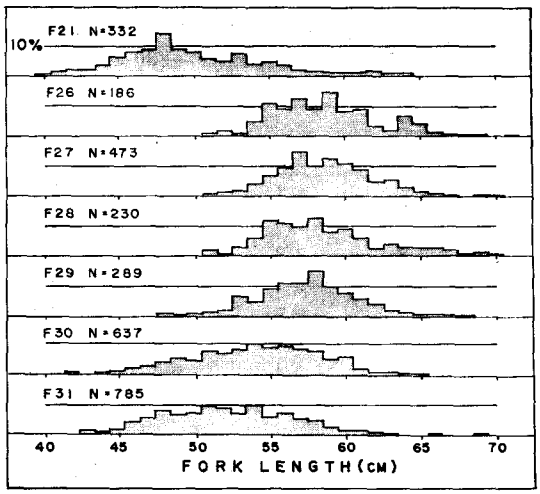

Fig. 2. Frequency distribution of fork length of chum salmon at the seven fishing locations (off Cape Navarin —F21, in the Gulf of Anadyr —F26–F29 and off the Gulf of Anadyr —F30 and F31), late July, 1966

followed by 37 percent three-year fish and 12 to 15 percent five-year fish. The age composition of the sample from F21 is composed of 67 percent three-year fish, 29 percent four-year fish and 4 percent five-year fish and is very similar to the samples collected from within the Gulf of Anadyr. However, as mentioned above, the fork length distribution of the samples taken off Cape Navarin (F21) differs completely from those taken in the Gulf of Anadyr (F26 to F29) and the fish are considered to be of different populations. Further, as seen in Fig. 2, the distribution mode is less for F21 than for F30 and F31, although the ranges are almost identical. This difference may be due to a greater number of three-year-old fish in the sample from location F21.

Table 5. Age composition of chum salmon sampled at the seven fishing locations (off Cape Navarin —F21, in the Gulf of Anadyr —F26–F29 and off the Gulf of Anadyr —F30 and F31), late July, 1966

Location	Age						Total
	3		4		5		
	No.	%	No.	%	No.	%	
F 21	145	66.5	64	29.4	9	4.1	218
F 26	79	49.7	72	45.3	8	5.0	159
F 27	34	58.6	21	36.2	3	5.2	58
F 28	139	63.2	70	31.8	11	5.0	220
F 29	152	68.5	63	28.4	7	3.1	222
F 30	104	36.6	145	51.5	35	12.3	284
F 31	74	37.0	97	48.5	29	14.5	200

An analysis of the age composition together with a study of the fork length distribution shows that fish in the Gulf of Anadyr are predominantly large-sized, three-year fishes. Fish in the Gulf of Anadyr were composed of more sexually mature individuals than those found in the area off the Gulf of Anadyr.

4. Gonad weight and sex ratio

Table 6 shows the weight frequency distribution for both female and male gonads. In this study, the weight of a female gonad is placed into one of 25 classes: the six classes from 1 g to 30 g are of 5 g each, the three classes from 31 g to 60 g are of 10 g each, and the sixteen classes from 61 g to 380 g are of 20 g each. The weight of a male gonad is placed into one of 21 classes: one class each is for the less than 1 g, the 1 g to 2 g, and the 3 g to 5 g groups; three classes from 6 g to 20 g, two classes from 21 g to 40 g are of 10 g each and thirteen classes from 41 g to 300 g are 20 g each.

Female gonads from both three- and four-year fish taken at F21, F30 and F31 were predominantly under 25 g in weight with only a few gonads presence of a larger size. In contrast, gonad weights from F26 to F28 were mostly larger 100 g to 200 g in size regardless of age. From F29, the three-year fish had larger gonads on the average than the four-year fish. Their gonad weights are distributed generally from 11 g to 340 g. In the case of the samples from F30, large gonads were present in addition to a predominance of fish with smaller gonads. It appears that in the two locations, F29 and F30, fish were made up of some individuals with large gonads mixed with those with small gonads.

Most of the male gonads in the samples from F21, F30 and F31 were less than 1 g, while fish from F26 to F29 had gonads larger than 41 g. The distribution widened more in the cases of F26 and F29. In such areas, fish with small gonads must intermingle with the more mature fish.

According to Matsushita (1964), females of chum salmon with gonad weight below 25 g are regarded as immature individuals that will not spawn during the year; fish with gonads more than 25 g in weight are considered to be maturing and all will spawn within the year. He also describes the 5 g level of weight for male gonads as the division between maturing and immature fish. Godfrey (1961) and Ishida, Takagi and Arita (1961) have shown that female fish would be judged mature if the gonad weights were 15 g to 20 g or more for three-year fish and 25 g for four-year fish. These authors have chosen the 2 g gonad weight as the point for dividing immature and mature males.

From the above, female with gonads larger than 26 g and male gonads exceeding 5 g was tentatively classified as mature. The proportion of mature and immature fish for the various locations is shown in Table 7. Fish from F26 to F29 combined were more than 84 percent mature with most of the mature fish in two of the samples, F27 and F28. In contrast, only 11 percent of the fish from F21

Table 6. Frequency distribution of gonad weights for chum salmon sampled at the seven fishing locations (off Cape Navarin —F21, in the Gulf of Anadyr —F26–F29 and off the Gulf of Anadyr —F30 and F31), late July, 1966

Range (g)	Female																					
	Age of fish by fishing location																					
	F 21			F 26			F 27			F 28			F 29			F 30			F 31		
	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5
1-5	20	3														2			8	1	
6-10	34	13								1			1			14	5		15	10	
11-15	11	9	1											5		9	22	1	6	26	3
16-20	2	4	1								1		1	4		2	18	4	1	9	7
21-25	1	1												2	1		5	10		4	2
26-30				1		1							1	1	1	1	1	3	1	1	
31-40														1		1		2			1
41-50		2			1									2			1			2	
51-60	1			2	2						2	1		2		1	1				
61-80	1			4	1					3	1	1	4	2		2	2		2		
81-100		1		1		1				8	1	1	8	1		1					
101-120	1			5	2					12	5		6	1			1			1	
121-140				2	2	1	2	2		8	4		15			1			1	1	1
141-160		1		11	9		5	2		15	9		20	3			1				
161-180		1		9	6		4			8	2		27	5	1		1				
181-200		1		2	3		5	3		10	5		9	1			1				
201-220	1		1	4	9		3	3	1	9	7		4	3		1					
221-240				1	3		1	1		1	1			3							
241-260					1		1	5		1	3	1	1								
261-280			1	2	2			1		1	1			3	1						
281-300											1			1							
301-320						1	1			1	2			1							
321-340										1				1							
341-360															1						
361-380									1		1										

Range (g)	Male																					
	Age of fish by fishing location																					
	F 21			F 26			F 27			F 28			F 29			F 30			F 31		
	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5
-1	70	23	4	1	3								5	4		51	58	8	27	22	9
1-2					1									3		4	13	2	7	12	4
3-5	1	1	1	3	6	2				1			1	4	1	11	8	4		7	2
6-10		2		1	1	2				1	1		1	2	1	1	4		5	1	
11-15		1		2	1						1		1	2				1			
16-20				1	2						1								1		
21-30										1	1										
31-40					1																
41-60									1	1	2		2								
61-80				1			2			3	4		4	1		1					
81-100	1			4	3					3	1	1	10	1							
101-120	1	1		8	8		1			10	2		7			1	1				
121-140				7	1		6			12	3	3	12				1				
141-160				6	3		1			14	2	1	10	2							
161-180				1			2			4	2		4								
181-200					1			3		5	2	2	3	1							
201-220										3	2										
221-240														1							
241-260										1											
261-280										1											
281-300																					

Table 7. Maturity of chum salmon sampled at the seven fishing locations (off Cape Navarin —F21, in the Gulf of Anadyr —F26–F29 and off the Gulf of Anadyr —F30 and F31), late July, 1966

Location	Maturity	Age			Total	%
		3	4	5		
F 21	Mature	6	10	2	18	8.3
	Immature	139	54	7	200	91.7
F 26	Mature	75	62	6	143	89.9
	Immature	4	10	2	16	10.1
F 27	Mature	34	21	3	58	100.0
	Immature	0	0	0	0	0
F 28	Mature	137	69	11	217	98.6
	Immature	2	1	0	3	1.4
F 29	Mature	144	41	2	187	84.2
	Immature	8	22	5	35	15.8
F 30	Mature	11	15	19	45	15.9
	Immature	93	129	16	238	84.1
F 31	Mature	10	6	2	18	9.0
	Immature	64	91	27	182	91.0

and F31 were mature. About twice the proportion of mature fish were found in the sample from F30 than from F21 or F31. The presence of both mature and immature fish at F29 and F30 suggests that mature and immature fish intermingle in these areas.

The sex ratios in the groups of fish that were divided by age and maturity is shown in Table 8. Most conspicous is the predominance of mature females in the

Table 8. Sex ratio of chum salmon sampled at the seven fishing locations (off Cape Navarin —F21, in the Gulf of Anadyr —F26–29 and off the Gulf of Anadyr —F30 and F31), late July, 1966

Location	Maturity	Age									Total		
		3			4			5					
		Female	Male	Ratio	Female	Male	Ratio	Female	Male	Ratio	Female	Male	Ratio
F 21	Mature	4	2	1 : 0.50	6	4	1 : 0.67	2	0		12	7	1 : 0.58
	Immature	68	71	1 : 1.04	30	24	1 : 0.80	2	5	1 : 2.50	100	99	1 : 1.00
F 26	Mature	44	31	1 : 0.70	41	21	1 : 0.57	4	2	1 : 0.50	89	54	1 : 0.61
	Immature	0	4		0	10		0	2		0	16	
F 27	Mature	22	12	1 : 0.55	18	3	1 : 0.17	2	1	1 : 0.50	42	16	1 : 0.38
	Immature	0	0		0	0		0	0		0	0	
F 28	Mature	78	59	1 : 0.76	45	24	1 : 0.53	4	7	1 : 1.75	127	90	1 : 0.71
	Immature	1	1	1 : 1.00	1	0		0	0		2	1	1 : 0.50
F 29	Mature	95	49	1 : 0.52	31	10	1 : 0.32	4	1	1 : 0.25	130	60	1 : 0.46
	Immature	2	6	1 : 3.00	11	11	1 : 1.00	1	1	1 : 1.00	14	18	1 : 1.29
F 30	Mature	8	3	1 : 0.38	9	6	1 : 0.67	5	1	1 : 0.20	22	10	1 : 0.45
	Immature	27	66	1 : 2.44	50	79	1 : 1.58	15	14	1 : 0.93	92	159	1 : 1.73
F 31	Mature	4	6	1 : 1.50	5	1	1 : 0.20	2	0		11	7	1 : 0.64
	Immature	30	34	1 : 1.13	50	41	1 : 0.81	12	15	1 : 1.25	92	90	1 : 0.98

samples from F26 to F29—especially four-year females. From the combined data from the four locations, the number of four-year females is 2.3 times that of males of the same age. Further, mature females of all ages from the same areas outnumbered the males by 1.7 times. The immature males were dominant in the samples from F29 and F30, mostly due to a prevalence of three-year male fish, while the immature fish from F21 and F31 consisted of about same number of both sexes.

5. Average fork length, body weight, gonad weight and coefficient of fatness

Three and four-year chum salmon that predominated at the seven locations were subdivided into eight groups according to sex and maturity. These groups were termed the "dominant component groups". The average gonad weight, the body weight and the fork length of each dominant component group at each location are given in Table 9. It is clearly apparent that values are quite similar for groups from F26 to F29 and for the groups from F30 and F31.

The mature fish in the Gulf of Anadyr were about 57 cm in length, 2500 g to

Table 9. Average gonad weight (g), fork length (cm) and body weight (g) of the dominant component groups found at the seven fishing locations (off Cape Navarin —F21, in the Gulf of Anadyr —F26–F29 and off the Gulf of Anadyr —F30 and F31), late July, 1966

Location	Group*	No. of fish	Range of gonad weight	Gonad weight	Fork length	Body weight
F 21	3-imm-F	68	1-20	7.6	46.6	1715
	3-imm-M	70	1	1	47.7	1335
	4-imm-F	30	2-25	11.0	52.0	1230
	4-imm-M	23	1	1	53.1	1852
F 26	3-mat-F	44	29-274	126.7	57.0	2706
	3-mat-M	27	60-160	141.6	57.8	2904
	4-mat-F	41	49-260	174.5	60.6	3168
	4-mat-M	16	81-184	114.5	59.3	3253
F 27	3-mat-F	22	25-314	185.1	57.4	2800
	3-mat-M	12	75-165	126.3	57.1	2771
	4-mat-F	18	121-264	187.9	60.3	3197
	4-mat-M	3	182-195	187.7	61.7	3533
F 28	3-mat-F	78	67-340	154.9	56.7	2593
	3-mat-M	57	46-278	142.1	57.4	2706
	4-mat-F	45	54-380	179.8	60.3	3176
	4-mat-M	20	46-205	127.3	61.7	3395
F 29	3-mat-F	94	61-242	149.8	56.2	2474
	3-mat-M	52	45-195	112.1	57.5	2813
	4-mat-F	31	26-322	165.8	59.8	3010
	4-mat-M	6	85-226	161.7	61.5	3443
F 30	3-imm-F	27	6-18	8.8	49.6	1600
	3-imm-M	51	1	1	50.5	1650
	4-imm-F	50	10-23	15.1	54.9	2118
	4-imm-M	58	1	1	55.7	2199
F 31	3-imm-F	30	2-16	8.1	48.6	1470
	3-imm-M	27	1	1	50.0	1578
	4-imm-F	48	4-24	13.3	53.8	1984
	4-imm-M	22	1	1	54.5	2168

* Age-Maturity-Sex; imm: immature, mat: mature, F: female, M: male

2800 g in body weight for the three-year group, and 61 cm and 3000 g to 3400 g for the four-year group. The average gonad weight, however, was greater in the samples from F27 and F28—the area nearest the Anadyr Bay—than from F26 and F29. In F30 and F31, the three-year fish were about 50 cm and 1500 g to 1650 g in size, and the four-year fish were 55 cm and 2000 g to 2200 g in size. No difference was found in gonad weight between samples from F30 and F31. Values obtained from fish taken at F30 and F31 were in every instance greater than those for fish from F21. The three-year fish from F21 averaged 47 cm and 1200 g to 1300 g in size and the four-year fish 52 cm to 53 cm and 1700 g to 1850 g; the gonad weights were only slightly different than those from fish taken at F30 and F31.

It is clearly evident that in all locations, the length and body weight of the male fish exceeded those for the female. For the three and four-year fish taken at the seven fishing locations, three predominant fish populations are evident: mature large-sized fish in the Gulf of Anadyr, immature small-sized fish off the Gulf of Anadyr, and immature small-sized fish off Cape Navarin.

The coefficient of fatness was calculated for the eight component fish groups in and off the Gulf of Anadyr using the formula, body weight/(fork length)$^3 \times 100$. The coefficient of fatness of mature fish was derived for the combined samples from F26 to F29, and for immature fish from F30 and F31. The data were not available for F21. From Table 10, it is easily seen that for mature fish, the values for all groups were 1.43 to 1.44, regardless of age, but for corresponding fork lengths, the values became higher for males (1.46–1.47) than for females (1.44). The values for immature fish were 1.26 to 1.28 except for the four-year males with the larger value 1.34. Within the same range of fork lengths and for both sexes, values for four-year fish somewhat exceeded those for the three-year fish. The coefficient of fatness of mature fish groups was identical even for the different age groups and sexes. Further, it appears that four-year immature males have a larger coefficient of

Table 10. Coefficient of fatness (F) of mature and immature chum salmon taken in the Gulf of Anadyr and off the Gulf of Anadyr, late July, 1966

Group*	No. of fish	Range of F.L. (cm)	F	No. of fish	Cor. range of F.L. (cm)	F
Female						
3-mat	229	51-64	1.43	150	56-64	1.44
4-mat	117	54-67	1.43	100	56-64	1.44
3-imm	57	43-55	1.28	21	50-57	1.21
4-imm	90	50-62	1.27	76	50-57	1.29
Male						
3-mat	140	53-65	1.44	102	56-64	1.47
4-mat	45	54-66	1.43	35	56-64	1.46
3-imm	79	45-56	1.26	40	50-57	1.21
4-imm	80	51-60	1.34	64	50-57	1.31

* Age-Maturity; mat: mature, imm: immatue

fatness than three-year immature males, though the immature females had similar values for both age groups.

Discussion

Although comprehensive surveys have been made of the distribution of chum salmon in the Bering Sea, only a few studies have been made in the central and northwestern Bering Sea — particularly in the area east of 180° longitude and north of 56°N latitude.

Before 1959, sporadic research cruises were made: the *Tsukiyama Maru* in 1955, *the Mitokof* in 1956 and the *Kano Maru* in 1959 (Manzer *et al.*, 1965). Information on the distribution of chum salmon reported by those vessels indicated that immature chum salmon, mostly three and four years of age, were concentrated in the central and northern part of the Bering Sea. It was also believed that in the late summer, the immature chum salmon were usually distributed along the edge of the continental shelf from the southeast northernly beyond Cape Navarin. Chum salmon are believed to migrate counterclockwise in the northern and central Bering Sea. Based upon the exploratory studies made during the three years since 1964 by the *Oshoro Maru*, evidence was obtained to show that the distribution of immature chum salmon extended not only to the west of Cape Navarin but also some distance to the east (Fac. Fish. Hokkaido Univ., 1965, 1966).

In late July 1966, the *Oshoro Maru* set salmon gillnets west of St. Lawrence Island, off the Gulf of Anadyr, and southeast of Cape Navarin. The results confirmed the belief that major immature chum salmon occurred in shoals along the continental shelf of the northeastern Bering Sea. At this time, the research vessel also explored the Gulf of Anadyr which had not been studied before. The results showed that immature chum salmon did not occur in any in the Gulf of Anadyr; instead, mature chum salmon were found in some abundance. It is certainly possible that this northwestern part of the Bering Sea can provide a very significant yield of chum salmon.

In considering the distribution of salmon, it is convenient to divide the areas covered by the present study into two regions by a line extending from Ugolnoi Bay to Cape Yakkum. Mature chum salmon are found in the region north of the line (i.e. within the Gulf of Anadyr), while immature chum salmon predominate south of this line (i.e. in the area beyond the Gulf of Anadyr and off Cape Navarin). The reason for this stratification of mature and immature fish in adjacent areas is still not clear, but the ecological or physiological causes are probably related to hydrographic conditions.

The dominant groups of mature chum salmon in the Gulf of Anadyr were remarkably similar in average fork length, body weight and gonad weight. This is strong evidence that chum salmon captured within the Gulf of Anadyr belong to

the same population or race. The coefficient of fatness also indicates a homogeneity between the mature fish taken from this area. The average gonad weight for females was from 130 to 190 g. According to Ishida *et al.* (1961), female gonads within this range are regarded as in the migratory nucleus stage and the individuals with such gonads will arrive on the spawning grounds within a month. Therefore, it is very likely that the mature chum salmon in the Gulf of Anadyr are spawners that will ascend the streams to spawn within a relatively short period of time. It is quite natural to consider that the Anadyr River (one of the largest rivers in northern Asia flowing into the Bering Sea) would be the destination of these fish but unfortunately a lack of information at present makes it difficult to draw any conclusions about the chum salmon in the Anadyr River or adjacent streams. We can only refer to Berg (1948) and Pravdin (1940). Berg cited Sokol'nikov (1911) in his book, describing the ripe chum salmon found in the Liman of Anadyr after August. Berg also notes that Pravdin (1928) gives an average body weight of 3.1 kg to Anadyr chum salmon — comparable to the average body weight for four-year fish examined in the present study. In detail, according to Pravdin (1940), "the average size of chums (1927) was 63.3 cm for males and 59. 4cm for females; the weight of the males was 3.3 kg and of the females 2.9 kg." It is also noted that "in July the males were in a majority, while in August it was the females". Although the gonad weight for ripe fish described by Sokol'nikov is not precisely defined, the occurrence of chum salmon in the Anadyr Bay as well as the body weight for four-year fish described by Pravdin tends to confirm the assumption that mature chum salmon found in the Gulf of Anadyr are bound for the Anadyr River. More positive evidence, however, would come from a comparison of the scale characteristics of salmon from the Gulf of Anadyr and from the Anadyr River or other streams.

In the rivers or in the coastal regions, it is quite common that the older chum salmon appear at the begining of fishing season, the dominant age class appear in the middle of the season, and finally near the end, the younger individuals are found. Kawakami (1937) reports that in the northern Kurile Islands, five-year chum salmon surpass all other age groups in the early part of the fishing season, while at the end, four-year fish were in greater numbers. Thornsteinson, Noerenberg and Smith (1963) studied variations in the age composition, fork length and sex ratio of chum salmon in streams on the Alaska Penninsula, Kodiak Island and Prince William Sound, 1948 to 1959. These authors point out that the age composition gradually changes from a predominance at five to three year fish as the season progresses. The latter authors also mention that males were abundant early in the season and decreased slightly as the season progressed. In a study of chum salmon in the three main rivers of Hokkaido for the three years beginning in 1927, Kawakami (1933) observed that although the sex ratio for the entire run was

equal, male fish were dominant in the earlier part of the season to be replaced later by females as the season progressed.

In the present study, the mature three-year-old individuals in the Gulf of Anadyr outnumbered the four- and five-year-old fish and the numbers of females exceeded the males. If it can be assumed that during the spawning migration the older fish ascend the rivers eariler and the sex ratio changes during the season, then we may conclude that the chum salmon taken in the Gulf of Anadyr were of a later spawning group.

In a comparison of fork length, body weight and gonad weight, the immature chum salmon fell into two groups: one for the area off the Gulf of Anadyr and the other for the area off Cape Navarin. Although all values were less for fish taken off Cape Navarin, these cannot be used to indicate a difference between the groups of fish from the two different areas since there was a period of over ten days between the catch at F21 and at F30 and F31. Unless we deny the possibility that growth could occur in this period of time, then the question of whether the immature chum salmon of both areas belong to one or different races remains unsolved. A comparison of scale characteristics as well as a study of growth is necessary to establish the validity of races within the samples. We were also unable to determine the relationship between the immature and mature chum salmon in the Gulf of Anadyr. It is, of course, possible that chum salmon off the Gulf of Anadyr are only a slower growing form of the fish found in the Gulf of Anadyr.

Summary

To determine the extent of the distribution of chum salmon, salmon-gillnet operations were carried out in late July of 1966 by the *Oshoro Maru*, a fisheries training ship of Hokkaido University, within and outside the Gulf of Anadyr, and in the more southern waters off Cape Navarin.

Chum salmon were found throughout the northwestern part of the continental shelf of the Bering Sea. An estimate of the relative abundance of chum salmon shows that the northwestern waters (including the Gulf of Anadyr) could potentially provide a considerably yield of chum salmon.

Mature chum salmon predominate in the Gulf of Anadyr while in the other areas, immature chum salmon are more abundant. In the Gulf of Anadyr, three-year-old fish averaging about 57 cm and 2700 g in size were more numerious than the four-year-old fish about 61 cm and 3200 g in size. The immature fish could be divided into two groups: one group occurred in the area off the Gulf of Anadyr and the other off Cape Navarin. In the area off the Gulf of Anadyr, the four-year-old fish averaging 54 cm and 2100 g in size predominated; the three-year-old fish were about 50 cm and 1600 g in size. Immature fish off Cape Navarin consisted of

a predominant three-year-old group 47 cm and 1300 g and four-year-old group 52.5 cm and 1800 g in size.

The data suggest that mature chum salmon taken in the Gulf of Anadyr were fish bound for the Anadyr River or adjacent streams to spawn within a month.

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