PROXIMATE COMPOSITION CHANGES IN SOCKEYE SALMON (Oncorhynchus nerka) DURING SPAWNING MIGRATION

by

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ABSTRACT

When sockeye salmon enter the spawning stream, they contain about 10 percent oil and 22 percent protein. The highest oil content is found in the belly flaps and in the dark meat (dark lateral muscle). The fish travel for 3 to 4 months over a distance of several hundred miles to reach the spawning grounds. Drastic changes take place in the composition of their flesh and organs during the migration: oil reserves are nearly depleted, except in the dark meat; protein is markedly decreased; and moisture and sodium are markedly increased.

INTRODUCTION

The sockeye salmon does not eat during its spawning migration which covers perhaps 300 to 800 miles and requires up to 3 or 4 months to complete. The fish expends a tremendous amount of energy in making the trip upstream (fig. 1) and in developing mature gonads. It dies shortly after spawning.

C. W. Greene (1913) reported on the changes that take place in the fat of king salmon during migration up the Columbia River. C. H. Greene (1919) and C. W. Greene (1919) reported that oil and protein contents of king salmon decreased markedly during spawning migration in the Columbia. Davidson and Shostrom (1936) studied physical and chemical changes that occur in pink salmon during migration and found an inverse relation between the sexual development and the amounts of oil, protein, and ash contents. Dunstan (1956) determined the variations in depot fat in the flesh of sockeye salmon caught at several localities in the Columbia River. The broadest, most complete study of the biochemical changes during migration of salmon yet attempted is being done at the Technological Station, Fisheries Research Board of Canada, Vancouver, B. C. (1958-60).

The present report concerns changes in proximate composition and sodium and potassium contents of sockeye salmon during their Columbia River migration in 1960. The specimens studied were from several hundred sockeye salmon collected during the migration to provide data for an investigation on energy expenditure.[1]

EXPERIMENTAL

Collection of Specimens

Three groups of fish were obtained from stations on the Columbia River (fig. 2): Group 1 near the mouth; Group 2 at an

[1] G. B. Collins and H. W. Newman. Manuscript in preparation. "Energy Expenditure of Salmon at Dams." Joint study by Corps of Engineers and Bureau of Commercial Fisheries.

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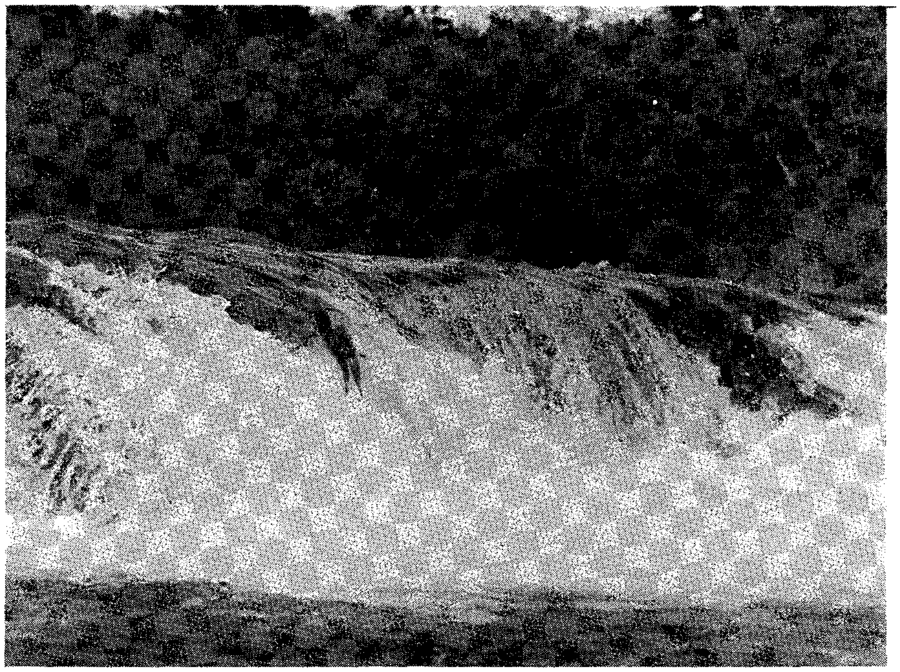

Figure 1.--Sockeye salmon leap at falls during spawning migration.

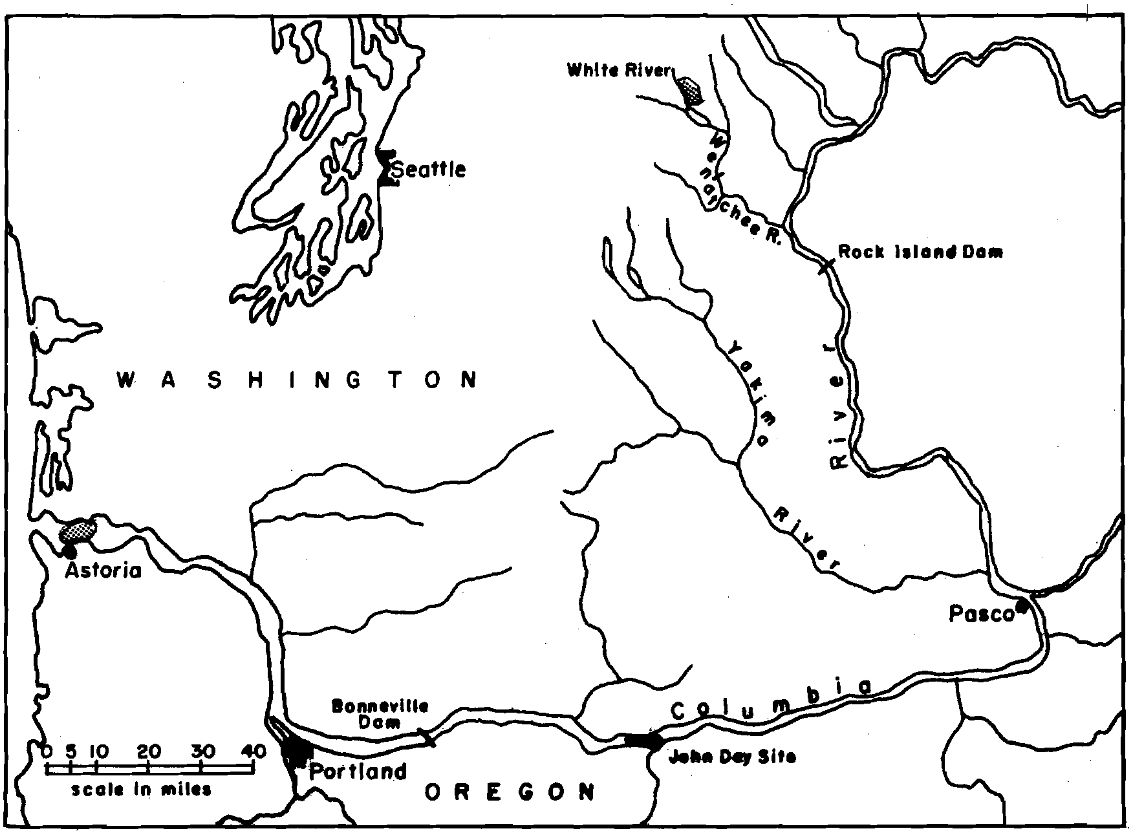

Figure 2.--Map of Columbia River showing collection areas.

intermediate point; and Group 3 at the spawning grounds. The first group consisted of 10 males and 10 females, selected to include a wide variety of sizes from a large group that were purchased from a commercial fisherman at Astoria, Oregon. They had been captured during 4- to 6-hour fishing periods from the 16th to the 19th of June. The second group consisted of 10 males caught at the John Day damsite (fig. 3), 225 miles upriver, during overnight fishing periods from July 13 to 15. The third group consisted of 10 males taken at the White River fish racks, 525 miles upriver. Artificially spawned fish carcasses obtained from hatchery crew members between September 2 and 9 made up this third group. These latter fish had been detained at the rack since their arrival beginning approximately August 19. Only males were available at the second and third locations.

The fish were processed in the field as follows: (1) weight was taken to the nearest gram, (2) length was measured in millimeters (±5 mm.) from hypural plate (base of tail) to snout by a spiral-drum measuring device, (3) sex was determined after making an incision in the belly, (4) each fish was placed in a numbered polyethylene bag and securely tied, and (5) except during transit, the bagged fish were held in a mechanical freezer. Transit times ranged from 4 to 6 hours.

Preparation of Samples

The frozen fish were removed from the bag and cut by bandsaw into cross sections approximately 2 inches thick. All of the edible flesh was removed from the nape, center, and tail sections. The dark lateral muscle (dark meat), and belly flaps were separated from the two remaining sections (fig. 4). The resulting five samples from each fish were individually ground and vacuum sealed in 1/4-pound fish cans for later analysis. No more than a partial thawing occurred during preparation and before the sealed samples were returned to the freezer.

Methods of Analysis

Each sample was analyzed in duplicate for moisture, protein, oil, ash, sodium, and potassium by standard methods previously described (Thurston, 1958a).

DISCUSSION AND RESULTS

The discussion can be conveniently grouped under the following topics: (1) comparison of physical data for the four series

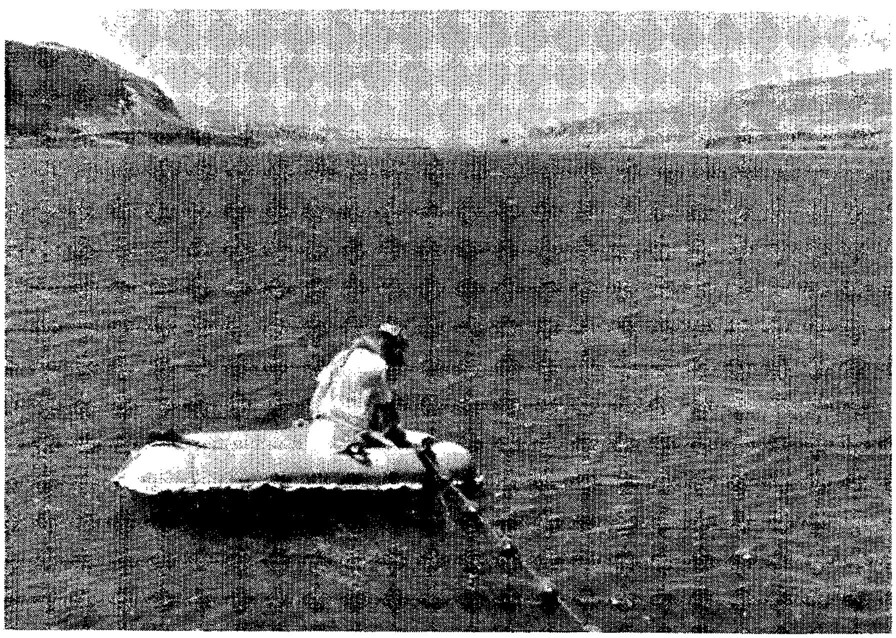

Figure 3.--Biologist fishing for sockeye salmon at John Day Dam site.

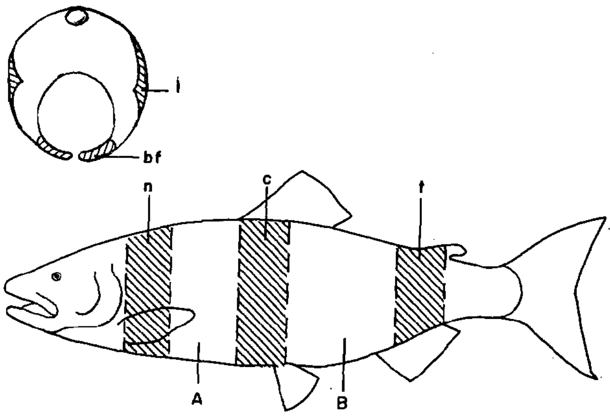

Figure 4.--Diagram of salmon showing sections from which samples were removed.

n - Nape
c - Center
t - Tail
l - Lateral dark meat
bf - Belly flap
A - Section from which l and bf were taken
B - Same as A

of samples of fish--one of females and three of males, (2) comparison of composition data for male and female specimens, (3) comparison of composition data for male specimens at the three stations--Astoria, John Day, and White River, and (4) comparison of results with findings of other investigators.

Comparison of Physical Data

The four samples were of quite uniform size (table 1). Average lengths were in close agreement, and variations within the samples were not large. The average weights of the samples were similar, although the ranges covered were slightly different. The range from the lightest fish to the heaviest was from 1.2 to 2.2 kg. There was also little variation in the physical appearance of the specimens in a given sample. Deterioration of specimens from the spawning grounds was very marked.

Comparison of Composition Data for Male and Female Specimens

The close agreement in composition between the sexes taken at Astoria is shown in table 2. Averages for nape, center, and tail steak sections were nearly identical for all constituents. The variations within the series were small except for sodium and potassium, but even in these constituents, the deviations from the average seldom exceeded 15 percent. The average values for nape, center, and tail sections, representing the average composition of the edible flesh, were nearly identical for all constituents. The definite increase in protein content and large decrease in oil content from nape to tail sections is characteristic for other species analyzed in this laboratory (Thurston, 1958b), as are the comparatively lower sodium and higher potassium contents of the center section. The belly flaps and the dark meat (dark lateral muscle) of the two sexes were also very nearly the same in composition. The belly flaps were higher in protein, moisture, sodium, and potassium than were the dark meat parts.

Comparison of Composition Data for Male Specimens at Different Stations

The same sequence of changes from head to tail found in the Astoria samples was also found in the John Day and White River

TABLE 1.--Physical data on four series of Columbia River sockeye salmon

Place of capture	Number of fish in samples	Sex	Length		Weight	
			Average	±	Average	±
			Cm.	*Cm.*	*Kg.*	*Kg.*
Astoria	10	Female	49	3	1.58	.3
Astoria	10	Male	50	2	1.68	.3
John Day	10	Male	48	5	1.78	.4
White River	10	Male	52	6	1.57	.4
Average			50		1.65	

TABLE 2.--Proximate composition of four series of Columbia River sockeye salmon

Location	Sex	Part	Moisture		Protein		Oil		Ash		Sodium		Potassium	
			Aver-age	±	Aver-age	±	Aver-age	±	Aver-age	±	Aver-age	±	Aver-age	±
			Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Mg Percent*	*Mg Percent*	*Mg Percent*	*Mg Percent*
Astoria	Female	Nape	65.6	2	20.9	1	13.2	2	1.13	0.03	42	4	365	20
		Center	67.5	1	22.1	1	10.3	2	1.16	0.05	36	5	379	13
		Tail	71.4	2	22.7	0.5	5.7	1	1.19	0.05	41	3	383	20
		Average	68.2		21.9		9.7		1.16		40		376	
		Belly flaps	58.3	3	18.5	2	22.2	2	0.95	0.1	52	8	292	20
		Dark meat	55.0	1	16.0	1	27.4	2	0.91	0.1	35	8	271	20
Astoria	Male	Nape	66.0	2	21.2	1	12.7	3	1.19	0.1	44	3	361	
		Center	67.3	2	22.4	1	10.5	2	1.24	0.1	36	2	375	
		Tail	71.4	2	23.1	1.5	5.7	2	1.28	0.1	40	6	377	
		Average	68.2		22.2		9.6		1.24		40		371	
		Belly flaps	58.5	2	19.1	1	21.9	4	0.97	0.1	56	5	292	30
		Dark meat	56.8	2	15.8	2	26.7	4	0.84	0.2	33	6	262	50
John Day	Male	Nape	71.7	4	20.7	2	7.7	4	1.14	0.1	55	10	354	40
		Center	72.4	3	21.9	1	5.9	2	1.13	0.1	41	12	370	30
		Tail	74.5	2	21.9	1	3.6	1	1.12	0.1	44	12	369	20
		Average	72.9		21.5		5.7		1.13		47		364	
		Belly flaps	67.7	6	20.0	2	12.3	7	1.04	0.1	53	10	333	40
		Dark meat	62.8	5	16.7	2	19.6	5	0.94	0.1	37	9	290	40
White River	Male	Nape	80.1	2	17.9	1	2.0	1	1.14	0.1	60	10	378	15
		Center	80.3	2	18.0	1	1.8	1	1.11	0.1	57	7	375	20
		Tail	79.8	2	18.4	1	1.6	1	1.10	0.1	58	8	366	15
		Average	80.1		18.1		1.8		1.12		58		373	
		Belly flaps	81.0	2	16.9	1	2.1	1	1.07	0.05	84	20	331	30
		Dark meat	77.3	4	15.5	1	6.8	4	0.88	0.05	65	10	264	20

samples (table 2), but the change in each constituent was uniformly large in most instances from Astoria to the White River. The large increases in moisture and sodium with corresponding decreases in protein and oil are similar to the results found for pink salmon (Thurston, 1958b). The high oil content of the dark meat in spawning specimens has also been noted in pink salmon (Thurston, 1958b). The small variation in potassium values is rather surprising in view of the large increase found for sodium. Usually, there is a fairly uniform inverse proportion between the sodium and potassium contents of fish flesh. This relation was not observed in the present spawning migration study.

Differences found in the oil content indicate that a more complete study of changes in lipids would be of interest. The lipid deposit found in the dark lateral muscle was not depleted as completely as were the deposits found in the belly flap and in the flesh sections. Iodine values were determined on the oil extracted from all the samples. Although the method used to extract the oil would be expected to cause a loss of unsaturation, all samples received the same treatment, and the results can be considered relative. The iodine value of the oil from steak sections from fish taken at the first two stations did not change and averaged 148. The average at the spawning grounds was 165. The iodine value in the dark meat did not change, and that of the belly flap increased from 137 to 147. In future investigations, the quantitative fatty acid composition of spawning salmon might well be determined and compared with that of fish from the beginning of the run.

As is shown in table 3, the comparable data obtained in this study are in good agreement with those reported by Canadian scientists in their extensive investigation of composition changes in sockeye salmon during their migration up the Fraser River (Idler and Bitners, 1958). The changes in moisture and oil were greater and the change in protein was smaller for the Columbia River specimens than they were for the Fraser River specimens, but the changes were of the same order.

TABLE 3.--Proximate composition of sockeye salmon from the Columbia and Fraser Rivers[1]

Location	Sex	Moisture		Protein		Oil	
		Columbia	Fraser	Columbia	Fraser	Columbia	Fraser
		Average percent	*Average percent*	*Average percent*	*Average percent*	*Average percent*	*Average percent*
Mouth of river	Female	68.2	67.0	21.9	22.0	9.7	10.6
Mouth of river	Male	68.2	67.2	22.2	21.9	9.6	9.3
Halfway point	Male	72.9	70.7	21.5	20.5	5.7	5.1
Spawning grounds	Male	80.1	78.2	18.1	16.8	1.8	3.2
Total change		+11.9	+11.0	-4.1	-5.1	-7.8	-6.1

[1] Fillets only, for three constituents (the only ones reported in the Fraser River study).

SUMMARY

1. The specimens in the different series of Columbia River sockeye salmon used in this investigation had the same range distribution for size.

2. Little difference was noted in composition of male and female specimens taken at the mouth of the river. The 22 percent protein and 10 percent oil contents, combined with a low sodium (40 mg. percent) content, indicate that sockeye salmon is a nutritious food.

3. At the spawning grounds, the protein content of the fish dropped markedly and the oil reserves were practically depleted.

This occurred even though the oil content of the dark meat remained high. The moisture and sodium contents greatly increased, but the potassium content remained about the same.

4. The iodine value of the oil, except for oil in the dark meat, tended to increase by the time the fish arrived at the spawning grounds.

5. Where data are available for comparison, as in amounts of moisture, protein, and oil, the changes in composition reported here are practically the same as the changes reported for sockeye salmon migrating up the Fraser River.

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