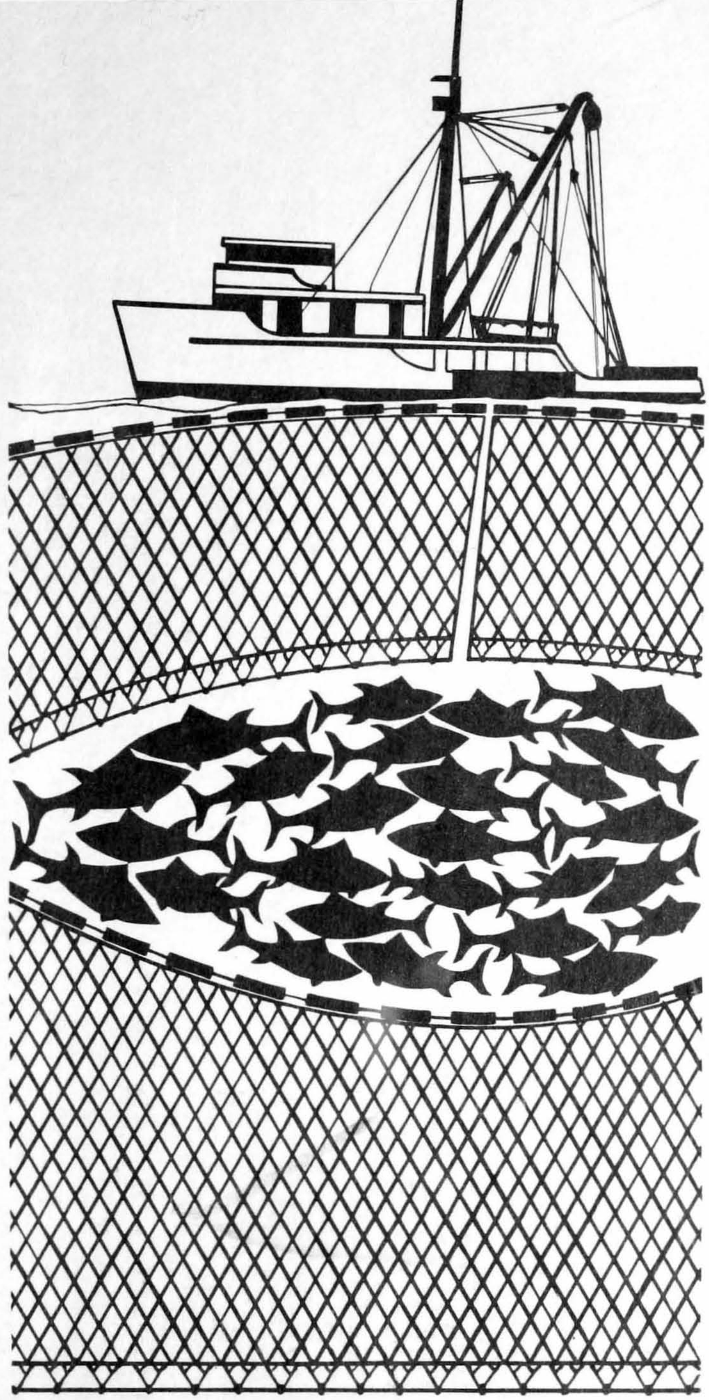

FISHERY INDUSTRIAL RESEARCH

VOLUME 3 NO. 3

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FISHERY INDUSTRIAL RESEARCH
Volume 3 -- Number 3

Washington, D. C.
DECEMBER 1966

PROXIMATE COMPOSITION OF THE PACIFIC COAST DUNGENESS CRAB (*Cancer magister*)

by

Robert N. Farragut and Mary H. Thompson

ABSTRACT

The proximate composition of Pacific Coast Dungeness crab is given. Data from 4 samples each of frozen body meat, claw meat, and offal of the Dungeness crab are reported, as is the composition of 2 types of cooked packs from the same lots. Changes in proximate composition resulting from processing are noted.

INTRODUCTION

The production of Dungeness crabs on the Pacific Coast has grown from 1.9 million pounds in 1942 (California Ocean Fisheries Resources, 1960) to 32.7 million pounds in 1961 (Rees, 1963). Prior to 1920, Pacific Coast Dungeness crabs were marketed in the fresh state. The commercial pack of canned Dungeness crab, which totaled 15 cases in 1920, was expanded to 170,000 cases by 1948 (Hipkins, 1957). At present, the largest portion of the catch (70-90 percent) is sold fresh or frozen; the remaining 10-30 percent is canned.

Research on the composition of the crabs has lagged behind the technological advances in the Dungeness crab fishery. To make processing adjustments when changes occur in the composition of fresh Dungeness crabs and to aid in market promotion, the fishery needs compositional data. Accordingly, the purpose of this paper is (1) to report the proximate composition of the Pacific Coast Dungeness crab and (2) to discuss any significant changes in the crab's proximate composition resulting from seasonal variations or from processing.

I. PROCEDURE

A. SAMPLING METHOD

Dungeness crabs were bought by members of the Bureau of Commercial Fisheries Technological Laboratory, Seattle, Washington, at Westport, Washington. 4 samples of fresh crab were obtained (12 debacked crabs in each sample), 1 each in January, March, June, and August. At the same time, 2 5-pound heat-processed cans of crab meat, 1 packed with brine and 1 without brine, were also obtained. The fresh samples were shipped to this laboratory packed in dry ice and were received in good condition.

The crabs, minus the claws, were divided into 2 groups and picked, and the edible, still-frozen body meat was homogenized in a ball-mill grinder. The claws from each lot were combined into 1 sample, cleaned, picked, and ground similarly. The inedible portion of the body and claws, consisting entirely of shell and cartilage, was combined as the offal sample and ground in a food grinder. The entire contents of the heat-processed cans were homogenized in a ball-mill grinder. Each ground sample was placed in a polyethylene bag; the bag was then sealed, placed inside a glass container, and held at 0° F. until the contents were analyzed. A cube of ice was placed in each glass container to prevent dehydration of the sample during storage.

B. CHEMICAL METHODS

The oil, ash, nitrogen, and moisture content of the crabs was determined substantially according to

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the official methods of analysis of the Association of Official Agricultural Chemists (1960). The only deviation was the substitution of reagent-grade ottawa sand for asbestos in the moisture determination. The data are reported as the average of 4 determinations in the case of the body meat and as the average from duplicate analyses in the cases of the claw meat and the waste material.

II. RESULTS

Data on the proximate composition of the body meat, claw meat, and offal of the Dungeness crab are listed in Table 1. The values listed in the weight columns are for the debacked crab minus the claws and are given only as an indication of the size of the crabs.

The proximate composition of all samples of the Dungeness crab was found to be quite similar to that of the blue crab *(Callinectes sapidus)* as reported by Farragut (1965).

The Dungeness crab industry uses only the male crab, which must have a carapace length of greater than 7 inches to be of legal size. The commercial season for Dungeness crabs opens and closes according to the spawning season and varies with the location. The Westport area, from which our samples were taken, has a closed commercial season from October through December, the spawning season in that area. Thus, the data reported here are for male crabs over 7 inches long and caught during the first 8 months of the year.

The seasonal variations reported by Farragut (1965) for the Chesapeake Bay blue crab were most pronounced during the mating and spawning season. Because the Dungeness crab samples used for our analyses were not obtained during these periods, we will not compare compositions of the 2 species.

Changes in proximate composition are said to be significant if the change exceeds the average of the 2 values by ± 2 times the standard deviation. Table 2 shows the standard deviation for proximate composition methods using Dungeness crab as the sample. Discussions in this paper are for the most part based on data calculated on a nitrogen-content basis; where moisture-content basis is used, it is so specified.

Figures 1-4 show the changes in proximate composition of the body meat, claw meat, and offal of the Dungeness crab for the period between January and August. The nitrogen content of the body meat and offal did change significantly (95-percent level or greater). The claw meat decreased significantly in nitrogen content from March to June. This change in the nitrogen content of the claw meat coincides with the maturation period for eggs and spermatozoa in June. The nitrogen content does not change

Table 1.—Weight and proximate composition of the Dungeness crab *(Cancer magister)*

Type of sample	Time when sample was obtained	Crabs in sample	Weight		Average proximate composition						
			Range	Average	Protein content	Moisture content	Oil content	Ash content	Moisture content	Oil content	Ash content
	Date	*No.*	*Grams*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Mg/mg. N.*	*Mg/mg. N.*	*Mg/mg. N.*
Body	1/7/63	12	175-220	197	17.5	80.0	1.6	1.36	28.6	0.6	0.48
	3/12/63	12	131-285	199	17.8	79.0	1.5	1.43	27.8	0.3	0.50
	6/3/63	12	136-196	169	16.6	80.3	0.9	1.45	30.3	0.3	0.54
	8/13/63	12	214-286	241	17.1	79.2	0.9	1.54	29.0	0.3	0.56
Claw	1/7/63	12	175-220	197	18.5	80.3	0.8	1.32	27.1	0.3	0.44
	3/12/63	12	131-285	199	18.6	78.5	0.8	1.40	26.4	0.3	0.47
	6/3/63	12	136-196	169	15.2	82.3	1.7	1.91	33.9	0.7	0.78
	8/13/63	12	214-286	241	15.6	81.5	0.7	1.71	32.7	0.3	0.68
Offal	1/7/63	12	175-220	197	14.7	56.7	1.5	15.19	24.1	0.7	6.46
	3/12/63	12	131-285	199	13.6	53.2	0.7	16.29	24.5	0.3	7.50
	6/3/63	12	136-196	169	13.4	61.2	0.5	14.59	28.5	0.2	6.78
	8/13/63	12	214-286	241	14.4	56.8	0.5	14.38	24.6	0.2	6.22

Table 2.—**Standard deviation for proximate composition methods using Dungeness crab *(Cancer magister)* as a sample**

Type of tissue	Standard deviation on a wet-weight basis of:				Standard deviation on a nitrogen-content basis of:		
	Nitrogen	Moisture	Oil	Ash	Moisture	Oil	Ash
	Percent	*Percent*	*Percent*	*Percent*	*Mg./mg. N.*	*Mg./mg. N.*	*Mg./mg. N.*
Body	.05	.61	.26	.10	.68	.09	.03
Claw	.03	.08	.16	.05	.11	.06	.02
Offal	.02	.30	.23	.17	.16	.10	.15

significantly (95-percent level or greater) in the body meat and claw meat of the Dungeness crab during the period before mating. In contrast, the changes reported by Farragut for the proximate composition of the blue crab prior to mating were pronounced.

An increase of 0.31 milligrams per milligram of nitrogen in the ash content of the claw meat occurs during the period from March to June. This change is significant at the 95-percent level and also coincides with the spermatozoa-ripening period.

A significant (95-percent level) increase in the moisture content of the body meat, claw meat, and offal occurred from March to June. The oil content in the body meat and offal changed inversely with the moisture content as would be expected. The oil content of the claw meat, however, increased 0.4 milligrams per milligram of nitrogen from March to

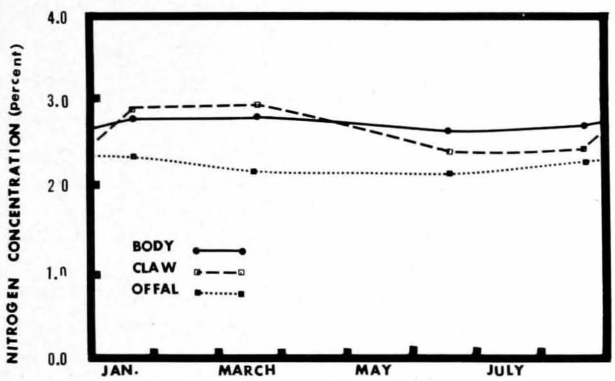

Figure 1.—Variations in the nitrogen content of the body meat, claw meat, and offal in the Dungeness crab *(Cancer magister)*.

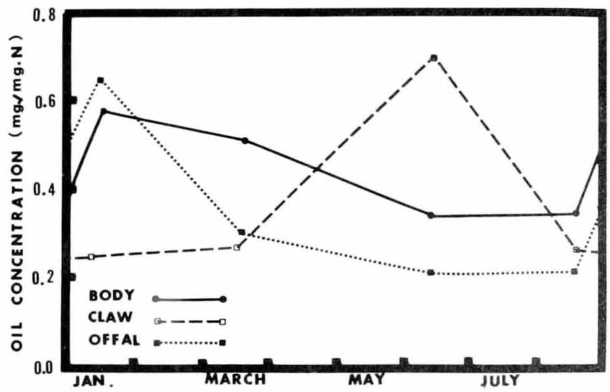

Figure 3.—Variations in the oil content of the body meat, claw meat, and offal of the Dungeness crab *(Cancer magister)*.

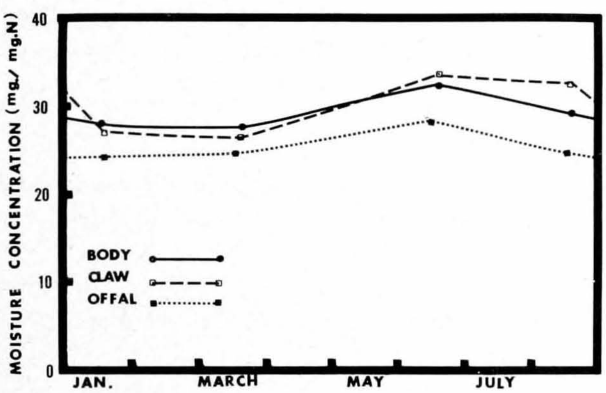

Figure 2.—Variations in the moisture content of the body meat, claw meat, and offal of the Dungeness crab *(Cancer magister)*.

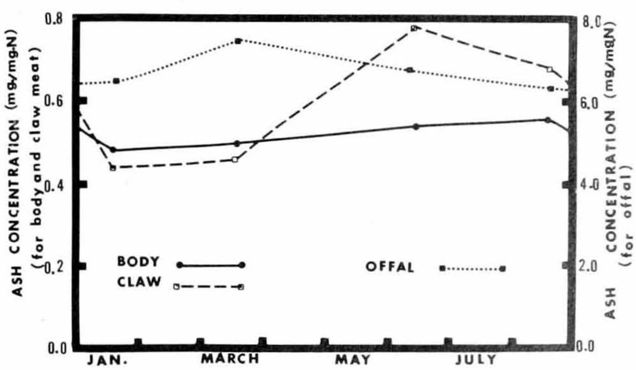

Figure 4.—Variations in the ash content of the body meat, claw meat, and offal of the Dungeness crab *(Cancer magister)*.

June, the moisture also increased during this period. An inverse relation is observed for the oil content of the body meat and offal.

Canned Dungeness crab processed from the same catch as the frozen crabs was analyzed concurrently with the fresh frozen crabs. The processed crab meat, which was packed dry in 5-pound cans, contained 1/2 body meat and 1/2 claw meat. 1 can contained meat cooked with brine, and 1 contained meat cooked without brine.

The proximate composition of the processed Dungeness crab is shown in Table 3. The ash content was higher in the pack with brine than in the pack without brine. The brine-packed crabs were significantly (95-percent level) higher in ash content than were either the frozen crabs or the crabs processed without brine. The latter 2 types of samples did not differ significantly, however, in ash content. The other small changes in nitrogen, oil, and moisture content of processed crab meat were not significant at the 95-percent level. Other differences noted between fresh frozen crabs and crabs cooked in either way were not significant at the 95-percent level.

Table 3.—Proximate composition of cooked, canned Dungeness crab *(Cancer magister)* meat

Type of sample	Time when sample was obtained	Average proximate composition						
		Protein content	Moisture content	Oil content	Ash content	Moisture content	Oil content	Ash content
	Date	*Percent*	*Percent*	*Percent*	*Percent*	*Mg./mg. N*	*Mg./mg. N*	*Mg./mg. N*
Dungeness crab with brine	1/7/64	17.9	77.9	1.4	2.32	27.1	0.5	0.80
	3/12/64	18.9	76.9	1.0	2.43	25.5	0.3	0.80
	6/3/64	18.9	77.7	1.2	2.78	25.7	0.4	0.92
	8/13/64	16.8	78.5	0.9	2.42	29.3	0.4	0.90
Dungeness crab without brine	1/7/64	19.6	77.7	1.1	1.18	24.8	0.4	0.37
	3/12/64	19.8	78.5	1.2	1.31	24.8	0.4	0.41
	6/3/64	21.3	76.6	1.1	1.49	22.5	0.3	0.43
	8/13/64	14.7	82.9	1.1	0.97	35.3	0.5	0.41

SUMMARY

The proximate composition of Pacific Coast Dungeness crab body meat, claw meat, and offal changed significantly for the period sampled. The oil and moisture content changed inversely in the body meat and offal but not in the claw meat. A significant decrease in nitrogen content occurred in the claw meat, the body meat, and the offal. The ash content of the claw meat changed significantly, but the ash content of the body meat and offal did not.

The proximate composition of Dungeness crabs processed with and without brine was significantly different in ash content only.

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MS #1531

MICROBIAL ANALYSES OF FROZEN RAW BREADED SHRIMP

by*

Bobby J. Carroll, Travis D. Love,

Benjamin Q. Ward, and Melvin E. Waters

ABSTRACT

164 commercially packed samples of frozen raw breaded shrimp from 14 processing plants were tested for total plate counts, coliforms, *Escherichia coli*, fecal streptococci, and coagulase-positive staphylococci. The aim of the study was to supply background data on which realistic future bacteriological standards can be based.

INTRODUCTION

The increased acceptance and consumption of frozen foods have caused an ever-increasing awareness of product quality and safety. This public awareness has resulted in the establishment of bacteriological standards for numerous frozen food products, and particularly for precooked and partially cooked seafoods.

The standards have varied rather widely, some permitting no more than 100,000 cells per gram and 1 permitting no more than 50,000 cells per gram, reflecting the difficulties in establishing standards. The United States Army currently requires that frozen precooked seafoods have a total plate count not exceeding 100,000 cells per gram (Rayman, Huber, and Zaborowski, 1955). Fitzgerald and Conway (Fitzgerald, 1947; Fitzgerald and Conway, 1937) recommended that frozen foods should have a maximum of 100,000 cells per gram, although higher counts could be tolerated. Since the establishment of the aforementioned requirements, the State of Massachusetts has established more stringent standards for precooked and partially cooked frozen foods. These standards require that the product contain less than 50,000 cells per gram, less than 10 coliform cells per gram, and no coagulase-positive staphylocci.

To obtain more data concerning the bacteriological picture of frozen raw breaded shrimp, we analyzed 164 commercially packed samples from 14 processing plants. We hope that the data obtained in this study — together with those from similar studies of Kachikian, Larkin, and Litsky (1960); Silverman, Nickerson, Duncan, Davis, Schachter, and Joselow (1961); and others — will produce much of the background data necessary for any future promulgation of realistic bacteriological standards for raw breaded shrimp.

I. MATERIALS AND METHODS

A. SAMPLES

All of the 164 samples used in this study were finished frozen raw breaded shrimp products collected at processing plants in the Southern United States. The frozen samples were transported to the Laboratory in insulated cartons containing dry ice. At no time were the samples allowed to thaw prior to being analyzed.

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B. DILUTIONS

All dilutions were made using buffered phosphate dilution water (Butterfield's). An initial 1:10 dilution was prepared by aseptically weighing 50 grams of breaded shrimp into a Waring blender jar[1] containing 450 milliliters of buffered dilution water and blending for 2 minutes. Further dilutions were made from the 1:10 dilution as required.

C. MICROBIAL ANALYSES

Analyses were made for total plate counts, coliforms, *Escherichia coli*, fecal streptococci, and coagulase-positive staphylococci.

1. Total Plate Counts

Total plate counts of the products were made on tryptone glucose extract agar (Difco). Plates were poured with the necessary decimal dilutions and incubated for 48 hours at 35° C. Duplicate plates were counted for each sample, and the average count was recorded as cells per gram of material.

2. Coliforms

Coliform density was estimated using the most-probable-number method, 1.0 milliliter of each decimal dilution of the shrimp homogenate being pipetted into 3 separate tubes of lauryl sulphate tryptose broth (Difco). The tubes were incubated for 48 hours at 35° C. After the tubes had been incubated, they were examined for gas. Recording of tubes positive for gas production at this point was of little value, however, because the nature of the product resulted in many extraneous fermentations.

We confirmed the presence of coliform organisms by inoculating tubes of brilliant green lactose bile broth (2 percent) (Difco) from the positive lauryl sulphate tryptose broth tubes. These tubes were incubated at 35° C. (± 0.5° C.) for 48 hours (±3 hours) and were observed for the production of gas. All tubes exhibiting the production of gas were streaked onto eosin methylene blue agar plates. These plates were incubated at 35° C. (± 0.5° C.) for 24 hours, at the end of which time several suspect coliform colonies were picked and inoculated into lactose broth and streaked onto nutrient agar slants. Colonies producing gas in the lactose tube were subjected to the IMViC (indole, methyl red, Voges-Proskauer, and citrate) test for further differentiation according to the procedures set forth in American Public Health Association's Standard Methods (1960).

[1] Trade names are used in this report to simplify our description of the experimental materials and equipment; no endorsement is implied.

3. *Escherichia coli*

Coliform differentiation was undertaken using the Eijkman test as outlined in Standard Methods; however, the high incidence of false positives obtained with the Eijkman procedure resulted in our ultimate abandonment of the Eijkman procedure and our complete reliance upon the IMViC series as definitive.

4. Fecal Streptococci

Fecal streptococci were detected by the use of azide dextrose as a presumptive medium and ethyl violet azide as the confirmatory medium. Quantitative determinations were made using the most-probable-number technique. In using this technique, we:

1. Inoculated azide dextrose tubes with 1.0 milliliter of each decimal dilution of the shrimp.
2. Made the contents of the tubes homogeneous and then incubated the tubes for 48 hours at 37.0° C.
3. Subcultured all positive azide dextrose tubes to ethyl violet azide for 48 hours at 37.0° C.
4. Determined the presence of fecal streptococci by noting the tubes with turbid media and "purple buttons" in the bottoms of the tubes.
5. Determined further the presence of streptococci by gram stained smears.

In a subsequent study, we have noted numerous "false positives" with typical "purple buttons" occurring in ethyl violet azide. These "false positives" have all been produced by an unidentified gram-positive bacillus. Obviously, the acceptance of the "purple button" without confirmatory microscopic examination, as is reputedly practiced by some workers, is unwarranted. We are now comparing the accuracy of this method with several other recommended methods of detection and enumeration of fecal streptococci.

5. Coagulase-Positive Staphylococci

Coagulase-positive staphylococci were counted by the technique outlined in *Methods for the Bacteriological Examination of Foods* (published by the United States Public Health Service in 1963). This technique uses a cooked meat medium (Difco) with 10-percent NaCl, 1.0 milliliter of each decimal dilution of shrimp homogenate being pipetted into 3 tubes as outlined above with regard to coliform density. The tubes were incubated at 35° C. for 24 hours. From each tube, duplicate plates of tellurite polymyxin egg yolk agar were streaked. The plates were incubated at 35.0° C. for 24 hours. Several suspect colonies, as determined by descriptions furnished in *Examination of Food for Enteropathogenic and Indicator Bacteria* (Lewis and Angelotti, 1963), were picked and transferred to tubes containing 5.0 milliliters trypticase soy agar slants. The trypticase soy agar slants were incubated at 35° C. overnight. By use of a straight needle, slant growth was removed, and a homogenous suspension of growth and water was made on a slide. To the suspension, we added a 3-milliliter-diameter loopfull of bacto-coagulase plasma (Difco). Positive microspopic clumping usually occurred in 10 to 15 seconds. Delayed reactions were regarded as doubtful or negative cultures. Gram stains of the culture were made simultaneously with the coagulase test.

II. RESULTS AND DISCUSSION

Results of the examination of the 164 samples of frozen raw breaded shrimp dramatized the great variability in both total plate counts and the numbers of each group that are to be expected with a product of this nature (Tables 1 and 2). Much of this variability is inherent in the raw product itself. Total plate counts on raw shrimp headed immediately after their being landed may vary from a few hundred cells per gram to several million cells per gram (Carrol and Ward, 1965[2]).

From past experiences, we feel that we cannot rely on total plate counts as an indicator of shrimp quality. Raw headless shrimp, for example, held in crushed ice have had a total plate count exceeding 200 x 10^6 and still have been Grade A according to organoleptic standards (Carroll and Ward, 1965[3]). We have failed to find any correlation between the total number of cells present and the quality of the product. Examination of these same samples of raw headless shrimp produce coliform counts of 24,000 per 100 grams, average fecal streptococcus counts of 7,500 per 100 grams, and average coagulase-positive staphylococcus counts of 4,600 per 100 grams.

Results from past analyses of several samples of raw peeled and deveined shrimp prior to breading produced a range of total plate counts of 3,800 to 2,250,000 per gram. The average total plate count was 1,000,000 per gram. This figure, when compared with the average total plate count of the raw headless shrimp examined, represents a 69-percent decrease in total plate count per gram. Examination of the peeled and deveined samples produced an average coliform count of 170,000 per 100 grams, fecal streptococcus count of 98,000 per 100 grams, and coagulase-positive staphylococcus count of 34,000 cells per 100 grams.

Although peeling, deveining, and washing reduce the total plate count considerably, there is at the same time a marked increase in the organisms of possible public health significance. The coliform count increased most, with a 140-percent rise. Coagulase-positive staphylococci and fecal streptococci increased 130 percent and 77 percent, respectively.

Bacterial increases continued throughout processing. The counts on the peeled and deveined samples illustrate the fact that shrimp have a well-established microbial population even before they reach the midway point during processing. Increased numbers of cells are added during the application of batter and breading. Our analysis of a limited number of batter samples that were added to a batter machine showed that the bacterial counts increased 56 percent after the samples were in the machine for 15 minutes. Similar bacterial increases can be demonstrated with the breading material. The increase in bacteria thus continues throughout processing.

The average total plate count per gram of shrimp was found to be 1,100,000. Kachikian, Fellers, and Litsky (1959) found that 36 percent of the raw and breaded shrimp they examined contained fewer than 500,000 cells per gram. Our results were similar; 39 percent of our samples contained fewer than 500,000 cells per gram. 35 percent of the samples contained more than 1,000,000 cells per gram.

The average coliform count on the samples examined was 59,000 per 100 grams. The coliforms and enterococci of total plate counts have little or no relation. *Escherichia coli* were demonstrated in only 15.2 percent of the samples examined. *E. coli* counts and fecal streptococcus counts did not seem to be related directly.

The average number of enterococci as determined by our methods was 81,000 per 100 grams. Of the samples examined, 84.7 percent contained members of this group. Many workers (Larkin, Litsky, and Fuller, 1956; Kachikian, Larkin, and Litsky, 1960) have suggested that, as an indicator of quality, fecal streptococci rather than coliforms or total counts should be used. We concur that a better indicator organism is needed; however, fecal streptococci do not appear to these workers to be the best indicator.

[2] Bobby J. Carroll and Benjamin Q. Ward, Shrimp, 1965, 12 pages. Presented at a symposium on shrimp by the Bureau of Commercial Fisheries, Pascagoula, Mississippi.

Table 1.—Bacterial counts on 164 samples of frozen raw breaded shrimp obtained from 14 processors

Processor	Total plate count	Coliforms	*Escherichia coli*	Fecal streptococci	Coagulase-positive staphylococci
	No. per g.	*No. per 100 g.*	*No. per 100 g.*	*No. per 100 g.*	*No. per 100 g.*
A	34,000	43,000	360	21,000	21,000
	1,500,000	43,000	0	9,100	0
	82,000	7,300	0	3,600	0
	170,000	43,000	620	9,100	0
	95,000	93,000	0	0	43,000
	21,000	15,000	360	21,000	0
	34,000	15,000	360	28,000	24,000
	34,000	46,000	360	46,000	0
	36,000	43,000	0	15,000	43,000
	97,200	6,200	360	43,000	7,300
	73,000	24,000	0	23,000	0
	73,000	43,000	0	3,600	0
B	340,000	93,000	0	120,000	2,300
	1,700,000	21,000	0	1,100,000	7,300
	610,000	24,000	0	75,000	15,000
	600,000	21,000	0	240,000	39,000
	2,000,000	21,000	0	1,100,000	7,300
	2,400,000	39,000	0	460,000	20,000
	2,800,000	240,000	0	240,000	43,000
	3,000,000	15,000	0	15,000	7,300
	3,000,000	15,000	0	910	7,300
	750,000	43,000	0	2,300	15,000
	1,100,000	9,300	0	1,500	43,000
	280,000	93,000	0	43,000	7,300
C	450,000	1,500	0	2,000	360
	120,000	24,000	0	2,300	730
	850,000	1,000	0	730	0
	1,400,000	240,000	0	24,000	9,300
	1,700,000	2,000	0	9,300	1,500
	1,500,000	610	0	0	7,200
	350,000	360	0	4,300	360
	560,000	15,000	0	7,500	0
D	740,000	24,000	0	0	9,100
	830,000	20,000	360	0	93,000
	3,000,000	39,000	0	0	23,000
	790,000	21,000	360	360	23,000
	870,000	2,300	360	360	11,000
	2,700,000	24,000	620	730	14,000
	520,000	2,300	0	910	13,000
	1,100,000	4,300	360	4,300	210,000
	740,000	9,300	360	0	93,000
	830,000	24,000	0	300	150,000
	1,000,000	2,300	0	0	35,000
	1,200,000	2,300	360	360	210,000
E	1,500,000	46,000	0	110,000	15,000
	980,000	29,000	0	64,000	46,000
	1,500,000	9,300	0	110,000	46,000
	2,400,000	24,000	0	75,000	75,000
	1,300,000	46,000	0	46,000	24,000
	890,000	110,000	0	110,000>	15,000
	1,200,000	9,300	0	46,000	1,500
	1,400,000	110,000>	0	110,000	2,000
	340,000	46,000	0	1,100,000>	9,300
	1,400,000	9,300	0	110,000	7,500
	1,500,000	110,000	0	24,000	4,300
	1,400,000	46,000	0	110,000>	24,000
F	330,000	110,000	0	2,300	9,300
	380,000	110,000	0	24,000	1,500
	2,510,000	9,300	0	4,300	150,000
	1,200,000	24,000	0	3,900	24,000
	560,000	110,000	0	4,300	15,000
	650,000	110,000	0	9,300	2,100
	360,000	110,000	0	4,300	1,500
	1,300,000	110,000	0	360	2,800
	1,500,000	110,000	0	2,300	15,000
	580,000	110,000	0	3,900	9,300
	1,200,000	46,000	0	0	24,000
	740,000	1,100,000	0	9,300	1,500
G	770,000	21,000	0	0	2,800
	510,000	110,000	0	0	2,100
	540,000	110,000	0	0	0
	1,300,000	150,000	0	0	15,000
	750,000	110,000	620	0	4,300
	980,000	110,000	360	0	2,800
	880,000	460,000	0	0	1,500
	310,000	46,000	0	0	21,000
	910,000	110,000	0	0	1,500
	800,000	110,000	0	0	910
	1,200,000	46,000	0	0	7,500
	840,000	46,000	0	0	9,300

Table 1.—Continued

Processor	Total plate count	Coliforms	*Escherichia coli*	Fecal streptococci	Coagulase-positive stapylococci
	No. per g.	*No. per 100 g.*	*No. per 100 g.*	*No. per 100 g.*	*No. per 100 g.*
H	630,000	2,300	360	150,000	15,000
	1,400,000	24,000	360	110,000	20,000
	2,000,000	24,000	360	150,000	20,000
	750,000	15,000	0	460,000	4,300
	170,000	24,000	0	46,000	2,800
	350,000	9,300	0	460,000	1,500
	660,000	9,300	0	46,000	9,300
	350,000	24,000	0	15,000	360
	87,500	46,000	0	46,000	360
	3,200,000	460,000	0	2,300	1,500
	180,000	24,000	0	39,900	360
	1,000,000	7,200	0	64,000	2,100
I	97,000	2,300	0	>100,000	9,300
	2,300	2,300	0	100,000	4,300
	1,600	9,300	0	46,000	2,100
	2,500	11,000	0	21,000	4,300
	2,400	11,000	0	460,000	910
	160,000	2,100	0	460,000	2,300
	2,600	2,300	0	110,000	15,000
	7,000	4,300	0	9,300	2,100
	520,000	2,300	0	21,000	360
	570,000	24,000	0	75,000	9,300
	73,000,000	2,300	0	4,300	15,000
	580,000	7,500	0	24,000	4,300
J	88,000	46,000	0	46,000	15,000
	600,000	4,300	0	9,300	110,000
	44,000	4,300	0	4,300	110,000
	50,000	7,300	360	2,300	1,500
	50,000	150,000	0	240,000	9,300
	56,000	110,000	0	110,000	3,500
	140,000	15,000	0	15,000	4,300
	110,000	24,000	0	24,000	910
	320,000	2,300	0	110,000	730
	135,000	46,000	2,300	46,000	24,000
	180,000	24,000	0	240,000	9,300
	290,000	20,000	0	7,500	1,500
K	4,300,000	43,000	2,300	730	9,400
	5,300,000	24,000	0	910	210,000
	2,490,000	75,000	0	730	44,000
	6,900,000	24,000	0	0	210,000
	7,000,000	24,000	620	300	360
	4,800,000	9,300	0	0	6,200
	2,300,000	43,000	620	910	11,000
	2,500,000	24,000	360	0	0
	1,500,000	24,000	360	360	0
	2,400,000	24,000	620	360	20,000
	4,100,000	9,300	0	360	62,000
	9,300,000	15,000	0	910	9,100
L	7,400,000	4,300	0	4,400	2,100
	1,020,000	360	0	0	7,500
	400,000	75,000	0	9,300	910
	1,500,000	75,000	0	75,000	910
	950,000	24,000	0	460,000	2,300
	370,000	110,000	0	15,000	300
	280,000	110,000	0	29,000	360
	230,000	110,000	0	24,000	1,500
	870,000	460,000	0	110,000	300
	530,000	2,300	0	75,000	2,300
	220,000	910	0	24,000	0
	200,000	2,100	0	110,000	910
M	1,000,000	46,000	0	110,000	3,500
	500,000	46,000	0	46,000	15,000
	4,600,000	24,000	0	1,100,000	15,000
	350,000	110,000	0	110,000	9,300
	420,000	7,500	0	46,000	360
	3,200,000	24,000	0	120,000	110,000
	1,500,000	46,000	0	110,000	1,100
	480,000	21,000	0	<110,000	3,600
	670,000	7,500	0	460,000	9,100
	520,000	4,000	0	110,000	730
	490,000	1,500	0	46,000	0
	850,000	4,300	0	46,000	1,500
N	220,000	460,000	0	15,000	360
	260,000	110,000	0	9,300	0
	250,000	110,000	0	110,000	360
	650,000	110,000	0	1,500	0
	420,000	110,000	0	9,300	0
	240,000	46,000	0	2,300	360
	350,000	24,000	0	110,000	300
	700,000	46,000	0	3,900	730
	350,000	110,000	0	4,300	0
	280,000	24,000	0	15,000	0
	400,000	46,000	0	46,000	0
	330,000	46,000	0	15,000	0

Table 2.—Average bacterial counts of finished product after freezing from each plant

Plant	Samples examined	Total plate count	Coliform	*Escherichia coli*	Fecal streptococci	Coagulase-positive staphylococci
	No.	*No. per g.*	*No. per 100 g.*	*No. per 100 g.*	*No. per 100 g.*	*No. per 100 g.*
A	12	190,000	35,000	202	19,000	12,000
B	12	1,540,000	53,000	0	280,000	18,000
C	8	860,000	35,000	0	6,300	2,400
D	12	1,200,000	15,000	202	610	73,000
E	12	1,300,000	50,000	0	170,000	22,000
F	12	940,000	170,000	0	5,700	21,000
G	12	810,000	120,000	82	0	5,700
H	12	890,000	56,000	120	130,000	6,500
I	12	410,000	63,000	0	120,000	5,800
J	12	170,000	37,000	240	71,000	24,000
K	12	4,400,000	28,000	380	460	49,000
L	12	1,250,000	81,000	0	78,000	1,600
M	12	1,200,000	29,000	0	20,000	1,500
N	12	370,000	100,000	0	28,000	180

Coagulase-positive staphylococci were present in 87 percent of the samples examined. This corresponds well with the 82-percent incidence reported in raw and breaded shrimp by Silverman and associates (1961). The average count for coagulase-positive staphylococci was 19,000 per 100 grams of product.

As the data here indicate, the processors need to improve the bacteriological control of their products considerably. Any improvement of the products from a microbial viewpoint will result, however, only after all segments of the industry (for example, vessel operator, transporter, and producer) make a concerted effort toward this end.

SUMMARY

1. The average total plate count per gram of shrimp was 1,000,000. Results showed that 39 percent of the samples contained fewer than 500,000 cells per gram and that 35 percent contained more than 1,000,000 cells per gram.

2. The average coliform count on the samples examined was 59,000 per 100 grams. There was little or no relation between the coliform count and the enterococcus count or the total plate count.

3. *E. coli* were demonstrated in 15 percent of the samples examined. There seemed to be no direct relation between *E. coli* count and fecal and streptococcus counts.

4. The average number of enterococci was 81,000 per 100 grams. Of the samples examined, 85 percent contained members of this group.

5. Coagulase-positive staphylococci were present in 87 percent of the samples examined. The average count for coagulase-positive staphylococci was 19,000 per gram of product.

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MS #1553

RECENT TECHNOLOGICAL STUDIES OF DUNGENESS CRAB PROCESSING. PART 4--PRELIMINARY REPORT ON SALT UPTAKE AND HEAT PENETRATION IN WHOLE-COOKED CRAB

by

Harold Barnett and Richard W. Nelson

ABSTRACT

A study undertaken to show the effect on whole Dungeness crab of varying the concentration of brine in the cook water indicated that salt is absorbed at a faster rate in leg meat than in body meat and that cooking crab in brine causes a slight weight loss.

An evaluation of the rate of penetration of heat in whole crab during brine cooking showed that whole crabs may sometimes be undercooked at the end of 23 minutes, which is the time normally used in commercial cooking.

INTRODUCTION

Dungeness crab of high quality is a gourmet's delight; however, parts of the process for producing crab meat are difficult to control, so the quality of the product is not always high. At the request of the National Fisheries Institute, the Bureau's Technological Laboratory in Seattle has been working since 1959 on problems of quality. During this period, laboratory personnel have studied such factors involved in the control of quality as drained weight, improved processing and handling practices, and proximate composition of the meat.

A large factor in quality is the maintenance of a uniform concentration of salt in the marketed product. Because the salt concentration in the cook water is seldom closely controlled, the uptake of salt by the whole crab may fluctuate widely.

Among the studies related to the effects of brine processing on the uptake of salt in fish products have been those by Cohen and Peters (1962); Holston and Pottinger (1954, 1955); Peters (1959); and Patashnik, Lee, Seagran, and Sanford (1964). Except, however, for a study by Nelson and Thurston (1964) on proximate composition, no systematic studies dealing with the uptake of salt in Dungeness crab during processing have been reported.

Another processing variable that can affect the quality of whole-cooked Dungeness crab is heat penetration. Insufficient penetration of heat results in an undercooked crab and decreases the yield of crab meat. A recent report by Ulmer (1964) evaluates the effect of heat penetration in Atlantic blue crab, but no comparable information has been reported for whole Dungeness crab. These 2 varieties of crab are so different, particularly in size, that extrapolating the findings for the 1 species to include the other is not warranted.

Our study thus is intended as the basis for a systematic approach to future studies of salt uptake and heat penetration into whole-cooked Dungeness crab. Our information, even though incomplete, is of immediate use to industry because of its relation to quality and economics. Accordingly, our purposes

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in making this report are to indicate in a preliminary way (I) the effects of cooking Dungeness crab in brine of various concentrations and (II) the rate of penetration of heat into the meat of whole crab during brine cooking.

I. EFFECT OF VARYING THE CONCENTRATION OF BRINE

In our study, 2 aspects of the effect of brine concentration were considered of major interest: (A) the effect on the absorption of salt by the crab meat and (B) the effect on the loss of weight of the meat.

A. SALT ABSORPTION AS AFFECTED BY BRINE CONCENTRATION

In studying salt absorption, we were concerned both with the amount of salt absorbed and with its effect on palatability.

1. Absorption of Salt

a. Procedure.

(1) *Samples.*—Live male Dungeness crabs, averaging about 2 pounds each, were purchased in March 1965 at Westport, Washington, and divided into 2 series. Series I, containing 16 crabs, was subdivided into 4 groups of 4 crabs each. 1 group was cooked in fresh water (that is, at 0° salinometer), and the other 3 groups were cooked in brine — the first at 30° salinometer, the second at 60° salinometer, and the third at 90° salinometer. Series II was subdivided into 5 groups of 6 crabs each. These crabs were cooked in fresh water and in brine at concentrations of 16°, 43°, 72°, and 97° salinometer.

This experiment was designed to simulate commercial processing. A stainless steel vessel large enough to allow the crabs to be well covered with brine or water was used in the laboratory. The concentration of salt (canners' grade) in the brine was adjusted with a salinometer when the temperature of the brine was at 60° F. Live steam piped into the bottom of the vessel supplied heat for the cooking. Salt was added periodically during the cooking to compensate for the dilution of brine by the condensing steam. When the water was boiling vigorously, the crabs were added. A 3-minute "come-up" time was used to simulate commercial practice. The crabs were then cooked an additional 20 minutes. At the end of the cooking, they were removed, cooled in tap water for about 2 minutes, and drained. The backs were then removed, and the crabs were cleaned and halved. 1/2 of the specimens were retained for future experiments. Sample portions were cracked and picked, and composites were made of the halves from each group. Body and leg portions were kept separate.

(2) *Chemical analyses.*—After the crabs were removed from the cooking vessel, the salinity of the cook water was determined with a salinometer. Concentrations of salt in the flesh of the crab were then determined by the method of Dyer (1943). Analyses were made in duplicate.

For comparison, the concentration of salt in 6 crabs cooked by commercial processors was also analyzed.

b. **Results.**

(1) *Laboratory-cooked crab.*—Increasing the concentration of salt in the cook water increased the amount of salt absorbed by the crab flesh (Table 1; Figure 1). The concentration of salt in leg meat varied from 0.54 percent for the crab cooked in fresh water to 1.77 percent for the crab cooked in brine at 97° salinometer, a threefold increase.

Table 1.—Salt concentration of body and leg meat of crab cooked 23 minutes in cook water of increasing brine strength

Brine strength	Salt concentration in:					
	Leg meat			Body meat		
	Replicate 1	Replicate 2	Average	Replicate 1	Replicate 2	Average
Degrees salinometer	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
0	0.55	0.54	0.54	0.44	0.44	0.44
16	0.74	0.75	0.74	0.51	0.50	0.50
30	0.90	0.92	0.91	0.62	0.-	0.62
43	1.06	1.04	1.05	0.68	0.65	0.67
60	1.00	1.11	1.05	0.74	0.73	0.73
72	1.47	1.41	1.44	0.77	0.76	0.76
90	1.54	1.40	1.47	0.88	0.88	0.88
97	1.72	1.82	1.77	1.04	0.90	0.97

The uptake of salt in the body meat increased in a manner similar to that in the leg meat, but at a slower rate. The concentration of salt ranged from a minimum of 0.44 percent (for the crab cooked in fresh water) to 0.97 percent (for the crab cooked in 97° salinometer brine), a twofold increase.

(2) *Commercially cooked crab.*—Hipkins (1957) reported that in industrial practice, whole Dungeness crabs are cooked in brine at about 12° salinometer. Our analyses of commercially cooked whole crab showed, however, that they had a salt content equivalent to crab cooked in a brine at about 64° sali-

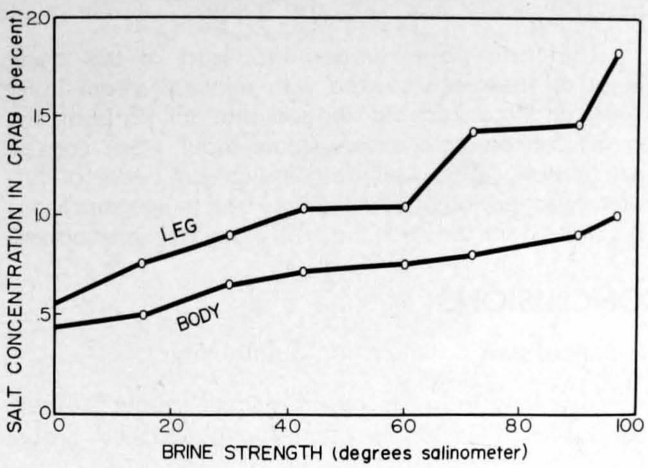

Figure 1.—Increase in salt concentration of body and leg meat of crab cooked 23 minutes in cook water of increasing brine strength.

nometer; the concentration of salt in the leg meat was 1.30 percent, and the concentration in the body meat was about 0.72 percent. The discrepancy between our findings and what is reported to be industrial practice requires further investigation.

2. Effect af Salt Absorption on Palatability

Because the concentration of salt affects the flavor of the product, a sensory evaluation was made to determine the optimum level of salt palatability. Several members of the staff, all experienced in the taste testing of crab products, unanimously agreed that the 1-percent level of salt was optimum. Similar findings were made by Holston and Pottinger (1955) on brine-dipped haddock fillets.

B. WEIGHT AS AFFECTED BY BRINE CONCENTRATION

Cooking in brine produced a slight but not consistent loss in weight in whole crab. Loss of weight ranged from 2.5 percent for the 16° salinometer brine cook to 3.5 percent for the 97° salinometer brine cook (Figure 2). The average loss in weight was 2.8 percent.

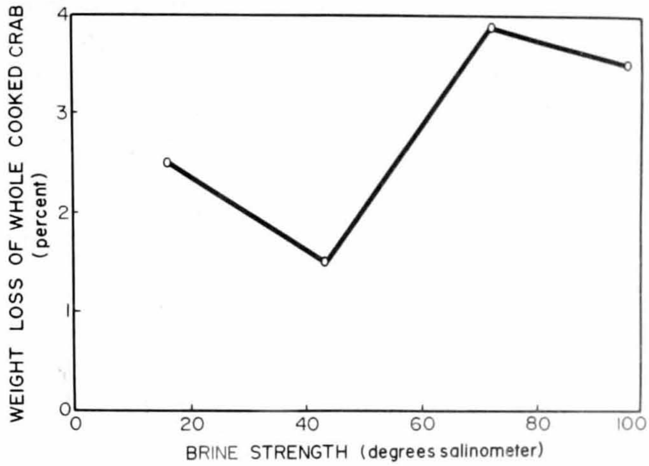

Figure 2.—Weight loss in crab cooked 23 minutes in cook water of increasing brine strength.

II. RATE OF HEAT PENETRATION INTO WHOLE CRAB DURING BRINE COOKING

A. PROCEDURE

The rate of temperature change in whole crab during brine cooking was determined in 2 experiments. Each experiment contained 6 crabs weighing about 2 pounds apiece. 1 crab was observed from each group. A thermocouple wire was passed through the posterior end of each of the crabs' bodies, and the end of the wire was located about midway relative to the sides. Then the crabs and the thermocouples were secured in wire baskets. The first group of 6 crabs was cooked in brine, using a minimal input of steam (the brine appeared to be boiling, but it was actually below 212° F.); and the second group of 6 crabs was cooked in brine, using an excess input of steam. (In commercial practice either condition could exist.)

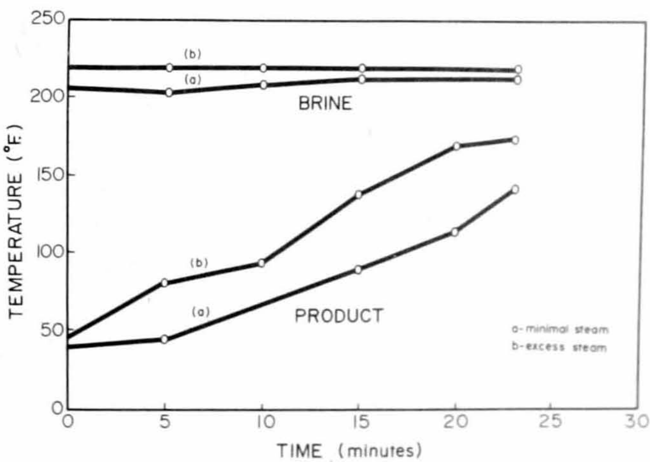

Figure 3.—Increase in internal temperature of product during cook in 97° salinometer brine water.

B. RESULTS

The rate at which heat penetrated the whole crab during the brine cooking is indicated in Figure 3. After a cooking period of 23 minutes, the internal temperature of the crab cooked with a minimal input of steam of 140° F. In contrast, the internal temperature of the crab cooked with an excess input of steam was 172° F.

The taste panel judged that part of the body meat of the crabs cooked with minimal steam input were undercooked but judged that all parts of the crabs cooked with excess steam input were cooked adequately. Thus, our data indicate a need for further investigation of cooking time and temperature versus the extent to which the crab have become cooked.

SUMMARY AND CONCLUSIONS

A preliminary evaluation of (I) the effects of varying the concentration of brine in cook water on whole Dungeness crab and (II) the rate of heat penetration into the meat of whole crab during the brine cook was undertaken. The findings were as follows:

I. In a 97° salinometer brine, leg meat absorbed almost twice as much salt (1.77 percent) as did the body meat (0.97 percent).

Salt at a concentration of about 1 percent in the meat was optimum for palatability.

Cooking in brine caused a small (about 2.8 percent) loss of weight in all the whole-cooked crabs.

II. The rate of penetration of heat into whole crabs was such that parts of the crabs cooked with minimal input of steam were undercooked. All of the crabs cooked with excess steam, however, were well cooked at the end of 23 minutes, which is the time normally used in commercial batch cooking.

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MS #1540

COMMERCIAL FISHERIES OF THE COLUMBIA RIVER AND ADJACENT OCEAN WATERS

by

A. T. Pruter

ABSTRACT

Fisheries in the Columbia River and the adjacent ocean waters constitute a large and valuable industry with important economic and recreational benefits to people of the Pacific Northwest. Rapidly developing agricultural and manufacturing industries in the Columbia River Basin, however, are placing increasing demands upon the fresh-water environment of resident and anadromous species. The advent of the nuclear age raises the possibility that man may adversely affect the ocean environment also.

This report examines the commercial fisheries in the river and ocean, stressing their importance in the overall development plans for the Columbia River Basin. The fisheries are classified into 3 groups: those for species resident in the Columbia, those for anadromous species, and those for marine species. The fisheries then are described on the basis of individual fish species within each of these groups. The descriptions include information on areas of capture, references to types of harvesting gear, and historical reviews of landings.

CONTENTS

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CONTENTS—Con.

INTRODUCTION

The salmon resource of the Columbia River was fundamental in the economy of the Indians, the settlers, and the traders of the area.

Prior to the arrival of the white man, the economy of the Indians living along the Columbia River was dependent largely on salmon (Figure 1). Early white settlers and fur traders were quick to recognize the potential of the resource and bartered with the Indians for salmon or caught the salmon themselves for local use or for limited export. The introduction of canning in 1866 marked the birth of the modern salmon industry, which then developed rapidly (Figure 2).

Figure 1.—Indians capturing salmon with dip nets. The salmon fishery has played an important role in the economy of the Indians living along the Columbia River.

Increasing settlement of the Columbia River Basin, along with the development of adequate overland transportation, led to the utilization of river species other than salmon and to the growth in adjacent ocean waters of sizeable fisheries for such species as halibut, sablefish, and crab. Within a comparatively short period, the river and nearby marine fisheries grew into a large and valuable industry with important economic and recreational benefits to peoples inhabiting the Columbia River Basin, as well as to those of the entire Pacific Northwest.

Large land-based industries—agricultural, lumbering, and others—developed in the Columbia River Basin coincidental with the growth of the fisheries. During their formative years, the fisheries and the land-based industries grew at about the same rate. In recent years, however, the land-based industries have grown faster than the fisheries. In the future, the rates of growth likely will become even more unequal as the number of people inhabiting the Columbia River Basin increases and as they apply advanced technological knowledge toward further development of land-based industries.

By placing increasing demands on available water supplies, these industries have adversely affected the fresh-water environment that supports valuable fisheries. Some of the effects, such as those from erosion and water diversions, have not always been immediately apparent; but over the long term, they have been detrimental. Other effects, such as those arising from pollution, construction of dams (Figure 3), and impoundment of water in reservoirs have been more apparent. As we enter the nuclear age, the possibility of man's adversely affecting the ocean environment is no longer remote. The atomic reactors at Hanford, Washington, which use water from the Columbia River for cooling purposes, not only have raised the temperature of the water discharged from the reactors, but have also yielded radionuclides that are now to be found in the ocean waters off the Columbia and in trace amounts in fish, shellfish, and mammals inhabiting these waters.

The burgeoning industries could disastrously affect the fisheries unless careful planning is exercised to minimize harm to the fresh-water and neighboring ocean environments. A prerequisite for careful plan-

Figure 2.—Warehouse of early salmon cannery where cans were cooled, hand-labeled, and cased.

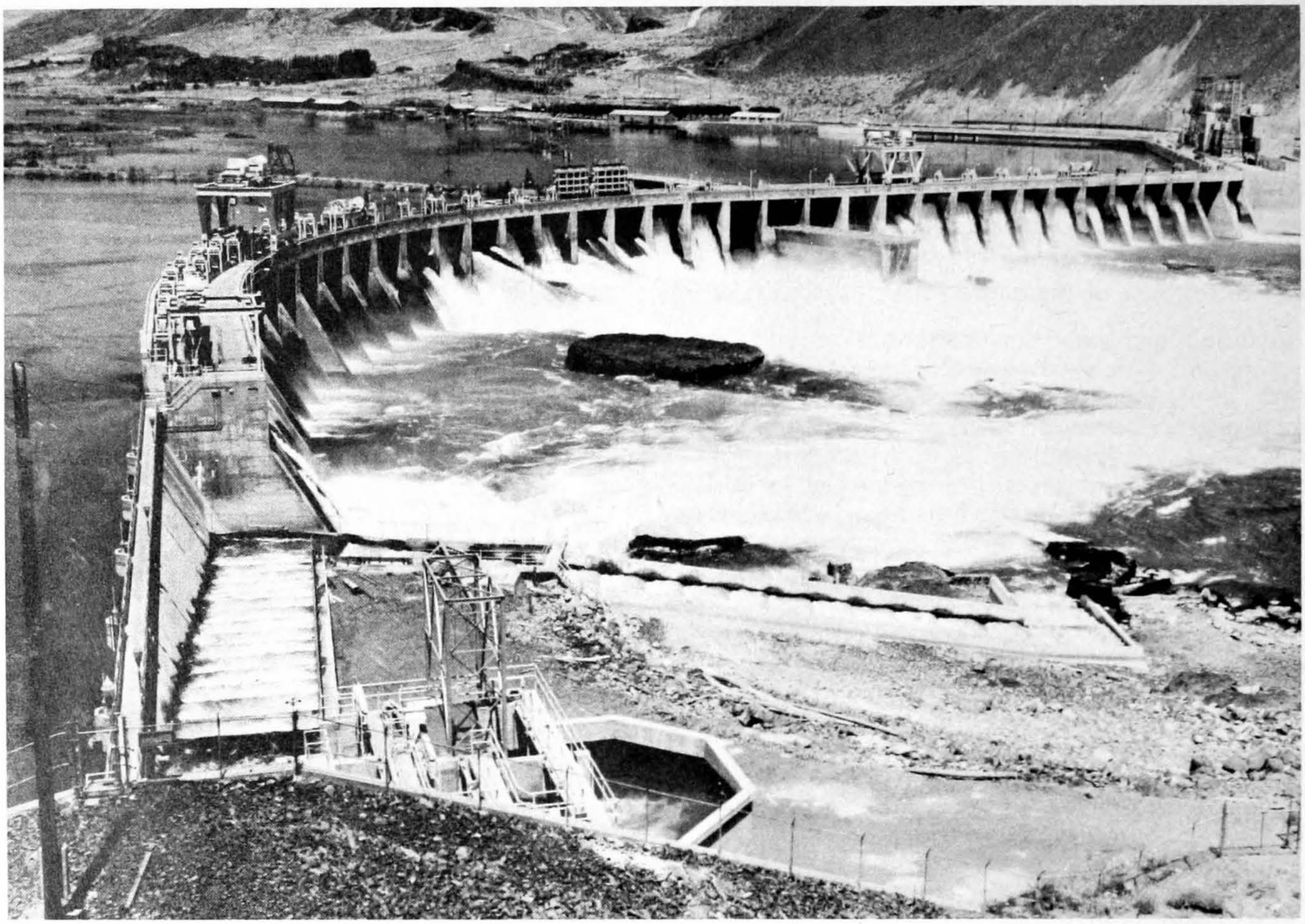

Figure 3.—**Fish ladder (on near shore) at Rock Island Dam in Central Washington. Even with fish ladders, dams impede the passage of migratory fishes.**

ning is an understanding of the river and ocean fisheries. Excellent descriptions of individual fisheries are available, but the commercial and recreational fisheries have not been examined as a whole.

The recreational fisheries are becoming increasingly important. For example, river and ocean sport fisheries account for a large share of the present harvest of Columbia River coho and chinook salmon. Sports fishermen catch large numbers of steelhead trout, probably even more than do commercial fishermen, and sport catches of rainbow and cutthroat trout are also large. Nevertheless, a study of the recreational fisheries was beyond the scope of this investigation. This paper therefore describes only the commercial fisheries in the Columbia River and adjacent ocean waters.

The fish constituting the commercial fisheries fall into 3 distinct categories: (1) Fresh-water species—that is, species resident in the Columbia—are available for harvesting throughout their lives. (2) Anadromous species—such as salmon, which migrate as adults from the ocean into the Columbia—are harvested during a comparatively short time near the end of their life span. These species may be harvested in either fresh or ocean waters. (3) Marine species—such as halibut, crabs, and shrimp—may be available at various times of the year and in different areas, depending upon their life histories.

I. FRESH-WATER SPECIES

Fresh-water fish resident in the Columbia River and its tributaries comprise large and diverse groups. 2 species—fresh-water crawfish and carp—are taken in considerable numbers by commercial fishermen. Descriptions of the crawfish and carp fisheries follow.

A. FRESH-WATER CRAWFISH

Several species of crawfish (genus *Pacifastacus)* are indigenous to streams and rivers of Oregon and Washington; *Pacifastacus trowbridgii* is common in the coastal rivers of Oregon. This species tolerates brackish water; for example, specimens collected at Youngs Bay in the main Columbia near Astoria, Oregon, had barnacles on their exoskeleton (Mason, 1963).

In the Columbia River Basin, crawfish are harvested mainly in the Cowlitz and Columbia Rivers near Vancouver and Longview, Washington, and in the Willamette and Sandy Rivers in Oregon. They are caught mostly with metal pots or traps, which are baited commonly with fresh or frozen heads of carp, shad, or salmon. Smaller crawfish are used mainly as bait in the sport fishery for trout, but many of the larger ones are marketed for human consumption. Commercial landings of crawfish peaked during the late 1800's and early 1900's, when annual landings ranged from 116,000 to 187,000 pounds (Table 1). Since 1941, annual commercial landings have averaged less than 40,000 pounds.

B. CARP

Carp *(Cyprinus* species), which probably originated in the temperate parts of Asia, were introduced in Europe and North America, where they are now widely distributed and abundant. They prefer quiet, weed-grown waters, but may inhabit rather swiftly flowing streams. Carp are able to withstand brackish waters and large variations in temperature. Construction of dams on the Columbia River and its tributaries has increased the habitats favorable to carp; this species has considerable commercial potential.

In the Columbia River Basin, carp have been harvested commercially in Moses, Sprague, Long, Roosevelt, and Banks Lakes and in McNary Pool upstream from McNary Dam. Carp have also been taken commercially in sloughs of the Lower Columbia. Small amounts of carp have been harvested with gill nets, but the bulk of the commercial catch has been taken with beach seines. The fish have been used for human consumption, for mink feed, and for reduction to fish meal. Washington landings of carp have far exceeded those in Oregon. In 1961-63, the 2 States combined averaged over 1,000,000 pounds annually (Table 2).

Table 1.—Commercial landings of crawfish in Columbia River districts of Oregon and Washington, 1888-1963

Years	Average[1] yearly landings	Years	Average yearly landings
	Pounds		*Pounds*
1888	14,000	1926-30	145,000
1892	20,000	1931-35	105,000
1895	59,000	1936-40	93,000
1899	116,000	1941-45	29,000
1904	187,000	1946-50	36,000
1908	178,000	1951-55	34,000
1915	184,000	1956-60	31,000
1922-25	88,000	1961-63	17,000

[1] Landings prior to 1922 were available only for the years shown. Sources: Sette and Fiedler (1929) for years 1888-1927; United States Fish and Wildlife Service, Fishery Industries of the United States for 1928-41, and Fishery Statistics of the United States for 1942-63.

Table 2.—Commercial landings of carp in Columbia River districts of Oregon and Washington, 1888-1963

Years	Average[1] yearly landings	Years	Average yearly landings
	Pounds		*Pounds*
1888	0	1926-30	522,000
1892	0	1931-35	93,000
1895	0	1936-40	140,000
1899	0	1941-45	110,000
1904	20,000	1946-50	9,000
1908	30,000	1951-55	16,000
1915	250,000	1956-60	178,000
1922-25	372,000	1961-63	1,053,000

[1] Landings prior to 1922 were available only for the years shown. Sources: Sette and Fiedler (1929) for years 1888-1927; United States Fish and Wildlife Service, Fishery Industries of the United States for 1928-41, and Fishery Statistics of the United States for 1942-63.

II. ANADROMOUS SPECIES

Anadromous species, which ascend rivers and streams from the ocean to spawn, are the best known and the most valuable of the 3 categories of fish—fresh-water, anadromous, and marine—described in this report. They include Pacific salmon *(Oncorhynchus* spp.), steelhead trout *(Salmo gairdneri)*, American shad *(Alosa sapidissima)*, eulachon *(Thaleichthys pacificus)*, sturgeon *(Acipenser)*, and Pacific lamprey *(Lampetra tridentata)*.

A. SALMON AND STEELHEAD TROUT FISHERIES

All 5 species of salmon found in waters along the Pacific Coast of North America occur in the Columbia River as does also the steelhead trout. Pink salmon *(O. gorbuscha)*, however, are found there only occasionally. Chum salmon *(O. keta)* catches have been small since the late 1940's, partly because of closed fishing seasons that prevent the catching of this species. Only 3 species—the chinook *(O. tshawytscha)*, the sockeye *(O. nerka)* or blueback, and the coho *(O. kisutch)* or silver—are now harvested in substantial numbers. Collectively, they support one of the most valuable fisheries in the Pacific Northwest. The Columbia River is also 1 of the principal steelhead trout *(Salmo gairdneri)* streams of the Pacific Northwest.

Man has affected the salmonid populations of the Columbia River in many ways. The most obvious way is through fishing. Another way is by building dams. For example, the extensive system of dams constructed on the Columbia River (Figure 4) has created obstacles to both the upstream migration of adult salmonids and the down-stream migration of young. Young salmonids that are migrating downstream may be killed or injured while passing through turbines or over spillways of dams. Some dams have flooded out natural spawning areas and, in some areas, have raised water temperatures to levels that favor undesirable predator and competitor species and promote fish diseases.

Other factors besides dams have lowered the survival rate of salmonids in the Columbia and its tributary streams. For example, mining, poor forestry practices, and some highway-construction programs have caused erosion and deposition of silt in stream beds. Improperly screened irrigation diversions have allowed young fish to stray into irrigation canals, where many have perished. Diversion of water has sometimes reduced the flow of streams to below minimum requirements for adult fish passage and has resulted in excessively high temperatures of water. Pollution has damaged some runs.

Attempts have been made to counter these inroads of civilization in several ways. An extensive system of hatcheries has been constructed along the Columbia River and its tributaries. Artificial spawning and incubation channels (Figure 5) are being built in an attempt to replace natural spawning areas lost through removal of gravel or flooding in the backwaters of dams. Many fish ladders (Figure 6) and screens have been constructed. The ladders facilitate the passage of adult fish; the screens protect downstream migrants.

The most comprehensive description of early and intermediate development of Columbia River fisheries is given by Craig and Hacker (1940). Much of the following text on the early and intermediate periods of development is based on their publication.

The Columbia River salmon fisheries developed in 3 stages: First was the period prior to the arrival of white men, when the Indians were the sole users of the resource. Second was the intermediate period, which was of short duration, when the white settlers and traders either bartered with the Indians for salmon or caught the fish for local use or limited export. The third period, the present stage of intense fishing, began in 1866 when canning of fish was introduced.

1. Aboriginal Fishery

Explorers found that the economy and the mode of life of the Columbia River Basin Indians depended on salmon. Salmon was not only the main source of food but also the principal medium of exchange. Lewis and Clark, during their voyage down the Columbia in 1805, found entire villages engaged in making salmon pemmican, which was traded with other tribes including the Plains Indians east of the Rocky Mountains.

Early explorers and settlers of the Columbia River Basin estimated the original Indian population in the early 1800's at about 50,000; Craig and Hacker (1940) estimated that the total annual catch of salmon by the Columbia River Basin tribes in the early 1800's approached 18,000,000 pounds. A succession of epidemic diseases brought by the white man swept through the various tribes killing thousands of people. By 1851, the population of Indians was under 10,000 —or less than 20 percent of its level at the time of the white man's arrival. Undoubtedly this reduced population contributed to the reduced catches during mid-century. It was not until the late 1870's that commercial catches of salmon on the Columbia River equalled the amount caught by the original Indian population; since the late 1940's, the catches have been considerably less.

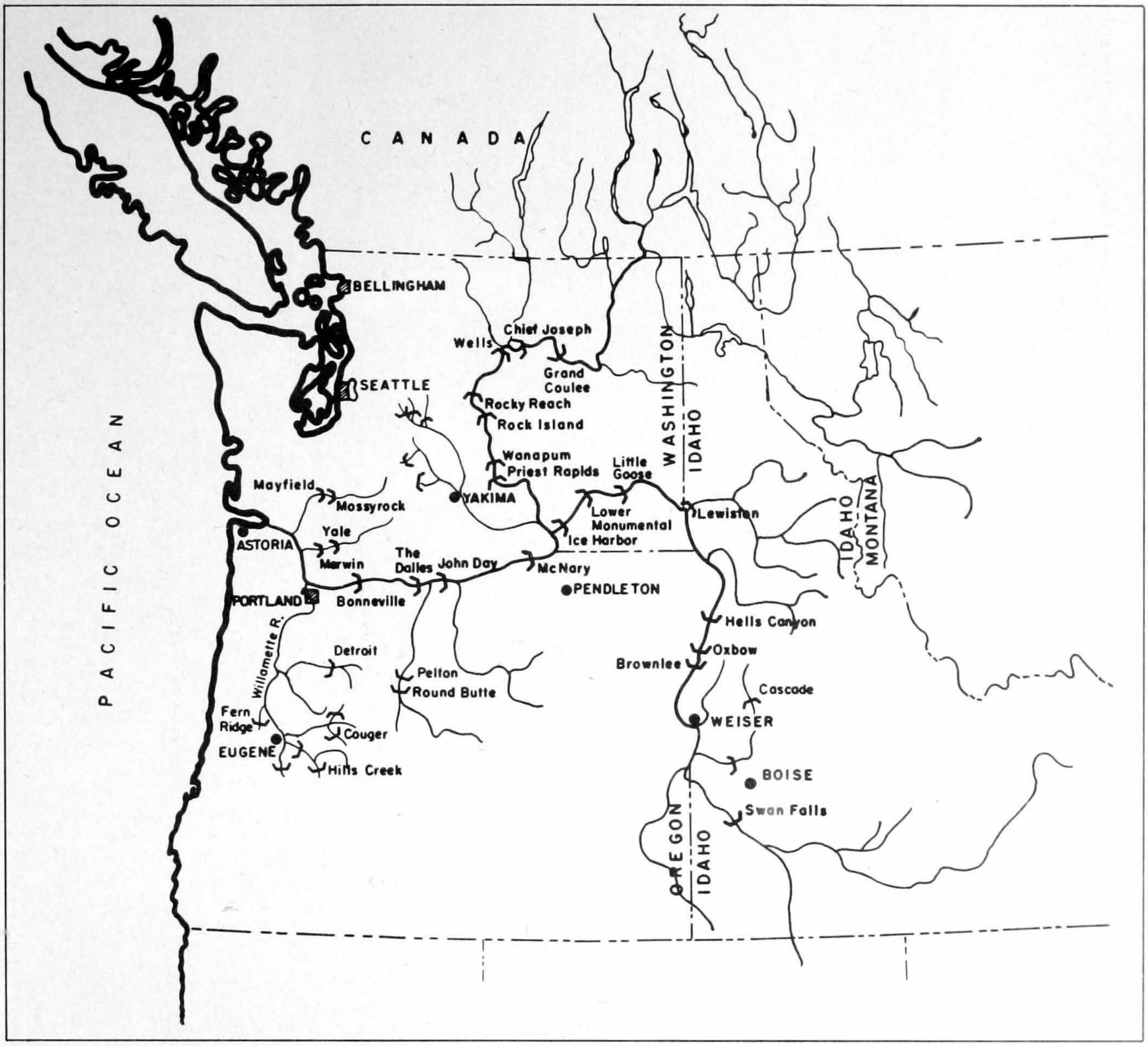

Figure 4.—Principal dams already built or under construction in the Columbia River Basin in 1963.

Indian fishing grounds were located on all major tributaries as well as on the Columbia River itself. Some of the most important and famous grounds on the main Columbia River were at Kettle Falls, Celilo Falls (Figure 7), Cascade Rapids, and The Dalles. Prominent tributary grounds included the San Poil River, Salmon Falls (on the Snake River), Willamette River Falls, and the falls of the Spokane River.

The Indians used a variety of fishing gear and methods for harvesting salmon and steelhead trout, all of which were quite efficient even by present-day standards and were well suited to their needs and culture. Fish traps, or weirs, constructed of willows or other flexible woods and supported by poles or tripods, were placed across the smaller tributary streams. Dip nets were used before white men appeared in the Columbia Basin and, except for the modern materials now used in their construction (Figure 8), have survived in the original form. Dip nets are plunged into eddies in the river, usually below falls or rapids where salmon congregate. The dip nets are either swept downstream with the current

Figure 5.—Channel for incubating salmon eggs in Abernathy Creek near Longview, Washington, to evaluate rearing capacity and effects of environment on survival.

Figure 7.—Indians fishing at Celilo Falls (1952).

Figure 6.—Moose Creek Dam, Idaho, with entrance of Denil-type fish ladder on the left and powerplant canal intake on the right (1964).

Figure 8.—Indian repairing dip net at Celilo Falls (1952).

and then raised from the water with a scooping motion or held stationary until the fish are felt striking against them. Wooden platforms for the fishermen to stand on are often placed at favorable locations. Indians at Celilo Falls, using dip nets in much the same manner as their ancestors, caught an average of over 2,600,000 pounds of fish each year during 1938-50 (Schoning, Merrell, and Johnson, 1951).

Seines up to 8 feet deep and 300 feet long made from wild hemp or cedar fiber were used extensively. Floats made of dry cedar supported the seine net at the surface; the leadline (formed from flat, circular stones with holes bored through their centers) was attached to the bottom of the seine. Canoes from 15 to 50 feet long were used to set the seines around schools of fish. The seines were then hauled ashore by ropes attached to the ends.

Additional methods of capturing fish were used by the Indians. Wicker baskets supported by long poles, the bases of which were anchored in rocks of the stream bed, were suspended below the falls, and broad wooden frames were spread above. Many of the fish attempting to leap the falls struck the frames and were thrown back into the baskets. This method was used extensively at Kettle Falls and continued to be used there until the Falls were flooded in the late 1930's by the reservoir created by Grand Coulee Dam. Spears were commonly used to take salmon and steelhead trout at falls and in smaller tributaries. Hook-and-line trolling gear was towed from canoes by Indians in the Lower Columbia River. The use of gill nets is not clearly documented in journals of early explorers, but it seems probable that they also were used.

Present Indian fisheries are largely confined to tributary streams and to the pools of the Bonneville Dam (Figure 9) and The Dalles Dam. In 1964, Indians caught 916,000 pounds of salmonids—comprising 782,000 pounds of chinook salmon, 57,000 pounds of sockeye salmon, 23,000 pounds of coho salmon, and 54,000 pounds of steelhead trout (Maltzeff, 1965). Most of the fishermen now use stationary gill nets as their primary gear. The fishery in the Bonneville pool has developed largely since the Indians' ancestral fishing grounds at Celilo Falls were flooded in 1956 by the reservoir formed by The Dalles Dam.

2. Modern Fishery

In turning from the Indian fishery to the modern fishery, we must consider both the river fishery and the ocean fishery because both harvest large numbers of Columbia River salmonids.

a. River fishery.—In this subsection, we consider the development of the fishery, the fishing gear used, and the fishing seasons.

(1) Development of the fishery.—From the time of Lewis and Clark and the early fur traders, the river fishery has played a significant role in the history of the region. Fur traders along the Columbia River exported salmon to outside markets. The Hudson Bay Company shipped salted salmon to the markets of Honolulu and London. Columbia River salmon were also introduced into the markets of California and the Eastern United States. The withdrawal of British interests from the river after 1846 left the development of the fisheries in American hands.

In the early 1850's, settlers entered the fisheries in increasing numbers; by 1861, commercial salmon fishing on the Columbia River was beginning to assume the status of an industry. Most of the salmon was salted, and much of it was shipped to the Hawaiian Islands. The amount of salmon used by the settlers and traders from 1820 to 1865, however, probably did not completely offset the decreased usage after the Indian population was depleted by epidemic diseases. Thus, the catch of salmon from 1835 to 1865 was probably less than at any other 30-year period during the previous several hundred years. Commercial landing statistics, compiled starting in 1866, are shown from that year through 1963 in Table 3.

The canning of salmon, which was introduced in 1866, along the Columbia grew rapidly at first and then declined. By 1873, 8 canneries had been established; by 1883, the number reached a peak of 39. The combined pack of these 39 canneries in 1883 was 629,000 cases (48 pounds net weight per case), valued at over $3,000,000. All salmon were hand-packed in hand-made cans. The commercial chinook salmon catch reached a maximum during 1881-85 (Table 3), coincident with the operation of the maximum number of canneries. By 1890, the number of canneries had declined to 21, and the combined pack from these 21 canneries had fallen to 436,000 cases. The reduction was due to a number of factors, including an apparent decline in abundance of chinook salmon. During 1961-64, an annual average of 90,000 cases was packed by the 8 canneries still operating along the Columbia (Table 4).

Figure 9.—Indian gill netting in the pool of the Bonneville Dam (1964).

Table 3.—Average annual Columbia River commercial salmon and steelhead trout landings, excluding troll catches, by species, 1866-1963

Years	Average annual landings					
	Chinook	Sockeye	Coho	Chum	Steelhead	Total
	Million pounds	*Million pounds*	*Million pounds*	*Million pounds*	*Million pounds*	*Million pounds*
1866-70	4.1	–	–	–	–	4.1
1871-75	19.4	–	–	–	–	19.4
1876-80	31.3	–	–	–	–	31.3
1881-85	39.4	–	–	–	–	39.4
1886-90	24.2	1.0	–	–	0.9	26.1
1891-95	24.2	2.4	2.4	0.3	3.7	33.0
1896-1900	23.3	1.8	3.3	0.4	2.1	30.9
1901-1905[1]	28.9	0.8	1.4	1.1	0.6	32.8
1906-10	23.3	0.7	2.9	2.2	0.6	29.7
1911-15	27.0	0.9	3.5	3.0	1.9	36.3
1916-20	30.4	0.8	4.5	3.5	2.0	41.2
1921-25	22.0	1.2	6.2	2.1	2.4	33.9
1926-30	20.3	0.7	6.0	4.0	2.9	33.9
1931-35	18.2	0.3	3.4	1.1	1.8	24.8
1936-40	14.8	0.3	1.8	1.5	2.1	20.5
1941-45	16.1	0.2	1.2	2.2	1.9	21.6
1946-50	14.0	0.2	1.1	0.7	1.3	17.3
1951-55	7.7	0.3	0.7	0.3	1.5	10.5
1956-60	5.9	0.5	0.3	0.0	0.7	7.4
1961-63	4.7	0.1	0.5	0.0	0.8	6.1

[1] Average for 1902-1905 because no breakdown of species was available in 1901.

Note: Troll catches are excluded because they contain an unknown proportion of salmon from the Columbia River—that is, not all troll-caught salmon landed in Columbia River district ports are of Columbia River origin.

Sources: Cleaver (1951) for years 1866-1949; Smith (1956) for 1950-53; United States Fish and Wildlife Service, Fishery Statistics of the United States for 1954-63.

Table 4.—Columbia River average annual canned salmon pack, 1866-1964

[Cases given in standard units of 48 pounds net weight]

Years	Average annual pack					
	Chinook	Sockeye	Coho	Chum	Steelhead	Total
	Cases	*Cases*	*Cases*	*Cases*	*Cases*	*Cases*
1866-70	60,000	–	–	–	–	60,000
1871-75	285,000	–	–	–	–	285,000
1876-80	460,000	–	–	–	–	460,000
1881-85	579,000	–	–	–	–	579,000
1886-90	356,000	15,000[1]	–	–	14,000[1]	385,000
1891-95	357,000	35,000	35,000[2]	5,000[3]	54,000	486,000
1896-1900	330,000	27,000	49,000	6,000	31,000	443,000
1901-05[4]	305,000	12,000	20,000	17,000	9,000	368,000
1906-10	237,000	11,000	43,000	32,000	9,000	332,000
1911-15	303,000	13,000	51,000	44,000	13,000	424,000
1916-20	402,000	12,000	66,000	51,000	19,000	550,000
1921-25	288,000	18,000	90,000	31,000	21,000	448,000
1926-30	282,000	11,000	84,000	58,000	24,000	458,000
1931-35	244,000	4,000	56,000	17,000	15,000	336,000
1936-40	228,000	12,000	61,000	28,000	22,000	351,000
1941-45	206,000	12,000	21,000	43,000	22,000	304,000
1946-50	183,000	8,000	27,000	17,000	16,000	251,000
1951-55	105,000	6,000	23,000	11,000	16,000	161,000
1956-60	80,000	19,000	16,000	5,000	8,000	128,000
1961-64	55,000	2,000	23,000	4,000	6,000	90,000

[1] No pack prior to 1889.
[2] No pack prior to 1892.
[3] No pack prior to 1893.
[4] Average for 1902-1905 because no breakdown of species was available in 1901.

Sources: Craig and Hacker (1940) for years 1866-1936; Pacific Fishermen, 62d Yearbook Number (volume 63, number 2, 1965), for 1937-64.

During the late 1890's, a transition occurred from heavy salting to mild curing (light salting) of salmon. Mild-cured salmon must be kept under refrigeration and are usually processed into a kippered product. Generally, only large, fat, red chinook salmon and, to a lesser extent, extra large coho salmon are used for mild curing. Prior to 1923, almost the entire mild-cured pack consisted of chinook salmon. Since 1923, mild-cured packs have been predominantly chinook, but they have included variable proportions of cohos. The largest mild-cured pack, over 8,000,000 pounds net weight, was put up in 1905, but the annual pack gradually fell thereafter. During 1961-64, the pack averaged about 30,000 pounds net weight annually (Table 5).

The marked decline in canned and mild-cured salmon packs reflects not only the reduction that has occurred in the abundance of Columbia River salmon but also the basic change that has occurred in marketing procedures. Growth of transportation facilities—including the completion of a transcontinental railroad to Portland, Oregon, in 1883—made possible the shipment of fresh fish to metropolitan markets on the Pacific Coast and in the Midwest. The development of mechanical refrigeration has enabled shipment of frozen salmon to markets throughout the United States and even to Europe.

(2) Fishing gear used.—In the early commercial fishery, gill nets were the original gear used by white men (Figure 10). Soon, fish wheels, seines (Figure 11), and traps were used also. Purse seines were used for a while at or near the mouth of the Columbia River. In the early 1900's, commercial trolling for salmon began in the adjacent ocean waters. Legislation has eliminated many types of gear, such as fish wheels, beach seines, and traps. Gill nets now account for almost the entire commercial catches in the river.

Table 5.—Columbia River average annual mild-cured salmon pack, 1897-1964

Years	Average annual pack		
		Weight	
	Tierces[1]	Net weight	Equivalent round weight
	Number	*Pounds*	*Pounds*
1897-1900	906	747,000	997,000
1901-05	6,566	5,417,000	7,223,000
1906-10	6,498	5,361,000	7,148,000
1911-15	5,808	4,792,000	6,389,000
1916-20	2,790	2,302,000	3,069,000
1921-25	2,301	1,898,000	2,531,000
1926-30	1,270	1,048,000	1,397,000
1931-35	1,856	1,531,000	2,042,000
1936-40	714	589,000	785,000
1941-45	89	73,000	98,000
1946-50	90	74,000	99,000
1951-55	49	40,000	54,000
1956-60	87	72,000	96,000
1961-64	36	30,000	40,000

[1] 1,100 pounds of round chinook or coho salmon are required to pack 1 tierce of 825 net pounds of fish.

Sources: Craig and Hacker (1940) for years 1897-1936; Pacific Fisherman, 62d Yearbook Number (volume 63, number 2, 1965), for 1937-64.

Figure 10.—Gill netting off Astoria in 1894.

Gill nets are walls of webbing suspended vertically in the water by means of floats attached to the top and weights attached to the bottom (Figure 12). The meshes of the webbing are of such size that a fish encountering the webbing will force its head through the mesh opening, become entangled at the gills or body and be unable to withdraw. By varying the amount of weight (leadline) used at the bottom, the net may be floated at the surface, submerged to the bottom, or held at intermediate depths. Gill nets may be anchored at a fixed location ("set nets") or allowed to drift downstream. Both set and drift gill nets have been used in the Columbia River, but at the present time only drift gill nets are permitted by law. Use of set nets was prohibited by Washington in 1935, and in 1950 they were effectively eliminated in Oregon (Wendler, 1965). An exception is the set gill nets that are the primary gear used by Indians.

Most drift gill nets now used are of the diver, or fully submerged, type and are operated with the leadline touching the river bottom. This type of fishing along the bottom requires that the bottom be free of all debris that would snag the nets. Gill-net fishermen cooperate in removing bottom obstructions, such as snags and sunken logs, and have developed exclusive "drift" rights. A "drift" is a section of the river channel, usually from 2 to 5 miles long, down which a net can be drifted before being picked up. To keep the net stretched taut and to comply with regulations, the fisherman must tie 1 end of the net to the fishing vessel as it drifts downstream.

Diver nets first appeared on the Columbia about 1900 and consisted of a single wall, or curtain, of webbing. This type of net was soon modified into a trammel net, which has a curtain of larger mesh webbing hung on either side of the ordinary gill net. The inside net has the greatest depth and hangs loosely between the outer curtains of webbing. A fish striking from either side passes through the large-meshed outer webbing, hits the small-meshed inner netting and carries it through the large mesh on the opposite side. The fish is trapped in the sack, or pocket, formed by the 2 intertwined nets. Trammel nets primarily are used as divers. Another variation in the trammel net is the addition of an apron, which floats ahead of the main net and catches fish that attempt to go over the net.

Chinook, sockeye, coho, and chum salmon, and steelhead trout are all harvested by gill nets in the river, with chinook constituting most of the catches. Commercial gill net fishing by non-Indians now takes place from the mouth of the Columbia

Figure 11.—Most seines were pulled by horses and laid out from skiffs towed by launches. Between 1927 and 1934, seines took about 15 percent of the total catch of salmon and steelhead trout from the Columbia River (Craig and Hacker, 1940).

to within 5 miles of Bonneville Dam, a distance of about 140 miles.

(3) Fishing seasons.—Since the early 1900's, fishing seasons have been the same for Washington and Oregon fishermen and have been progressively shortened over the years. In 1938, there were 272 open-season days for commercial fishing below Bonneville Dam; in 1964, there were 83 days. The main fishing season generally has opened about May 1 and continued until the latter part of August. It is then opened again for a few weeks starting in early September. Fishing is never permitted on weekends. Largest landings normally have occurred from May through September.

b. Ocean fishery.—Chinook and coho salmon are readily taken by trolling with a moving bait or lure in the ocean or in estuarine waters. Indians were well aware of this fact and, using smelt for lures, trolled for salmon from canoes near the mouth of the Columbia and to a lesser degree elsewhere along the coast. As gasoline motors for fishing became common, trolling increased along the Pacific Coast. About 1912, fishermen discovered they could catch chinook and coho salmon by trolling off the mouth of the Columbia (Van Hyning, 1951). About 500 boats were trolling there in 1915. By 1919, the number had increased to between 1,000 and 2,000 (Van Hyning, 1951). Since then, the number of vessels and men has decreased (Figure 13), but their efficiency has increased greatly.

Modern salmon trolling vessels are normally of wood and are about 25 to 60 feet long. They use either gasoline or diesel engines for propulsion. Each carries 1 or 2 men. Many are capable of remaining at sea for 2 or more weeks. When not fishing for salmon, many vessels also longline for halibut or troll for albacore tuna. 3 lines usually are trolled off each of a pair of outrigger poles. From 3 to 6 hooks are attached to each line. Herring are used for bait, and trolling spoons or plugs may be used as lures. When fishing, the boats cruise slowly, towing

Figure 12.—Typical Columbia River gill-net vessel. Note that the net is hauled from the bow.

Figure 13.—Trolling vessels at Westport, Washington, in 1957.

the lures or baited hooks through the water at depths regulated by the weights of lead sinkers attached to the end of the lines. Most boats are equipped with power gurdies for pulling in the lines and fish (Figure 14).

Silliman (1948) suggests that the proportion of Columbia River chinook in Pacific Coast troll catches generally decreases the farther northward the fish are caught from the mouth of the Columbia River. The proportion has varied over the years, depending upon the percentage of Columbia River chinooks in the ocean populations of salmon. Fin-clipping of large numbers of hatchery-reared fall chinook salmon was begun in 1962 so that the contribution of hatchery-reared fish to the catch could be evaluated. Preliminary recoveries of marked fish indicate that Columbia River chinooks are substantial contributors to the ocean troll fisheries of Oregon, Washington, and British Columbia.

Although Columbia River chinook salmon are mainly harvested in ocean troll fisheries northward of the river mouth, coho salmon tend to range southward from the river mouth during their residence in the ocean. Thus, coho salmon of Columbia River origin are mainly harvested off the mouth of the river and to the south (Washington State Department of Fisheries, 1959).

B. AMERICAN SHAD

American shad *(Alosa sapidissima)*, which belong to the herring family, were transplanted from the Atlantic Coast to the Pacific Coast. In 1871, shad were planted in the Sacramento River, California. By 1876 or 1877, the first fish from this planting appeared in the Columbia. Subsequently, in 1885 and 1886, almost 1,000,000 shad fry from the Susquehanna and Potomac Rivers were planted in the

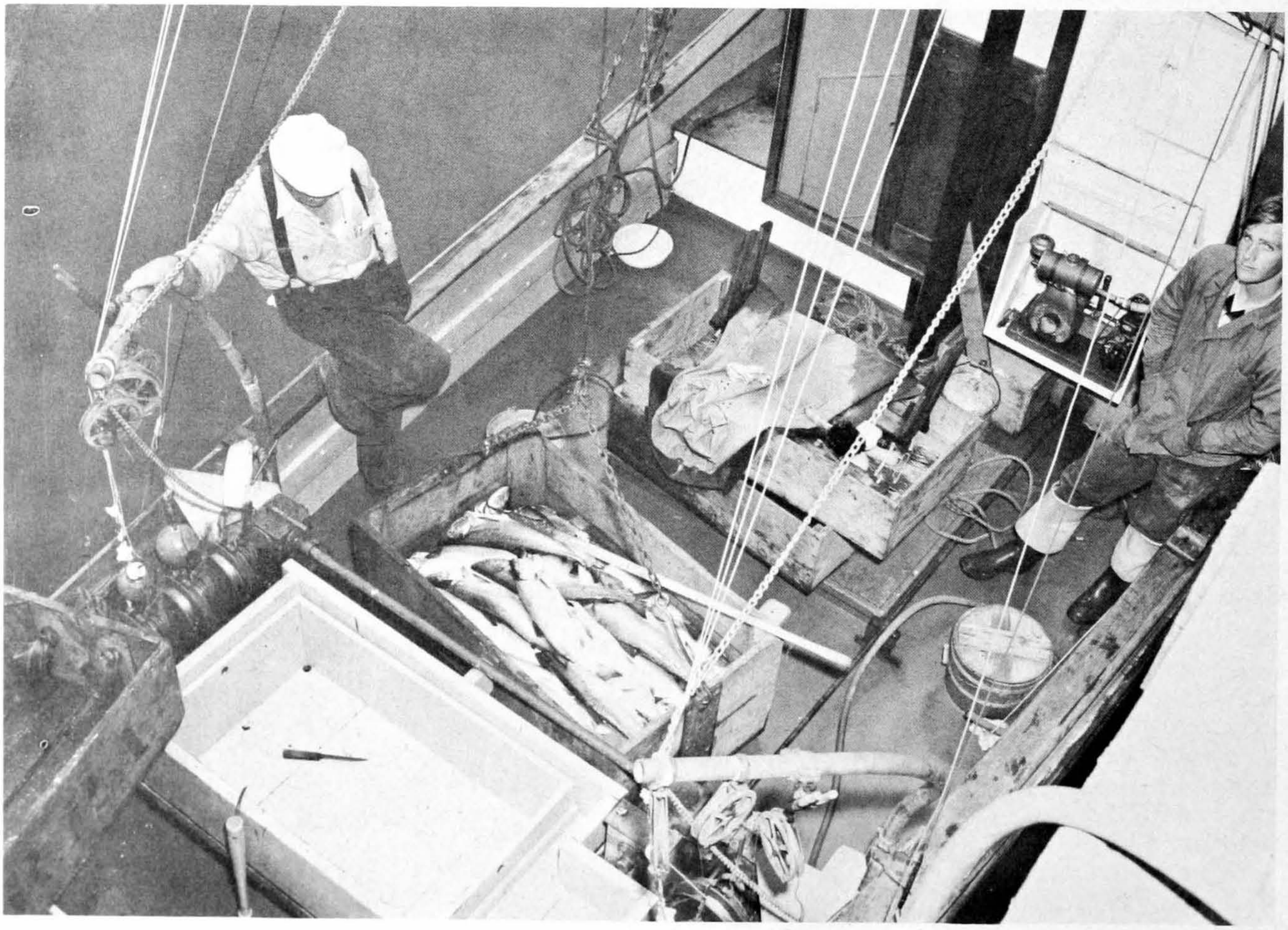

Figure 14.—Unloading coho salmon from troller. Power-operated gurdies for hauling lines are located on either side of the vessel. They are shown in the lower part of the figure.

Columbia, Willamette, and Snake Rivers by the United States Commission of Fish and Fisheries. By 1888, salmon traps had sizeable catches of shad; and in 1889, the first commercial landings (50,000 pounds) were reported. The Columbia is now 1 of the principal shad-producing rivers in North America, with commercial landings amounting to several hundred thousand pounds annually (Table 6).

Table 6.—Average annual commercial landings of shad in the Columbia River districts of Oregon and Washington, 1889-1963 (Landings prior to 1925 are known only for the indicated years)

Years	Average annual landings	Years	Average annual landings
	Pounds		*Pounds*
1889-90	68,000	1926-30	1,245,000
1891-92	170,000	1931-35	483,000
1896-1900	572,000	1936-40	295,000
1902-05	189,000	1941-45	545,000
1906-10	357,000	1946-50	841,000
1915	581,000	1951-55	311,000
1923	334,000	1956-60	178,000
1925	665,000	1961-63	945,000

Sources: Cleaver (1951) for years 1889-1949; Smith (1956) for 1950-53; United States Fish and Wildlife Service, Fishery Statistics of the United States for 1954-63.

In the Columbia, traps, seines, and fish wheels have all been used to catch shad; at the present time, however, they are harvested commercially only by gill nets. Shad are valued for their roe and to a lesser extent as animal food and for human consumption. Shad are caught mostly in May, June, and July, during the spawning migrations. They are abundant in the lower reaches of the Columbia, and some have been taken as far upstream as the Snake River. In 1963, the commercial catch of Columbia River shad was 1,535,000 pounds, the largest harvest since 1947. Also in 1963, nearly 390,000 shad were counted at Bonneville Dam compared with the record high count of 465,000 fish in 1962.

C. EULACHON

The eulachon *(Thaleichthys pacificus)*, known locally as the Columbia River smelt, appear from Northern California to the Bering Sea. Eulachon are especially abundant in the Columbia and Fraser Rivers. Prior to the manufacture of candles, these fish were dried, fitted with wicks, and used as a source of light. This application explains why eulachon are still sometimes referred to as candlefish. Indians formerly used substantial quantities of them for food and also rendered them into oil for cooking. During the winter, eulachon enter the Columbia in dense schools and ascend various tributaries, mainly the Cowlitz, Lewis, Grays, and Sandy Rivers.

Records do not show when eulachon first became commercially important, but in 1895 over 250,000 pounds of eulachon was landed. Commercial landings were largest from the late 1930's through the 1940's, reaching an alltime high of 5,750,000 pounds in 1945. Recent commercial landings of eulachon have ranged between 1,000,000 and 2,000,000 pounds annually (Table 7), exceeding landings for all other species taken in the Columbia except chinook salmon.

Table 7.—Average annual commercial landings of eulachon in the Columbia River districts of Oregon and Washington, 1895-1963 (Landings prior to 1925 are known only for the indicated years)

Years	Average annual landings	Years	Average annual landings
	Pounds		*Pounds*
1895	282,000	1931-35	1,612,000
1896-1900	832,000	1936-40	2,548,000
1902-1905	474,000	1941-45	3,437,000
1906-1910	524,000	1946-50	2,731,000
1911-1912	435,000	1951-55	1,728,000
1923	1,188,000	1956-60	1,787,000
1925	1,578,000	1961-63	1,205,000
1926-30	1,277,000		

Sources: Cleaver (1951) for years 1896-1949; Smith (1956) for 1950-53; United States Fish and Wildlife Service, Fishery Statsitics of the United States for 1954-63.

As the eulachon ascend the Columbia, they are harvested with gill nets. After they enter the tributaries, dip nets are used (Figure 15). The Cowlitz River has usually accounted for about 1/2 the total landings. Commercial landings have been governed more by market demands than by abundance. Eulachon are almost entirely used for human consumption.

D. STURGEON

2 species of sturgeon, the white sturgeon *(Acipenser transmontanus)* and the green sturgeon *(A. medirostris)*, are found in the Columbia River. As a food fish, the white sturgeon (Figure 16) is considered to be superior to the green sturgeon.

When white men arrived on the Columbia, sturgeon were abundant. At some places on the river, they were so numerous that they caused considerable damage to the gill nets used by salmon fishermen. For years, the smaller sturgeon (generally those under about 50 pounds) caught by salmon fishermen were deliberately killed; and in a few places on the river, special efforts were made to eradicate them. Sturgeon were caught in all the major types of salmon gear, including gill nets, seines, fish wheels (Figure 17), and traps, as well as on hook and line gear.

Figure 15.—Boat used to take eulachon commercially by means of dip nets.

Sturgeon found limited use as food by the original Indians and early white settlers of the Columbia Basin. About 1880, a commercial fishery commenced. In 1888, a rail shipment of frozen sturgeon to the East marked the beginning of an important industry. Quick acceptance of smoked Columbia River sturgeon and of caviar made from sturgeon eggs stimulated rapid development of the fishery; by 1892, a peak production of 5,500,00 pounds was reached. Despite relatively heavy fishing effort expended in subsequent years, landings fell rapidly (Table 8), and the fishery soon became incidental to other fisheries. Since World War II, commercial landings of sturgeon have generally ranged between 250,000 and 500,000 pounds annually. Although sturgeon is highly esteemed as a fresh fish, the bulk of the catch is smoked and canned.

Table 8.—Average annual commercial landings of sturgeon caught in the Columbia River and tributary streams, 1889-1963 (Landings prior to 1925 are known only for the indicated years)

Years	Average annual landings	Years	Average annual landings
	Pounds		*Pounds*
1889-90	2,416,000	1926-30	181,000
1891-92	4,514,000	1931-35	93,000
1895	4,704,000	1936-40	109,000
1899	73,000	1941-45	170,000
1904	138,000	1946-50	414,000
1915	135,000	1951-55	320,000
1923	183,000	1956-60	341,000
1925	231,000	1961-63	277,000

Sources: Cleaver (1951) for years 1889-1949; Smith (1956) for 1950-53; United States Fish and Wildlife Service, Fishery Statistics of the United States for 1954-63.

Commercial regulations, which include closed seasons and prohibitions against retention of immature (under 4 feet long) and large (over 6 feet long) sturgeon, together with a changed attitude by commercial fishermen, probably account for the increasing abundance of sturgeon in recent years. At the present time, most commercially caught sturgeon are taken in gill nets during salmon and steelhead fishing, but a few are taken with handlines. The average weight of sturgeon caught in gill nets in recent years has been about 40 pounds (Wendler, 1959).

E. PACIFIC LAMPREY

The Pacific lamprey *(Lampetra tridentata)*, which occurs from Southern California to Alaska, is an eel-like vertebrate with a long slender body and a jawless mouth surrounded by a horny, sucking disk containing platelike teeth. The earliest known use of lamprey was for food by Indians. The Pacific lamprey is not used now to any extent as food. Present-day anglers use it as bait for sturgeon and other fishes.

Figure 16.—This female white sturgeon, which weighed 497 pounds, was caught near Hood River, Oregon.

Figure 17.—A 673-pound white sturgeon caught in McGowan's fish wheel near Cascade Locks in 1912.

The fishery commenced at Oregon City on a limited scale in 1941. Statistics on landings are available starting with 1943. The fishery peaked in 1946, when 397,000 pounds was landed (Table 9). Last reported landings were for 1952.

Formerly, Pacific lamprey were harvested commercially as they ascended the fish ladder at Willamette Falls in Oregon City. Lamprey entered 1 of a series of traps placed along the sides and the upper ends of the pools in the ladder. A trough led from each trap into a flume and then into a central live box. The lamprey were dipped from the live box with scoopnets, placed in drums, barged downstream, transferred to a truck, and hauled to a reduction plant. Oil containing vitamin A was extracted, and the residual material was manufactured into fish meal for feeding poultry and livestock (Mattson, 1949).

Table 9.—Annual commercial landings of Pacific lamprey at Willamette Falls, Oregon, 1943-52

Year	Landings	Year	Landings
	Pounds		*Pounds*
1943	207,000	1948	231,000
1944	73,000	1949	115,000
1945	249,000	1950	0
1946	397,000	1951	184,000
1947	360,000	1952	262,000

Sources: Cleaver (1951) for years 1943-49; Smith (1956) for 1950-52.

III. MARINE SPECIES

In the description of fisheries of the Columbia River and adjacent ocean waters, the term "adjacent ocean waters" is somewhat ambiguous, since the origin of catches for most marine species is usually reported by broad geographical units. For some species (such as razor clams in Oregon, which are abundant only on a short strip of beach near the mouth of the Columbia), use of the term presents no problem, because the entire State catch can be arbitrarily assigned to 1 region. Assigning an area of origin is more complex for species such as albacore, which appear in different localities off the Oregon and Washington coasts from year to year. For such species, statewide landings have been used, supplemented by reference to the percentage of the State total made in Columbia River ports. Some of the more important Pacific Northwest geographic reference points and landing ports are shown in Figure 18.

A very large number of marine species occur in ocean waters adjacent to the Columbia. Not all are the object of commercial fisheries: species such as Pacific hake (Figure 19) and some flounders (Pleuronectidae) constitute latent resources for the future.

As human and animal food resources, marine species greatly exceed the Columbia's fresh-water and anadromous species. Past and present fisheries for marine species include those for fish and shellfish and for mammals.

A. FISH AND SHELLFISH

1. Fish

The marine fishes taken adjacent to the Columbia River include both the bony (true) fishes and the elasmobranch fishes.

a. Bony fishes.—Of the bony fishes, both the pelagic and demersal kinds are taken.

(1) Pelagic.—The pelagic fishes comprise principally (1) albacore, (2) Pacific sardine, (3) northern anchovy, and (4) Pacific herring.

(a) *Albacore.*—The albacore *(Thunnus alalunga)* (Figure 20) is the most highly prized of the tunas. Almost the entire catch is canned. Albacore inhabit all warm and temperate seas and have been reported along the Pacific Coast from the Revilla Gigedo Islands, Mexico, northward into the Gulf of Alaska. The best fishing grounds lie between Central Baja California, Mexico, and the Columbia River.

Fishing for albacore in the Pacific Northwest normally begins in mid-July, peaks in August and September, and tapers off in late October. Fishing activity typically begins between Newport and Astoria, Oregon, and gradually extends northward to Washington and to Southern Vancouver Island, British Columbia.

Although for many years occasional albacore were caught by salmon trollers, the first commercial landings in Oregon were not made until 1936. Many salmon trollers first actively sought albacore in 1937 and landed 1,500,000 pounds in Oregon and Washington ports. By 1941, some 500 vessels participated in the Pacific Northwest albacore fishery. A record high of over 34,000,000 pounds of albacore was landed in Oregon and Washington in 1944, of which over 1/2 was discharged at Columbia River ports (principally Astoria— Figure 21). This pattern of the greatest share of the landings' being made in Columbia River ports has continued to the present time (Table 10).

Figure 18.—Important Pacific Northwest landing ports and geographic reference points.

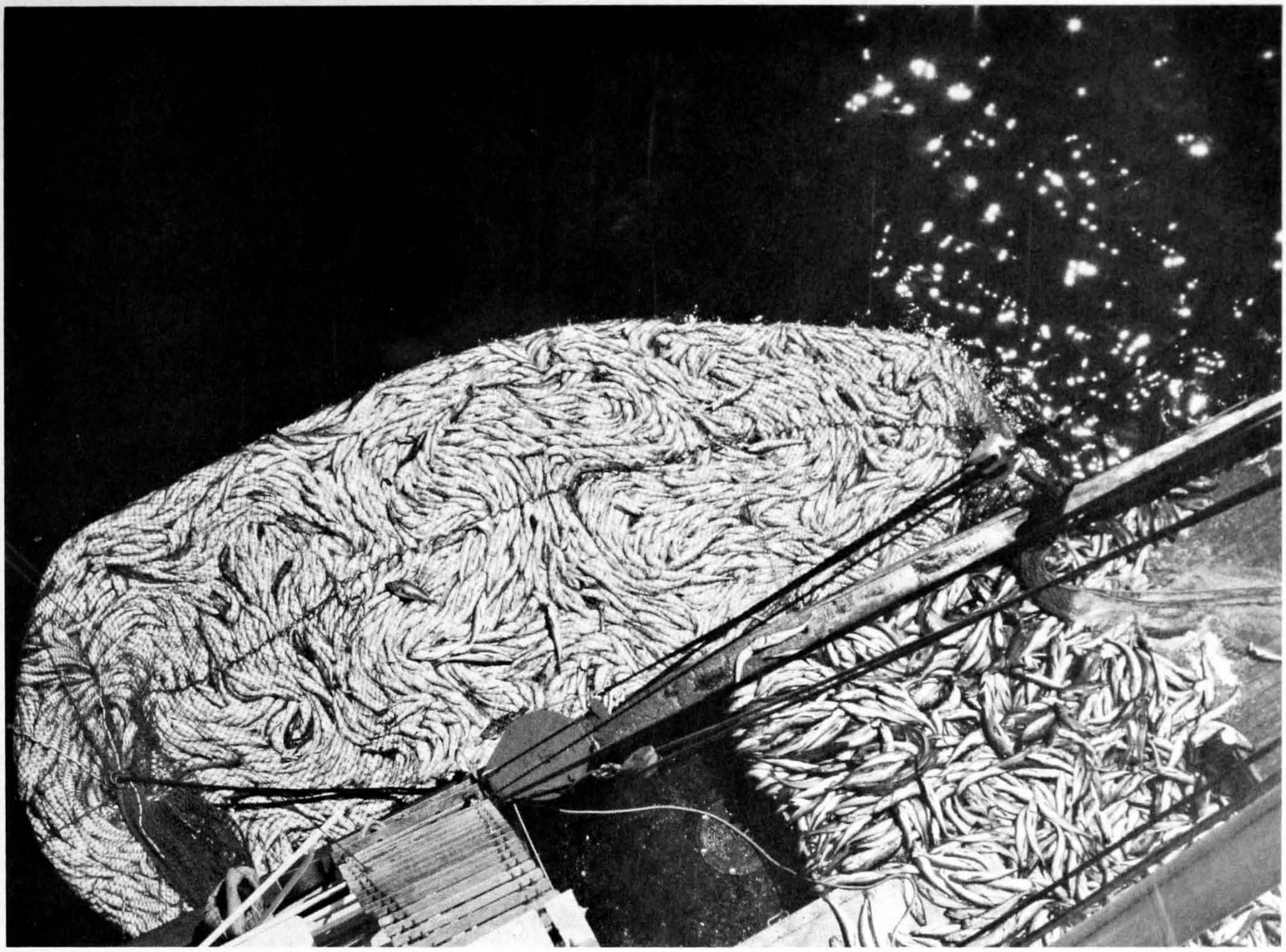

Figure 19.—20 tons of Pacific hake *(Merluccius productus)* caught by Bureau of Commercial Fisheries research vessel *John N. Cobb* in 1-hour midwater trawl haul.

Table 10.—Average annual commercial landings of albacore in Oregon and Washington and percent of landings made in Columbia River district ports, 1936-63

Years	Average annual landings	Relative landings in Columbia River district ports
	Million pounds	*Percent*
1936-40	6.2	60
1941-45	18.0	60
1946-50	10.8	46
1951-55	1.8	50
1956-60	7.5	61
1961-63	8.3	65

Sources: United States Fish and Wildlife Service, Fishery Industries of the United States for years 1936-41, and Fishery Statistics of the United States for 1942-63.

Different types of fishing gear have been used to harvest albacore. At first, albacore were taken principally by trolling feathered jigs at the surface. About 1941, California-based tuna clippers started live-bait fishing (Figure 22) for albacore in Pacific Northwest waters. This practice of carrying live bait (such as anchovy, herring, sardine, or sand lance) in holding tanks aboard the vessels for use in chumming albacore was quickly adopted on many of the larger, resident Pacific Northwest crafts, such as halibut schooners and trawlers, and it continued to be followed until the late 1940's. Purse seines also have been used to harvest albacore in Pacific Northwest waters, but they have never been a primary factor in the fishery. The bulk of the albacore fleet now consists of salmon trollers whose equipment, depending upon the relative availability and price differential of salmon and albacore, can be changed from the gurdy-hauled lines and deep-trolled lures used to catch salmon to the hand-hauled lines and surface jigs used to catch albacore.

Washington and Oregon landings of albacore include variable and, in some years, substantial proportions of fish caught off California and British Columbia. Many Pacific Northwest vessels seek alba-

Figure 20.—An albacore caught by surface jig trolled in ocean waters adjacent to mouth of Columbia River.

core off California and make a practice of landing, in their Pacific Northwest home port, fish that have been caught on their last trip off California. Waters southwest of the mouth of the Columbia River are prime producers of albacore for trollers that land their catch in Oregon ports during the first 1 or 2 months of the season (Ayers and Meehan, 1963). Landings of albacore in Washington and Oregon during 1956-60 ranged from 3,000,000 to 13,500,000 pounds annually, with the annual average exceeding 7,000,000 pounds (Table 10). Since strong westerly winds frequently hamper fishing, the large year-to-year fluctuations reflect weather conditions as well as changing availability of this species to the fishery.

(b) *Pacific sardine.*—The Pacific sardine *(Sardinops sagax)*, or pilchard, is found from the Gulf of California, Mexico, to Southeastern Alaska (Figure 23). In the 1930's and early 1940's, the Pacific sardine supported the largest fishery in the Western Hemisphere, accounting for over 1 billion pounds taken from California waters in some years. When the population was large, immense numbers of adult sardines migrated northward and provided important summer and fall fisheries off Oregon, Washington, and British Columbia. Since the late 1940's, few sardines have appeared in the waters of the Pacific Northwest; commercial landings were last reported in Oregon in 1949 and in Washington in 1951. This decline apparently resulted from a great decrease in the sardine population off California.

Although sardines had been known to occur in Pacific Northwest waters and substantial landings had been made in British Columbia since the early 1920's, State laws in Oregon and Washington prohibited the reduction of sardines to oil and meal. Repeal of the laws in 1935 resulted in the establishment of reduction plants (Figure 24). That same year, over 52,000,000 pounds of sardines was landed in Oregon, and 13,000,000 pounds was landed the following year in Washington. The fish-

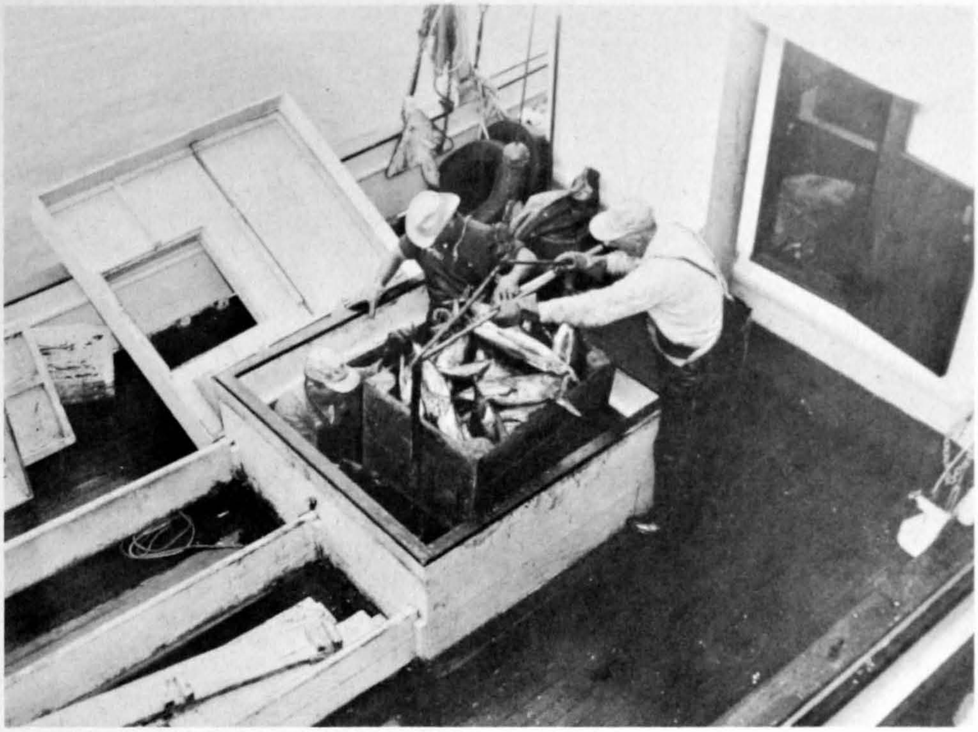

Figure 21.—Unloading albacore from hold of a vessel at Astoria.

ery reached the peak output in 1938-39 (Table 11), when the combined Washington and Oregon landings exceeded 80,000,000 pounds per year. The fishery, however, was relatively short-lived. After 1947, combined Oregon and Washington annual landings failed to exceed 1,000,000 pounds, and the last reported landings in 1951 in Washington were only about 2,000 pounds.

Both the Oregon and the Washington sardine fisheries were conducted entirely by purse seines that were similar to those used for salmon except for their smaller mesh, larger size, and greater number of corks (Chapman, 1936). Although the fishing grounds off Washington were located along the entire coast, they changed from year to year, depending upon the availability of sardine in relation to the location of reduction plants. From 1935 through 1937, a substantial proportion of the Oregon sardine catch was taken off Southern Oregon and landed at reduction plants in Coos Bay. After 1937, most of the sardine were caught close to the Columbia River and landed in Astoria; by 1940, all the Oregon sardine reduction plants were located in or near Astoria (Harry, 1948).

During the later years of the Pacific Northwest sardine fishery, catches were primarily composed of fish 5 years old or older; whereas in 1940, 4-year-olds dominated the catches (Harry, 1948). Increasing dependence of the fishery upon older

Table 11.—Average annual commercial landings of Pacific sardines in Oregon and Washington, 1928-63.

Years	Average annual landings in:		Total average annual landings
	Washington	Oregon	
	Pounds	*Pounds*	*Pounds*
1928-30	0	10,000	10,000
1931-35	2,000	10,494,000	10,496,000
1936-40	27,539,000	29,374,000	56,913,000
1941-45	12,252,000	7,860,000	20,112,000
1946-50	3,061,000	6,568,000	9,629,000
1951-55	400	0	400
1956-60	0	0	0
1961-63	0	0	0

Sources: United States Fish and Wildlife Service, Fishery Industries of the United States for years 1928-41, and Fishery Statistics of the United States for 1942-63.

fish during the 1950's stemmed from the poor recruitment of young fish and a relatively intense fishery off California. Resumption of a fishery in Pacific Northwest waters cannot be expected until the sardine population off Southern California increases to a size commensurate with that existing in the 1930's and early 1940's.

(c) ***Northern anchovy.***—The northern anchovy ***(Engraulis mordax)*** occurs from Baja California to Northern Vancouver Island, British Columbia. Anchovies are most abundant off California, but they also occur in dense schools along the Oregon and Washington coasts. Although they are available

Figure 22.—Live-bait fishing for albacore using poles and lines.

throughout the year, they are most accessible to capture in the summer and fall, when they enter bays and inshore waters. Large numbers of anchovies occur in the ocean waters adjacent to the mouth of the Columbia River.

Anchovies were the most important species used for bait during the Pacific Northwest live-bait fishery for albacore tuna in the 1940's. Although no records exist of the amounts so used, catches are known to have been large. When they were to be used for bait, small schools of the anchovies were seined, and the fish were dipped from the net into live wells aboard the tuna clippers, where they were held until needed.

Commercial landings of anchovies reported in Washington in 1947-49 ranged from 43,000 to 402,000 pounds annually; the landings in Oregon in 1948 and 1953 amounted to 62,000 and 168,000 pounds, respectively. This species could form the basis for a future fishery.

(d) *Pacific herring.*—Pacific herring *(Clupea harengus pallasi)* occur from Southern California to the Bering Sea and are most abundant off British Columbia and Alaska, where they sustain major commercial fisheries. Herring are caught in bays and inshore waters with seines, gill nets, and dip nets.

Aboriginal use of herring in the lower Columbia River was limited. Indians living near the river mouth caught herring with brush snares. Some of the fish were used locally, but many were "dried and smoked and sewed tail to head in fathom-long bands and traded upriver" (Hewes, 1947). In British Columbia and Alaska, herring now are mainly used for fish meal and oil, although substantial amounts are also used for human food and fish bait. Along the Oregon and Washington Coasts, small quantities of herring are harvested for bait in the commercial salmon troll fishery and the longline fisheries for halibut, sablefish, and lingcod. Some herring have been used for animal food. Increasing numbers are being used as bait in the rapidly growing ocean sport fishery for salmon. Annual landings in Oregon during 1951-60 ranged from 0 to 38,000 pounds and averaged 7,000 pounds; in the coastal district of Washington, the landings ranged from 0 to 266,000 pounds and averaged 27,000 pounds.

(2) Dermersal.—The principal demersal fisheries are for halibut, sablefish, and certain trawl-caught fish.

(a) *Pacific halibut.*—The Pacific halibut *(Hippoglossus stenolepis)* occur from Southern California to the northwestern areas of the Bering Sea, with the area of greatest primeval abundance being off British Columbia (Figure 25).

The fishery for halibut is 1 of the oldest on the Pacific Coast. Halibut were very important in the diet of many of the coastal Indians, particularly those residing at Neah Bay, Washington; Sitka, Alaska; and on the Queen Charlotte Islands, British Columbia. They probably were used only to a limited extent by the Indians residing near the mouth of the Columbia River.

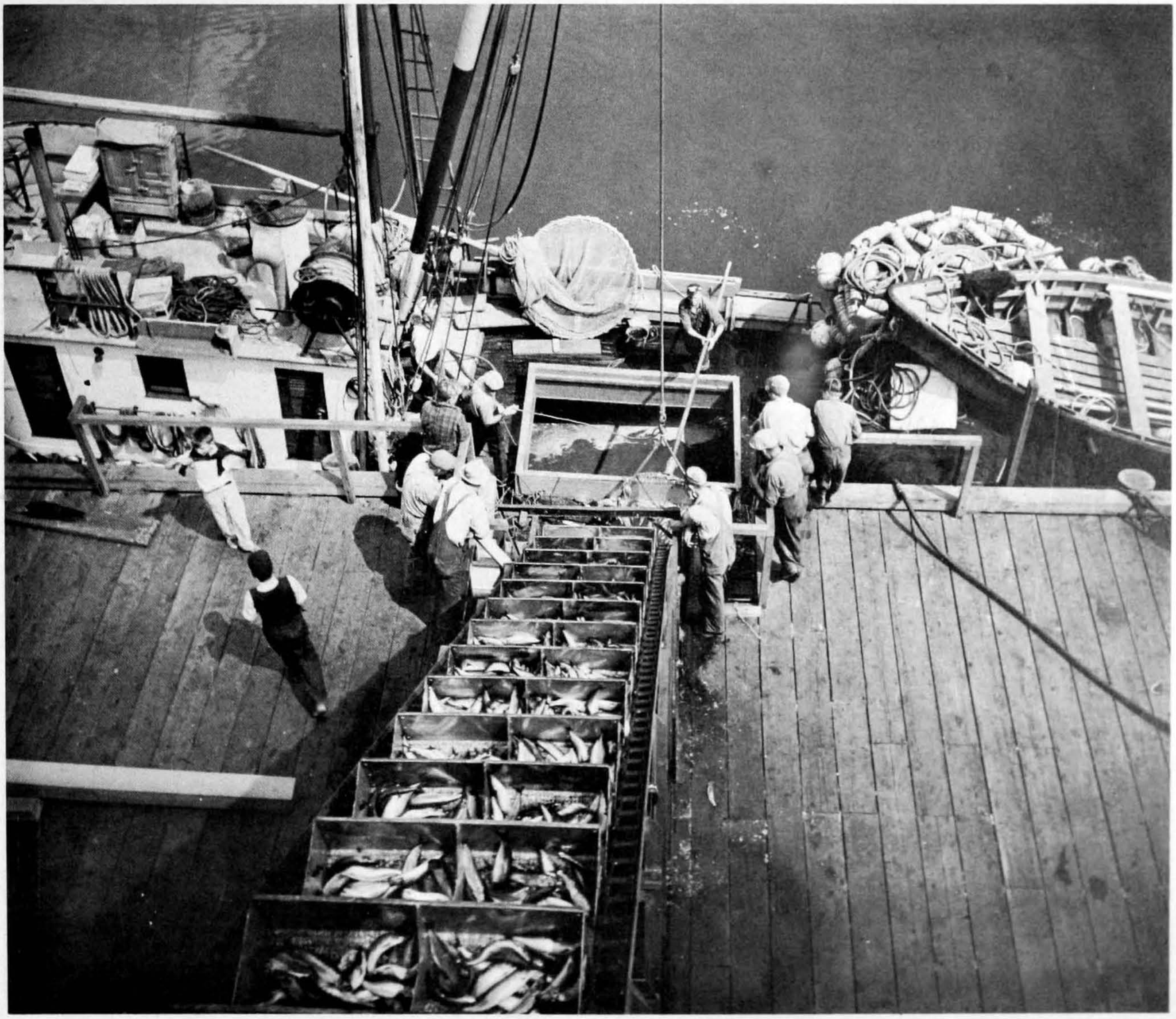

Figure 23.—Sardines being transported from sardine seiner to reduction plant at Aberdeen, Washington (August 1938).

Figure 24.—Brailer used to unload sardines from vessel to conveyor belt at reduction plant in Aberdeen, Washington.

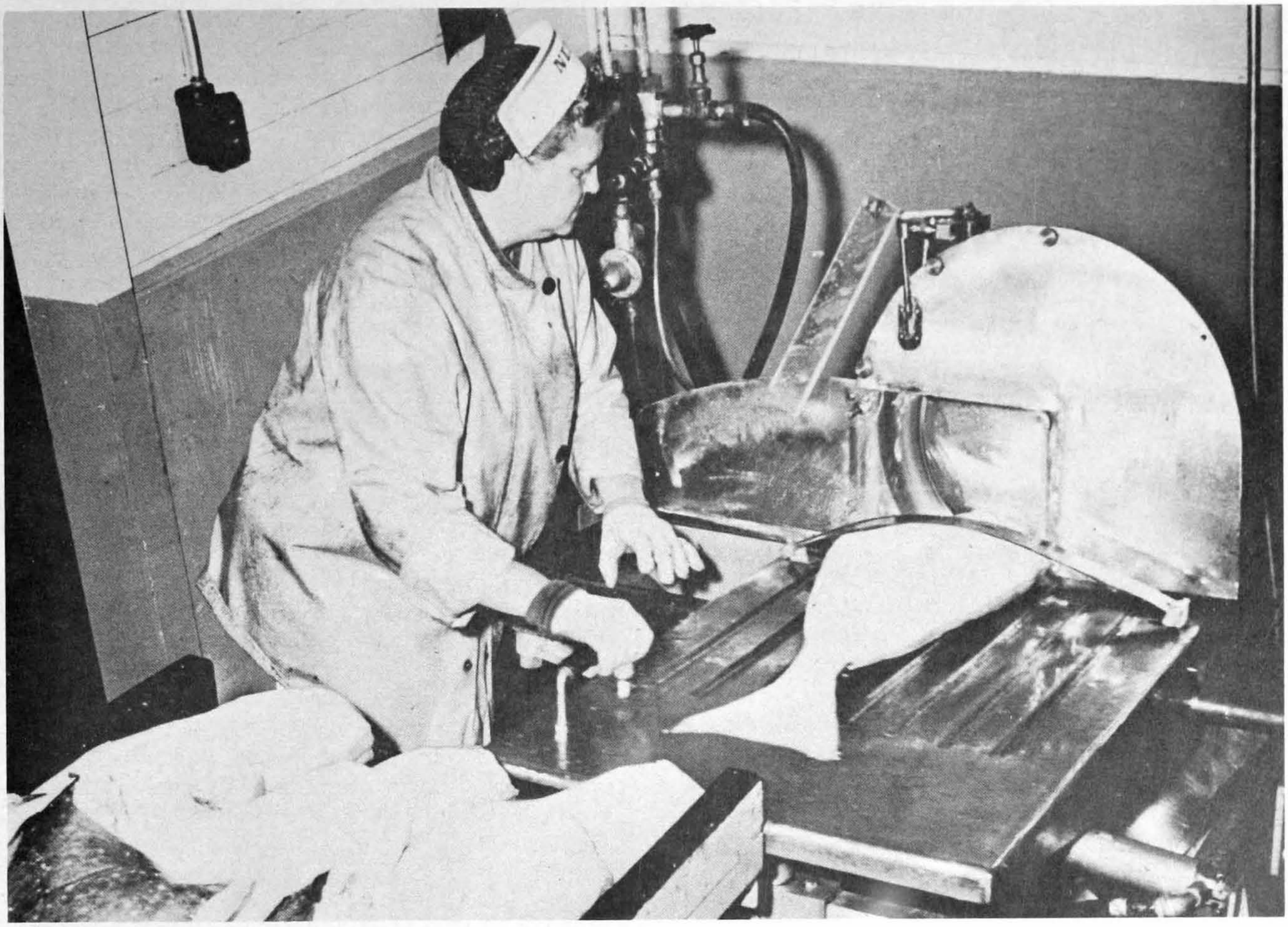

Figure 25.—A small halibut being sawed into slices for subsequent cutting into steaks.

Until the railroads were completed across the continent in the late 1880's, the halibut caught commercially by white men were primarily used locally. Until about 1910, the fishery was conducted mainly on nearby fishing grounds. These readily accessible grounds were soon depleted, and expansion to offshore grounds, as well as to northern grounds off Alaska, was necessary. Extended operations became more practical as a result of the evolution in the means of propulsion—from sails to steam engines to gasoline engines and finally to diesel engines.

Although during the early years of the fishery most of the United States landings were made at Seattle and Alaska ports, a significant portion of the catch was taken off the coast of Oregon. A few halibut were landed in Portland as early as 1885. In 1889 and 1890, the steam schooner *George H. Chance* landed several catches in Portland; some of these fish were caught on Heceta Bank and other Oregon grounds (Thompson and Freeman, 1930). Some grounds off Oregon provided large catches of halibut in early years; however, the fishery was based on stocks of older fish, which were not replaced after being depleted. In May and June of 1915, practically the entire Seattle halibut fleet, as well as some Canadian vessels, was reported fishing off the Columbia River. Some 50 to 60 vessels, congregated in a 2-square-mile area, reportedly caught 2,000,000 pounds of halibut (Johnston, 1917). The early heavy yields were short-lived, however, and since 1950, landings from waters south of Willapa Harbor, Washington, have amounted to only 200,000 to 600,000 pounds annually (Table 12). This annual take is between 0.3 and 1 percent of the total United States and Canadian Pacific halibut landings. Grounds off the Columbia River and on Heceta Bank, off Central Oregon, have contributed the major share of the catches made off Oregon. Included in the Area 1 landings shown in Table 12 are incidental catches of halibut taken by vessels fishing mainly for other species off Northern California.

The Pacific Coast halibut fishery is perhaps the outstanding example of successful international

Table 12.—Average annual commercial catches of Pacific halibut from waters south of Willapa Bay, Washington (International Pacific Halibut Commission Regulatory Area 1), 1916-63

Years	Average annual landings	Years	Average annual landings
	Pounds		*Pounds*
1916-20	299,000	1941-45	352,000
1921-25	737,000	1946-50	433,000
1926-30	1,044,000	1951-55	511,000
1931-35	1,134,000	1956-60	388,000
1936-40	797,000	1961-63	262,000

Source: Reports of the International Pacific Halibut Commission.

management of a high-seas fishery to produce the maximum sustainable yield. Declining yields in the early 1900's led to the signing, in 1923, and ratification, in 1924, of a conservation convention between the United States and Canada (subsequently modified in 1930, 1937, and 1953). The convention established the International Fisheries Commission, renamed the International Pacific Halibut Commission in the 1953 Convention, and charged it with investigating the fishery, recommending methods of control to rebuild the stocks from their overfished state, and determining the ultimate maximum sustainable yields. Management techniques used have included controlling the harvest by establishment of annual catch limits or by regulation of the length of the seasons, closing the nursery grounds, and prescribing minimum size limits (heads-on length of 26 inches or heads-off weight of 5 pounds). Management of the fishery has increased United States and Canadian Pacific Coast annual yields from 44,000,000 pounds in 1932 to an average of about 70,000,000 pounds in recent years. The catch now is thought to be close to the level of maximum sustainable yield (Chapman, Myhre, and Southward, 1962).

Present-day halibut vessels are of 2 general types: the schooner (Figure 26) and the combination seine-type vessel, both of which use longline gear. Conventional halibut longline gear is made up in units called skates, each skate being 250 to 300 fathoms long (Thompson, Dunlop, and Bell, 1931). A skate consists of a groundline to which are attached gangions (leaders) with hooks on 1 end. Gangions are 4 to 5 feet long and are usually spaced 13 or 18 feet apart along the groundline. Skates are baited and coiled and set overboard through a chute on the stern of the vessel. When the gear is set, 2 or more skates are joined to form a string or set. Each string is anchored at the ends; a buoy line runs from each anchor to a buoy keg at the surface.

Although longline has been the most important gear for harvesting Pacific halibut, other types of gear have also been used (Bell, 1956). Trawl gear, for example, was used for several years prior to 1944. It has since been prohibited because trawls tend to retain a large number of small halibut. Trollers fishing for salmon are permitted to retain halibut caught during the regular open halibut season. A significant share of the halibut caught off Oregon and Northern California in the fall of the year has been taken incidental to longlining for sablefish. From 1937 through 1965, regulations allowed a "permit fishery," after the close of the regular halibut season, during which time halibut could be retained by longline vessels in the ratio of 1 pound of halibut to 7 pounds of other bottomfish. This permit provision was discontinued in 1966.

(b) *Sablefish.*—The sablefish *(Anoplopoma fimbria)*, or blackcod, occurs from Southern California to the Northwestern Bering Sea. Sablefish are found over a wide range of depths, from intertidal waters to a depth of over 600 fathoms.

The fishery for sablefish is 1 of the oldest on the Pacific Coast. It began in the 1890's off Washington and British Columbia and subsequently expanded to California, Oregon, and Alaska. Although the original fishery was based entirely on longline gear and though this gear still accounts for practically all of the landings in British Columbia and Alaska, otter trawlers take an increasingly large share of the catch in Washington, Oregon, and California. The increase is partly due to the progressive shift of trawlers into deeper water where substantial quantities of large sablefish occur.

The increased demand for fishery products created by World War I stimulated the development of the fishery, and in 1917 the Pacific Coast landings of sablefish reached 13,000,000 pounds. Under the stimulus of World War II and a strong demand for liver and viscera (a source of natural vitamin A), annual landings reached about 15,000,000 pounds in 1946. From 1950 to 1960, annual landings averaged about 9,500,000 pounds. Washington and Alaska accounted for about 2/3 of the total, with annual landings of sablefish in each of these States averaging about 3,000,000 pounds during 1950-60. Annual landings of sablefish during this period averaged about 2,000,000 pounds in California, 330,000 pounds in Oregon, and 1,000,000 pounds in British Columbia.

Off Oregon, major longline fishing areas for sablefish are Heceta Bank, the grounds off Newport, and the grounds off the Columbia River. It is difficult to determine the area of origin of these fish, for landings by port do not necessarily reflect the origin of the catch. As a case in point, a considerable portion of longline-caught sablefish landed at Seattle are caught off Oregon.

Bell and Pruter (1954) made the most recent detailed examination of sablefish caught in Ore-

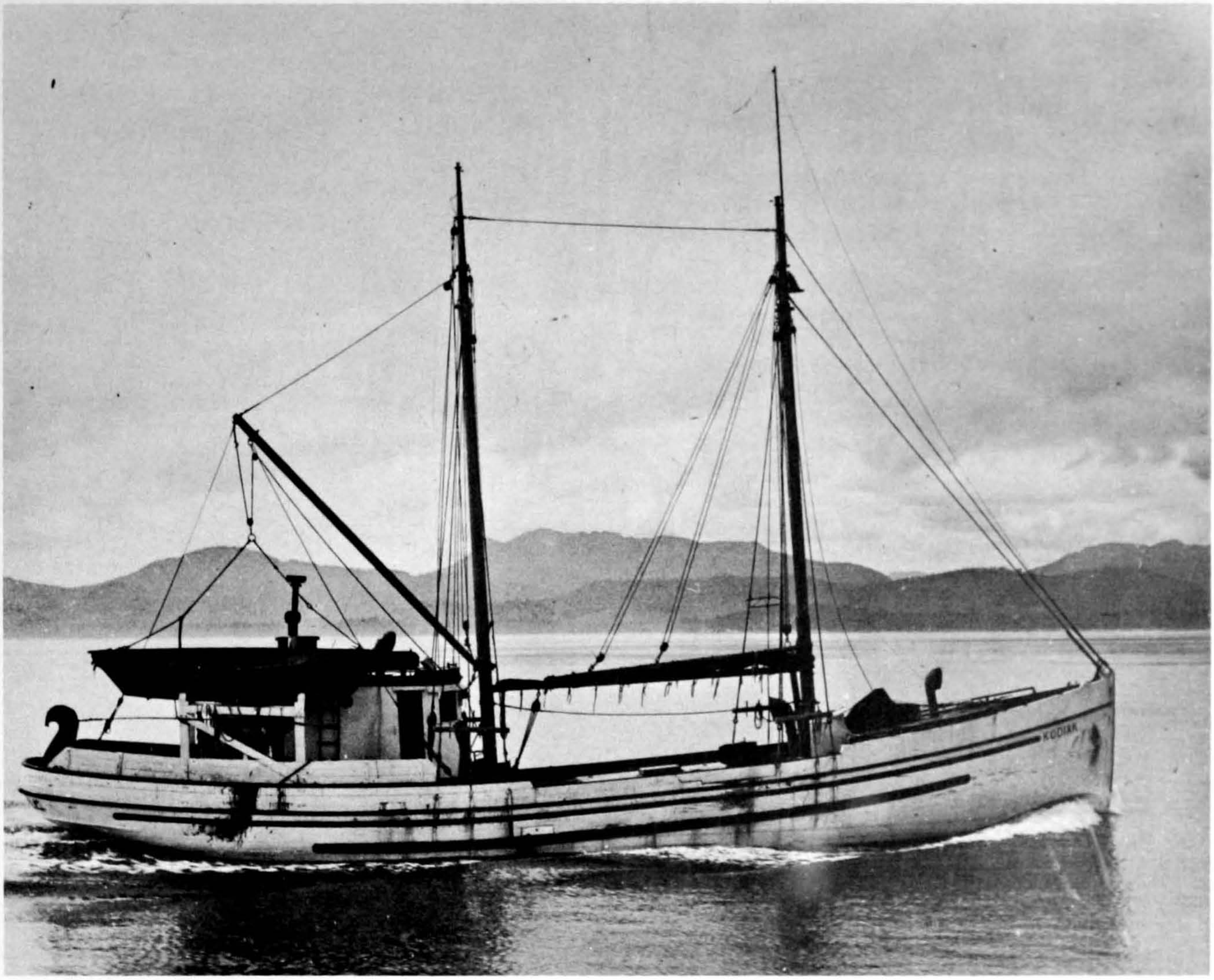

Figure 26.—Pacific Northwest halibut schooner.

gon waters by both Oregon- and Washington-based trawlers and longliners. Their data are reproduced in Table 13 in terms of average annual catch by 5-year intervals for 1915-52. (Comparable statistics for the years after 1952 are unavailable for this report; however, information that is available indicates that they probably would not differ greatly from those shown in Table 13.) About 33 percent of the catches off Oregon after 1952 probably has been taken in the region between Tillamook Head and the Columbia River.

Sablefish are not as abundant on the shoal grounds off Oregon as in former years (Bell and Pruter, 1954). Catches of 40,000 to 60,000 pounds per vessel were landed in Astoria between 1936 and 1939; now a catch of 20,000 pounds is considered unusually large. The decline in the abundance of sablefish was accompanied by a decrease

Table 13.—Average annual commercial landings of sablefish caught off Oregon, 1915-52

Years	Average annual landings	Years	Average annual landings
	Pounds		*Pounds*
1915	16,000	1936-40	597,000
1916-20	205,000	1941-45	757,000
1921-25	324,000	1946-50	780,000
1926-30	859,000	1951-52	606,000
1931-35	427,000		

Source: Bell and Pruter (1954).

in their average size. In the late 1920's, the average sablefish caught by longline and landed in Oregon weighed about 12 pounds. By the early 1940's, the average weight had decreased to about 9 pounds, and by 1952 it was between 7 and 8 pounds.

Figure 27.—An otter trawler. Large otter boards on stern are used to open mouth of net, which is dragged on ocean bottom.

The largest exploratory trawl catches of sablefish made off the Columbia River were taken in deeper water than is customarily fished by commercial trawlers and longliners (Heyamoto and Alton, 1964). These deep-dwelling fish are relatively unharvested and may be a large latent resource in the waters off the coasts of Oregon and Washington.

(c) *Demersal species caught by otter trawl.*—Although trawling has been practiced intermittently in Pacific Northwest waters from as early as 1884 (Harry and Morgan, 1963), the industry did not become important until about 1940 (Cleaver, 1949), when World War II created an additional demand for fishery products. Trawling off Oregon and Washington in the late 1930's was primarily for petrale sole *(Eopsetta jordani)* and was largely confined to grounds adjacent to Astoria and Coos Bay, Oregon, and to grounds between Umatilla Reef and Cape Flattery, Washington. During World War II, the fishery expanded to include the offshore grounds between Southern Oregon and Northern British Columbia and many species besides petrale sole.

Vessels operating in the Pacific Northwest otter trawl fishery are of 2 basic types: the halibut schooner and the West Coast purse seiner. Most trawlers are from about 50 to 85 feet long and carry a load of about 30 to 55 tons (Alverson, Pruter, and Ronholt, 1964). Crew size ranges from 2 to 5 men, but most vessels carry either 3 or 4 men (Figure 27).

Pacific Northwest trawlers are highly mechanized; many now have power drums mounted on the afterdeck, for example, to haul the wings and body of the trawl net in over the stern. The most common trawl net now used is the 400-mesh Eastern net (Greenwood, 1958), which is effective for capturing bottomfish because the nets are dragged directly on the ocean floor. In recent years, more vessels have begun using rollers (bobbins) on the footrope of the net to permit fishing over relatively rough bottom.

Trawling off Oregon is now most intense on grounds between Columbia River and Tillamook Head. Other heavily fished Oregon waters are located near Stonewall Bank (northwest of Newport) and Heceta Bank. Astoria-based trawlers frequently fish off Southern Washington and, at times, as far north as off Vancouver Island. A considerable part of the Washington-based trawl fleet's effort is expended off the west coast of Vancouver Island and in Hecate Strait. An estimated 75 percent of the Washington fleet's effort during 1955-57 was spent at depths of from 11 to 100 fathoms, and the remainder at depths of from 101 to 300 fathoms (Alverson, 1960).

The most important species now harvested are shown in Table 14. They include a number of flounders or "soles" (Pleuronectidae and Bothidae), rockfishes (Scorpaenidae), and "cods" (Gadidae, Hexagrammidae, and Anoplopomatidae).

Species sought have varied mainly in response to changing market demands. Development in 1946 of a fishery for Pacific ocean perch (Alverson and Westrheim, 1961) resulted in an increased harvest of deepwater rockfishes (Figure 28). Pacific cod catches by trawlers increased rapidly in the late 1940's and 1950's following the introduction of "fish sticks."

Annual landings in Oregon and Washington of major species groups are shown in Table 15 for 1950-63. Not included in the table are landings of trawl-caught elasmobranchs (shark, skate, and ratfish), which, during 1950-63 in Oregon and Washington, ranged between 2,700,000 and 6,400,000 pounds and averaged 4,400,000 pounds annually. Elasmobranchs are discussed separately in the following sections.

Figure 28.—Otter trawl catch taken off Oregon, consisting mainly of rockfish.

Table 14.—Important Pacific Coast trawl-caught fishes

Fishes	Common name	Scientific name
Flatfishes	Dover sole	*Microstomus pacificus*
	English sole	*Parophrys vetulus*
	Petrale sole	*Eopsetta jordani*
	Rock sole	*Lepidopsetta bilineata*
	Arrowtooth flounder	*Atheresthes stomias*
	Starry flounder	*Platichthys stellatus*
	Rex sole	*Glyptocephalus zachirus*
	Sand sole	*Psettichthys melanostictus*
	Butter sole	*Isopsetta isolepis*
Roundfishes:		
Rockfishes ...	Pacific ocean perch	*Sebastodes alutus*
	Canary rockfish	*Sebastodes pinninger*
	Yellowtail rockfish	*Sebastodes flavidus*
	Bocaccio	*Sebastodes paucispinis*
	Chilipepper	*Sebastodes goodei*
	Silvergray rockfish	*Sebastodes brevispinis*
	Black rockfish	*Sebastodes melanops*
	Flag rockfish	*Sebastodes rubrivinctus*
	Blackthroat rockfish	*Sebastodes aleutianus*
Others	Pacific cod	*Gadus macrocephalus*
	Pacific hake	*Merluccius productus*
	Lingcod	*Ophiodon elongatus*
	Sablefish (blackcod)	*Anoplopoma fimbria*

During 1950-63, Washington landings of all trawl-caught species except elasmobranchs averaged about 39,000,000 pounds annually; Oregon averaged about 23,000,000 pounds. Most of Oregon's landings came from waters adjacent to that State, whereas over 50 percent of Washington's trawl landings was obtained from waters off British Columbia. Fish in trawl landings taken from waters adjacent to Washington were mainly obtained from grounds off the northern part of the State between Cape Flattery and Destruction Island.

Flatfishes constituted the most important group of species landed at Washington and Oregon ports from 1950 to 1963, averaging about 26,000,000 pounds annually. The landings were divided almost equally between Washington and Oregon. Dover sole contributed the most poundage, followed by English sole, petrale sole, and rex sole.

Rockfishes accounted for the second highest landings, with an annual average of about 21,000,000 pounds during the period of comparison. About 58 percent of the total rockfish landings was made in Washington ports. Pacific ocean perch was the most important species, accounting for about 50 percent of the total rockfish landings.

Roundfishes (other than rockfishes) made up the third group. During 1950-63, about 15,000,000 pounds of roundfishes were landed annually, with most of the landings' being made in Washington. Pacific cod dominated the roundfish landings until 1960-62, when their availability declined. This decline is generally thought to have been caused by unfavorable environmental factors (Ketchen, 1961) that lowered the survival rate for several successive years. In 1963, the condition of the stocks improved, and the market improved as well. The Columbia River marks the approximate southern limit of commercially available Pacific cod; hence, most Pacific cod were landed in Washington ports. Lingcod and sablefish accounted for most of the remaining landings of the roundfish group.

A large proportion of otter trawl catches consists of unmarketable fish that are discarded at sea. In 1950, logs of a large group of Washington trawlers fishing off the northern coast of Washington and off British Columbia showed that 49.5 percent (by weight) of the catches consisted of trash fish (Bell, 1956). Samples taken aboard Oregon trawl vessels in 1950-61 indicated that between 50 and 60 percent of the catches was discarded at sea (Herrmann and Harry, 1963).

Table 15.—Commercial otter trawl landings of flatfishes, rockfishes, and other roundfishes in Oregon and Washington, 1950-63

Year	Landings											
	Flatfishes			Roundfishes						Total species		
				Rockfishes			Others					
	Oregon	Washington	Total	Oregon	Washington	Total	Oregon	Washington	Total	Oregon	Washington	Total
	Million pounds			*Million pounds*			*Million pounds*			*Million pounds*		
1950	12.6	10.4	23.0	5.6	12.2	17.8	0.9	10.8	11.7	19.1	33.4	52.5
1951	5.6	11.1	16.7	5.5	9.9	15.4	1.5	13.5	15.0	12.6	34.5	47.1
1952	12.1	13.0	25.1	8.4	10.4	18.8	1.0	13.5	14.5	21.5	36.9	58.4
1953	8.7	8.3	17.0	5.8	7.2	13.0	0.7	10.0	10.7	15.2	25.5	40.7
1954	10.8	13.3	24.1	7.9	12.9	20.8	1.4	18.3	19.7	20.1	44.5	64.6
1955	13.0	13.9	26.9	6.9	9.1	16.0	1.0	16.7	17.7	20.9	39.7	60.6
1956	14.4	16.8	31.2	10.3	10.7	21.0	0.7	17.1	17.8	25.4	44.6	70.0
1957	14.3	13.8	28.1	11.5	8.8	20.3	1.5	14.8	16.3	27.3	37.4	64.7
1958	15.2	12.6	27.8	8.9	8.3	17.2	1.0	16.0	17.0	25.1	36.9	62.0
1959	14.0	13.7	27.7	7.8	12.1	19.9	0.9	19.1	20.0	22.7	44.9	67.6
1960	13.8	16.3	30.1	10.3	11.6	21.9	1.7	11.3	13.0	25.8	39.2	65.0
1961	13.3	16.5	29.8	11.4	14.6	26.0	1.1	8.7	9.8	25.8	39.8	65.6
1962	17.1	14.1	31.2	13.7	21.2	34.9	1.1	9.8	10.9	31.9	45.1	77.0
1963	16.3	13.2	29.5	13.1	23.3	36.4	0.9	9.8	10.7	30.3	46.3	76.6
Average	12.9	13.4	26.3	9.1	12.3	21.4	1.1	13.5	14.6	23.1	39.2	62.3

Source: United States Fish and Wildlife Service, Fishery Statistics of the United States for years 1950-63.

Principal uses of trawl-caught fish are for human food (Figure 29) and animal food (mainly for mink, Figure 30). The proportion of landings used for animal food is much higher in Oregon than in Washington. During 1956-63, from 15 to 57 percent (by weight) of Oregon's total trawl landings was converted into animal food; during the same period, less than 10 percent of Washington's landings was used for this purpose. "Soles" and rockfishes account for most of the fishes landed from ocean waters for animal food.

During 1956-60, the average annual landing for all species of trawl-caught fishes from a 33-mile strip adjacent to the mouth of the Columbia River (Statistical Area 2D in Pacific Marine Fisheries Commission 14th Annual Report for the year 1961) was 10,750,000 pounds. This relatively high production may be attributed to 2 primary factors. First, the proximity of the fishing grounds to the Astoria base of the trawl fleet facilitated year-round harvesting even during the relatively brief good-weather periods that prevail in the area during the winter. Second, the basic productivity of the grounds off the mouth of the Columbia River was high.

Utilization of demersal resources may be assessed in terms of annual yield per unit area of Continental Shelf or of slope area from which the fish are caught. About 4-1/2 pounds of salable, trawl-caught fishes are harvested per acre per year in the Oregon-Washington region (Alverson, Pruter, and Ronholt, 1964). This yield may be contrasted with an average harvest during 1956-60 of over 11 pounds of salable, trawl-caught fish per acre per year for the area adjacent to the mouth of the Columbia. The annual yield per acre of ocean bottom on grounds adjacent to the mouth of the Columbia was higher than that for any other statistical area examined in the entire region. (Pacific Marine Fisheries Commission Statistical Areas 2A, 2B, 2C, 2D, 3A, 3B, and 3C extend from Crescent City, California, to Esteban Point, Vancouver Island.)

Yields of rockfishes per unit area are particularly high for grounds adjacent to the Columbia (Area 2D), amounting to almost 2 times the yields for the second highest statistical area examined (Area 3B—Cape Flattery to Point Grenville, Washington) and 5 times the average for all other statistical areas examined. Yields of flounder—particularly petrale sole, Dover sole, and rex sole—in Area 2D also exceed those in any other statistical area examined.

b. Elasmobranchs.—Landings of elasmobranchs (shark, skate, and ratfish) in Washington have far exceeded the landings of elasmobranchs in Oregon. During the decade prior to 1950, grayfish (spiny dogfish) and soupfin shark were the elasmobranchs most eagerly sought; they formed a highly valuable fishery, whereas the other elasmobranchs were little sought after. Accordingly, we shall discuss only the grayfish and soupfin shark.

Figure 29.—Trawl-caught English sole being filleted for human use.

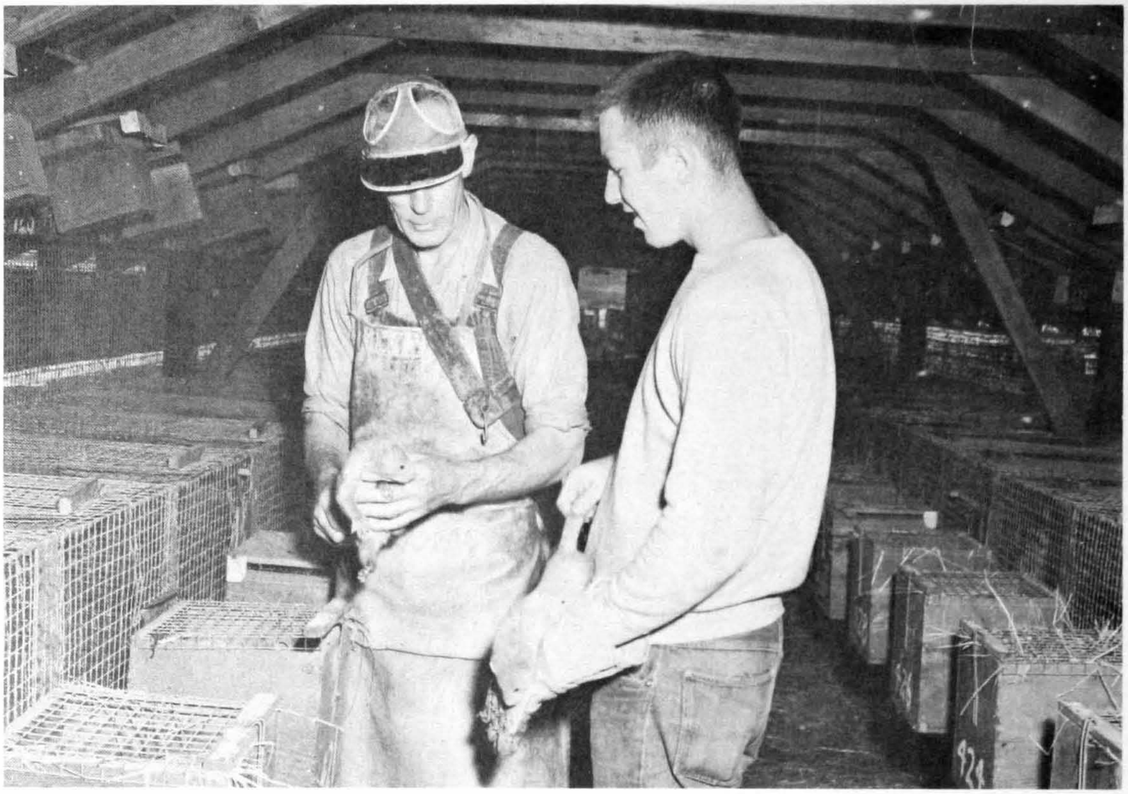

Figure 30.—Mink raised on trawl-caught fish.

(1) Grayfish. — Grayfish, or spiny dogfish, *(Squalus acanthias)* are found in the Eastern Pacific from Baja California to Alaska; in the Western Pacific off Japan and Northern China; and throughout the temperate and subarctic waters of the North Atlantic. They occur over a wide range of depths from intertidal water to waters of over 300 fathoms. The largest concentrations off the coast usually occur in depths of from 50 to 150 fathoms, although at times large numbers are observed swimming at the surface.

Landings of grayfish are reported separately in Table 16. The sudden increase in landings between 1940 and 1941 was due to the shortage of vitamin A brought about by World War II and the rapidly growing recognition of the grayfish liver as an excellent source of this vitamin (Figure 31). The equally abrupt decrease in landings between 1949 and 1950 was due, first, to increased imports of low-cost vitamin A oil from foreign sources, principally from Japan, and, second, to the development of synthetic vitamin A.

Most of the ocean catch of grayfish has been made by otter trawl vessels (Figure 32). Off Oregon, fishing occurs mainly during the fall, winter, and spring, when large numbers of the fish appear on the trawl grounds. Oregon trawlers fished for grayfish from Coos Bay to Vancouver Island, whereas

Table 16.—Commercial catches (round weights estimated primarily from amounts of livers landed) of grayfish *(Squalus acanthias)* in Oregon and Washington, 1937-63

Year	Catch		
	Oregon	Washington	Total
	Pounds	*Pounds*	*Pounds*
1937	--	1,620,000	1,620,000
1938	--	578,000	578,000
1939	--	2,365,000	2,365,000
1940	1,244,000	3,347,000	4,591,000
1941	5,084,000	23,980,000	29,064,000
1942	1,313,000	17,374,000	18,687,000
1943	2,299,000	23,546,000	25,845,000
1944	4,374,000	41,018,000	45,392,000
1945	2,220,000	23,414,000	25,634,000
1946	3,109,000	22,132,000	25,241,000
1947	2,824,000	15,282,000	18,106,000
1948	4,659,000	12,504,000	17,163,000
1949	3,423,000	10,645,000	14,068,000
1950	703,000	1,928,000	2,631,000
1951	152,000	2,452,000	2,604,000
1952	47,000	3,065,000	3,112,000
1953	37,000	2,405,000	2,442,000
1954	39,000	2,012,000	2,051,000
1955	0	1,935,000	1,935,000
1956	57,000	1,526,000	1,583,000
1957	24,000	1,861,000	1,885,000
1958	65,000	4,233,000	4,298,000
1959	64,000	3,092,000	3,156,000
1960	47,000	1,378,000	1,425,000
1961	50,000	791,000	841,000
1962	10,000	763,000	773,000
1963	0	867,000	867,000

Sources: Alverson and Stansby (1963) for years 1937-59, and United States Fish and Wildlife Service, Fishery Statistics of the United States for 1960-63.

Washington trawlers fished for them in Puget Sound and in coastal waters from Grays Harbor, Washington, to Hecate Strait, British Columbia. In recent years, most of the grayfish have been caught in Puget Sound with only sporadic catches being taken in coastal waters off Oregon and Washington.

(2) Soupfin shark.—Soupfin shark *(Galeorhinus zyopterus)* are found from Southern California to Northern British Columbia. They derive their name from the fact that their fins make a soup highly prized by the Chinese.

Soupfin shark formerly were eagerly sought by fishermen because of the high prices paid for their livers, the oil of which has an unusually high content of vitamin A. The fishery began off California, where it reached a peak in 1937. It expanded into Oregon and Washington waters about 1940 or 1941, with the largest catches (over 2,000,000 pounds) being taken by Oregon-based vessels in 1943 and the largest catches (over 5,000,000 pounds) being taken by Washington-based vessels in 1942 (Table 17). The catches were calculated primarily from the amounts of livers landed. Landings fell rapidly after World War II, and during 1955-63 Oregon-Washington annual catches averaged only about 5,000 pounds.

Soupfin shark were first caught in Pacific Northwest waters with modified halibut longline gear, which is fished on the ocean bottom, generally in depths of less than 100 fathoms. Diver and floater gill nets came into use about 1941. Diver nets, about 400 fathoms long, were set on the bottom in depths of from 20 to 80 fathoms. Sets were most successful during the winter months (Westrheim, 1950). Floater gill nets became important about 1945, when it was discovered that soupfin shark could be caught near the surface up to 100 miles offshore in the spring and summer. Floater nets, which were from 750 to 1,600 fathoms long, were fished at night from 3 to 11 fathoms beneath the surface.

Figure 31.—Removing livers from grayfish. The livers are placed in 5-gallon cans to facilitate storage on the vessel and further handling.

Figure 32.—Grayfish being emptied from cod end of a trawl net. Although grayfish may reach a length of 5 feet, the average length is much smaller as shown here.

Table 17.—Commercial catches (round weights primarily estimated from amounts of livers landed) of soupfin shark *(Galeorhinus zyopterus)* by vessels based in Oregon and Washington, 1940-63

Year	Catches		
	By Oregon-based vessels	By Washington-based vessels	Total
	Pounds	*Pounds*	*Pounds*
1940	361,000	121,000	482,000
1941	1,093,000	1,472,000	2,565,000
1942	1,458,000	5,214,000	6,672,000
1943	2,272,000	3,805,000	6,077,000
1944	1,667,000	3,237,000	4,904,000
1945	587,000	1,410,000	1,997,000
1946	856,000	779,000	1,635,000
1947	667,000	583,000	1,250,000
1948	408,000	660,000	1,068,000
1949	538,000	572,000	1,110,000
1950	165,000	126,000	291,000
1951	8,000	109,000	117,000
1952	3,000	15,000	18,000
1953	1,000	18,000	19,000
1954	1,000	37,000	38,000
1955	0	10,000	10,000
1956	0	1,000	1,000
1957	14,000	1,000	15,000
1958	0	7,000	7,000
1959	0	2,000	2,000
1960	3,000	2,000	5,000
1961	trace	1,000	1,000
1962	0	trace	trace
1963	2,000	2,000	4,000

Sources: United States Fish and Wildlife Service, Fishery Industries of the United States for years 1940-41, and Fishery Statistics of the United States for 1942-63.

2. Shellfish

a. Crustaceans.—The principal crustaceans taken commercially in this area are pink shrimp and Dungeness crab.

(1) Pink shrimp.—The pink, or ocean pink, shrimp *(Pandalus jordani)* is found from Southern California to Central Alaska (Figure 33). Pink shrimp primarily live in depths of from 40 to 100 fathoms on bottoms consisting of green mud or green mud and sand. On occasion, they apparently leave the bottom to spend an unknown amount of time at intermediate depths. When this happens, the shrimp are not available to the fishing gear.

The first commercial landings of pink shrimp occurred in Morro Bay, California, in 1951. Landings of pink shrimp in California averaged about 2,000,000 pounds annually during 1960-63. Although several tons of shrimp were landed in Coos Bay and at Garibaldi, Oregon, in 1952, a major fishery did not develop in Oregon and Washington until 1957, when 2,790,000 pounds was landed (Table 18). During 1955-63, Oregon accounted for about 43 percent, and Washington for the remaining 57 percent, of the landings. Pink shrimp are mainly used in cocktails, either in a fresh or in a canned form.

Table 18.—Commercial landings of ocean-caught pink shrimp in Oregon and Washington, 1955-63

Year	Landings		
	Washington	Oregon	Total
	Pounds	*Pounds*	*Pounds*
1955	0	23,000	23,000
1956	40,000	6,000	46,000
1957	2,387,000	403,000	2,790,000
1958	6,657,000	1,523,000	8,180,000
1959	2,943,000	2,734,000	5,677,000
1960	1,781,000	1,149,000	2,930,000
1961	1,437,000	1,464,000	2,901,000
1962	1,367,000	2,777,000	4,144,000
1963	956,000	3,028,000	3,984,000

Source: United States Fish and Wildlife Service, Fishery Statistics of the United States for years 1955-63.

Harvesting and processing gear have evolved considerably during the short history of the fishery. At first beam trawls (socklike nets held open across the mouth by rigid beams of wood or pipe) were used to harvest pink shrimp. The more efficient Gulf of Mexico shrimp trawls (small otter trawls with an otter board attached to each wing of the net) soon came into use, and all pink shrimp now harvested off Oregon and Washington are caught with this type of gear. Another development contributing to the efficiency of the fishery was the installation of shrimp-peeling machines at various Washington and Oregon ports. During the 1958 peak, 11 machine peelers and 51 boats were operating in the fishery. By 1961, however, only 4 peelers and 19 boats (Magill and Erho, 1963) were in operation.

Until 1961, grounds off Grays Harbor, Washington, were the best producers of shrimp, accounting for 51 percent of the total landings in Oregon and Washington. The second highest producing grounds were those between the Columbia River and Cape Perpetua, which, during 1956-61, accounted for about 33 precent of the catches by Oregon and Washington boats. In the same 6-year period, grounds between Willapa Bay and the Columbia River produced only 4 percent of the catches. Off Northern Oregon, the best producing grounds were those between the Columbia River and Cape Lookout, although since 1958 their importance in relation to other Oregon grounds, particularly those off Coos Bay, has decreased markedly.

Figure 33.—Conveyor for use in grading pink shrimp by size.

In recent years, the relatively small landings of pink shrimp have been associated with declines in availability and reduced market demands. Whether the declines in availability are consequences of fairly intense fishing, or whether they are due primarily to such natural factors as changed oceanographic conditions and increased predation, is not known.

(2) Dungeness crab.—Dungeness crabs *(Cancer magister)* are found from Magdalena Bay in Baja California, Mexico, to Northwestern Alaska and range from the shallow waters of bays to open ocean. Most crabs are harvested commercially at depths of from 2 to 25 fathoms. Dungeness crabs favor sandy bottoms but are found on most other bottoms as well.

Investigations suggest that stocks of Dungeness crabs are not harmed by intensive fishing as long as only males above prescribed size are harvested; therefore, size limits have been established that allow some 80 percent of the males to mate at least once before they are harvested. In Oregon and Washington, regulations prohibit retention of females, yet allow almost unrestricted harvesting of ocean-caught males that are 6-1/4 inches in carapace width. 90 percent or more of the marketable-sized males available during a single season has been harvested without affecting the next year's supply.

Pots account for most of the commercial crab catch. The pots are formed of circular iron frames (Figure 34) around which strips of rubber innertube are wrapped to serve as insulation. Wire-mesh netting encloses the rubber-insulated frames. A funnel leads into the center of the pot, where bait is suspended to attract the crabs. Individual boats employ up to 900 pots, which are hauled, baited, and reset at intervals of from 1 to 7 days, depending upon fishing success and the weather.

Laws prohibit crabs being marketed during the primary molting season because soft-shell crabs yield meat of poor quality. In the ocean, molting occurs during the fall, varying somewhat according to locality. As a result of the intensive fishery, most of the commercial catch (Figure 35) is taken during the first 2 months of the season, after which time the marketable supply decreases rapidly.

Fluctuations in catch from year to year are caused primarily by a lesser abundance of crabs. Although the first commercial crab landings were reported in the late 1800's, a significant fishery did not develop in Oregon and Washington coastal waters until the late 1920's. Coastal landings were high during the late 1940's, reaching, in 1948, a combined maximum for Oregon and Washington of almost 31,000,000 pounds. During 1956-60, Oregon-Washington coastal landings ranged from 15,100,000 to 22,800,000 and averaged 18,600,000 pounds annually (Table 19), with Columbia River district ports accounting for 18 percent of the total.

Figure 34.—Dungeness crab pots on dock at Newport, Oregon.

Table 19.—Average annual commercial landings of Dungeness crab from Oregon and Washington coastal waters (excluding Puget Sound) and percent of coastal landings made in Columbia River district ports, 1928-63

Years	Landings	Relative landings in Columbia River district
	Million pounds	*Percent*
1928-30	1.8	1
1931-35	2.6	–
1936-40	7.6	–
1941-45	10.9	–
1946-50	18.4	19
1951-55	12.4	18
1956-60	18.6	18
1961-63	11.4	16

[1] Relative landings in Columbia River ports prior to 1946 are omitted because the data were ambiguous on this point.

Sources: United States Fish and Wildlife Service, Fishery Industries of the United States for years 1928-41, and Fishery Statistics of the United States for 1942-63.

Until 1915, over half the crabs landed in Oregon came from the vicinity of the mouth of the Columbia River; the remainder was taken in Coos, Alsea, Yaquina, and Tillamook Bays (Figure 36) (Waldron, 1958). Crabs were first taken in quantity in the open ocean off Oregon in 1915; today, well over 90 percent of Oregon catches is taken from the ocean. Ocean waters adjacent to the mouth of the Columbia River still contribute substantially to Oregon catches. In 1956-60, about 29 percent of the total Oregon landings of Dungeness crab was made in Columbia River district ports. In Washington, the major fishing grounds for Dungeness crabs extend from the Columbia River to north of Grays Harbor. In 1956-60, Washington landings in Columbia River district ports ranged between 4 and 10 percent of the State total for coastal crab, but additional catches from the vicinity of the Columbia were landed in Willapa Harbor, Washington. Frozen crab meat is the primary product from Dungeness crab. Lesser amounts are frozen in the shell, marketed whole, or canned.

b. Mollusks.—The principal mollusks taken commercially in this area are clams and oysters.

(1) Clams.—Bay clams and razor clams *(Siliqua patula)* have been used as food since earliest times and now support major commercial fisheries in Oregon and Washington. Bay clams, which are harvested with shovels and rakes, include the horseclam *(Schizothaerus nuttalli)*, the cockle *(Clinocardium nuttalli)*, the soft-shell clam *(Mya arenaria)*, the butter clam *(Saxidomus giganteus)*, the native littleneck *(Protothaca staminea)*, and the Manila clam, or Japanese littleneck, *(Venerupis japonica)*. Razor clams of Oregon and Washington are harvested with specialized narrow pointed shovels (called "clam guns") and cylindrical cans or tubes almost exclusively on beaches along the open coast. These beaches are composed mainly of fine sand and are exposed to the full force of the surf. Small beds of razor clams are also found on the inland side of spits at the mouths of some of the larger bays.

Figure 35.—Crab boat preparing to unload catch into live boxes at Westport, mouth of Grays Harbor, Washington.

Figure 36.—Whole-cooked crab being rinsed and cooled after being cooked in brine water.

(a) *Bay clams.*—Tillamook, Yaquina, and Coos Bays account for most of Oregon's bay-clam production. The largest commercial production of bay clams in Oregon occurred during the late 1930's, when annual landings of the meat ranged from 77,000 to 93,000 pounds. From 1956 through 1963, Oregon's production of bay-clam meat ranged between 10,000 and 27,000 pounds annually. Eastern soft-shell clams account for most of the production in Oregon.

Most of Washington's commercial take of bay clams is from Puget Sound beaches. Coastal production consists mainly of Manila clams from Willapa Harbor (Figure 37). The commercial bay-clam fishery on the coast of Washington developed much later than that in Oregon. Only sporadic and relatively small landings were made in Washington coastal areas prior to 1950. From 1950 through 1963, Washington coastal production of bay-clam meat ranged between 6,000 and 81,000 pounds annually.

The combined annual landings of bay-clam meat from the coastal districts of Oregon and Washington between 1926 and 1963 are shown in Table 20. The increase in the relative importance of production in Washington in the early 1950's is clearly evident from the table.

Table 20.—Average annual take of bay-clam[1] meat by commercial diggers in coastal districts of Oregon and Washington, 1926-63

Years	Average annual take	Relative take in:	
		Oregon	Washington
	Pounds	*Percent*	*Percent*
1926-30	18,000	92	8
1931-35	33,000	97	3
1936-40	80,000	100	0
1941-45	38,000	100	0
1946-50	46,000	92	8
1951-55	83,000	41	59
1956-60	65,000	30	70
1961-63	29,000	67	33

[1] In Washington, principally Manilas *(Venerupis japonica)*, which yield 25 percent meat; in Oregon, mainly Eastern soft-shell clams *(Mya arenaria)*, which yield 21 percent meat.

Sources: United States Fish and Wildlife Service, Fishery Industries of the United States, for years 1926-41, and Fishery Statistics of the United States for 1942-63.

(b) *Razor clams.*—Razor clams, which are found from Northern California to Alaska, have a characteristic elliptical shape that differentiates them from the other clams in this area (Figure 38). Over 90 percent of the razor clams dug in Oregon is taken on the 18-mile-long Clatsop County beaches between the Columbia River and Tillamook Head. During World War II, military restrictions on the beaches, together with fewer diggers, resulted in low harvest. Immediately following the war, the amounts increased markedly, reaching 90,000 pounds of meat in 1948.

The razor-clam fishery in Oregon is considerably smaller than that in Washington. During 1956-60, Oregon commercial landings averaged a little over 67,000 pounds live weight, or 28,000 pounds of meat, annually, which was a little over 8 percent of the Washington commercial landings during this period. The razor clams dug for recreation in Oregon nearly equalled those dug commercially during the late 1940's. The recreational fishery now takes from 600,000 to 2,100,000 clams annually, an amount that greatly exceeds the amount dug commercially (personal communication from D. Demory, Fish Commission of Oregon).

Figure 37.—Clam diggers. Otherwise inaccessible bay-clam beaches are reached by small outboard powered boats.

Figure 38.—Razor clams are dug day or night when tides are favorable.

Razor-clam beaches (Figure 39) stretch almost continuously from the north entrance of the Columbia River to the beaches some 60 miles up the Washington Coast. Commercial production of razor clams (Figure 40) in Washington averaged almost 2,000,000 pounds live weight, or over 800,000 pounds of meat, annually during the late 1930's. Between 1950 and 1960, commercial landings in Washington averaged 293,000 pounds of meat annually. The recreational fishery for razor clams on Washington beaches has grown spectacularly. In 1962, some 683,000 recreational diggers dug over 11,000,000 razor clams on Washington beaches (Tegelberg, 1962). The commercial and Indian harvest in 1962 probably amounted to only about 20 percent of the number of clams taken by the recreational fisherman.

Statistics on the amount of razor clams dug are available starting with 1904, when 133,000 pounds of meat were reported for Washington and 31,000 pounds of meat were reported for Oregon. In 1927, commercial landings reached an alltime high of slightly over 2,000,000 pounds of meat for Oregon and Washington combined. During 1951-63, Oregon-Washington commercial landings averaged 345,000 pounds of meat annually (Table 21).

Table 21.—Average annual take of razor-clam[1] meat by commercial diggers in Oregon and Washington, 1928-63

Years	Average annual take	Relative take in:	
		Oregon	Washington
	Pounds	*Percent*	*Percent*
1928-30	1,193,000	5	95
1931-35	712,000	7	93
1936-40	936,000	11	89
1941-45	395,000	7	93
1946-50	614,000	13	87
1951-55	383,000	25	75
1956-60	358,000	8	92
1961-63	258,000	5	95

[1] Based on a meat yield of 42 percent.
Sources: United States Fish and Wildlife Service, Fishery Industries of the United States, for years 1928-41, and Fishery Statistics of the United States for 1942-63.

(2) Oysters.—The Western, or Olympia, oyster *(Ostrea lurida)* was undoubtedly utilized by peoples inhabiting the Pacific Northwest from earliest times. It formerly flourished in Willapa Harbor, Washington, and in Yaquina Bay, Oregon, but is now harvested in substantial quantities only in the southern part of Puget Sound. The virtual disappearance of the Olympia oyster from Willapa Bay and Yaquina Bay has been attributed to several factors, including overfishing, severe winter freezes, pollution, and the siltation of beds—a result of the deforestation of neighboring areas.

Oyster farming is important in both Washington and Oregon. Experimental plantings of the Eastern oyster *(O. virginica)* on the Pacific Coast were not successful, so the Pacific, or Japanese, oyster *(Crassostrea gigas)* was imported. Trial plantings of Pacific oysters proved successful. This species now forms the mainstay of the Pacific Northwest oyster industry. Water temperatures in the Pacific Northwest often are lower than those required for successful seed production of the Pacific oyster; consequently, to ensure adequate seed stock, oyster growers import the seed stock from Japan each year.

Pacific oysters are grown in many bays along the Oregon Coast. The habitat is particularly favorable in Tillamook, Netarts, Yaquina, and Coos Bays. Willapa Harbor has been the largest producer in Washington, followed in importance by Puget Sound and Grays Harbor, respectively.

Figure 39.—Razor-clam beach. Redigging hundreds of marked razor clams annually from staked study areas has shown they do not migrate horizontally.

Figure 40.—Buyer weighs commercial fisherman's razor clams.

Production of oyster meat from Oregon-Washington coastal districts (excluding Puget Sound) averaged about 7,400,000 pounds annually during 1936-63. Over 90 percent of the combined production has come from Washington beds (Table 22). Fisheries scientists are now attempting to determine causes for a marked decrease recently in survival of Pacific oysters.

Table 22.—Average annual commercial production of oyster[1] meat in coastal districts of Oregon and Washington, 1926-63

Years	Average annual production	Relative amount produced in:	
		Oregon	Washington
	Pounds	*Percent*	*Percent*
1926-30	86,000	5	95
1931-35	2,354,000	1	99
1936-40	7,413,000	4	96
1941-45	8,328,000	6	94
1946-50	7,812,000	4	96
1951-55	7,458,000	9	91
1956-60	6,783,000	8	92
1961-63	5,677,000	7	93

[1] Entirely Pacific oysters (*Crassostrea gigas*) in recent years based on 12 percent yield.
Sources: United States Fish and Wildlife Service, Fishery Industries of the United States for years 1926-41, and Fishery Statistics of the United States for 1942-63.

B. MAMMALS

1. Sea Lions and Seals

Sea lions are found off the coasts of Washington and Oregon, particularly on the rocks off the Oregon Coast. Although their commercial use is limited, they do have a recreational and esthetic value in the pleasure they give to tourists (Figure 41).

Seals frequent the bays along the Oregon Coast. Sealers in Tillamook Bay catch seal pups by surrounding them with nets and then removing them with dip nets to sell to zoos.

2. Whales

A whaling operation was tried from 1911 to 1925 at Bay City, Washington, on the south side of Grays Harbor. From 2 to 4 killer ships landed an average of 193 whales annually during the 14-year period of the fishery (Scheffer and Slipp, 1948). The whaling season usually extended from April to October, but most of the whales were taken in August. Humpback and finback whales together accounted for over 90 percent of the landings; sperm, sei, and bottlenose whales made up the remainder. The operating radius of the killer vessels was about 135 miles from Bay City; however, occasional trips were made to Southern Oregon or to Vancouver Island (Scheffer and Slipp, 1948).

The first known whaling venture out of the Columbia River was begun in 1961 by the converted halibut schooner *Tom and Al* armed with a 90-millimeter whaling harpoon gun (Figure 42). 4 whales were taken by the *Tom and Al* in 1961 and towed to a reduction plant in Warrenton, Oregon. The fishery has been continued on a limited scale by the *Tom and Al* with temporary assistance, in 1962, from the *Sheila*, a converted 110-foot naval vessel.

Humpback and finback whales weighing from 30 to 50 tons apiece are now the main species taken. Only waters within about 100 miles of the coast are included in the area of operations.

The higher quality whale meat is used as food for mink; the blubber is rendered into oil; and the bone and the remainder of the meat are made into meal for poultry and animal feed.

Compared with whaling activities elsewhere in the world, the venture out of the Columbia River is small. It demonstrates, however, that whales are available near the Columbia and that they may be successfully harvested.

Figure 41.—Near Cape Meares, Oregon, tourists aboard a commercial fishing vessel find sea lions an attraction.

Figure 42.—The *Tom and Al* returning after a successful whale hunt.

SUMMARY

Fresh-Water Species

Fresh-water crawfish and carp are taken in considerable numbers by commercial fishermen. Crawfish are caught with pots and traps, mainly in the Cowlitz and Columbia Rivers near Longview, Washington, and in the Willamette and Sandy Rivers in Oregon. Commercial harvests of crawfish reached a maximum in the early 1900's, when average annual landings approached 200,000 pounds. During 1956-63, annual commercial landings averaged less than 30,000 pounds.

Carp are harvested commercially with beach seines and, to a limited extent, with gill nets in several lakes within the Columbia River Basin, in McNary Pool above McNary Dam, and in the sloughs of the lower Columbia. The construction of dams has increased the number and size of favorable habitats available to carp. Commercial landings in 1961-63 averaged over 1,000,000 pounds annually.

Anadromous Species

Salmon and steelhead trout have been the most valuable of the anadromous species. Chinooks have dominated salmon catches throughout the history of the river fishery. Gill nets have always been the primary commercial gear used by white men. Commercial landings of salmon and steelhead trout in the Columbia from 1956 through 1963 amounted to about 7,000,000 pounds annually, compared with annual landings that exceeded 30,000,000 pounds during 1891-1930. Large numbers of chinook and coho salmon of Columbia River origin are also caught in the ocean by commercial trollers.

Other important anadromous species include shad, eulachon (Columbia River smelt), sturgeon, and Pacific lamprey.

Shad are presently harvested commercially by gill nets. During 1961-63, annual commercial harvests averaged 945,000 pounds; in 1962 and 1963, record numbers of shad were counted at Bonneville Dam and at The Dalles.

Eulachon are taken commercially by gill nets as they ascend the main Columbia and by dip nets after they enter tributary rivers and streams. The Cowlitz River usually accounts for about 50 percent of the total landings. Recent commercial landings of eulachon range from 1,000,000 to 2,000,000 pounds annually and exceed landings of all other species in the Columbia except chinook salmon.

Both the white and the green sturgeon are found in the Columbia. The white sturgeon is more important than the green sturgeon. Commercially caught sturgeon are usually taken in gill nets incidental to salmon fishing. When white men arrived on the Columbia, sturgeon were so abundant that they were a nuisance in the salmon fishery; and in some areas efforts were made to erradicate them. The commercial production peaked at 5,500,000 pounds in 1892, but landings fell rapidly thereafter. Sturgeon abundance apparently has increased in recent years. Since World War II, commercial landings have ranged between 250,000 and 500,000 pounds annually.

Pacific lamprey were harvested for reduction purposes at Willamette Falls from 1941 through 1952. Highest production occurred in 1946, when almost 400,000 pounds were taken. An ingenious system of troughs and traps was used to collect lamprey as they ascended the fish ladders. Lamprey are now used as bait for sturgeon fishing.

Marine Species

As food resources, marine species greatly exceed the Columbia's fresh-water and anadromous species. Past and present fisheries for marine species include those for albacore, Pacific sardine, Pacific herring, northern anchovy, Pacific halibut, sablefish, flatfishes, rockfishes, grayfish or spiny dogfish, soupfin shark, pink shrimp, Dungeness crab, clams, oysters, and whales.

The Pacific Northwest troll fishery for albacore typically begins in mid-July between Newport, Oregon, and the mouth of the Columbia and gradually extends northward to Washington and Southern Vancouver Island, British Columbia. A record high of over 34,000,000 pounds of albacore was landed in Oregon and Washington in 1944; over 1/2 was discharged at ports on the Columbia River. The 1956-63 landings of albacore in Washington and Oregon averaged almost 8,000,000 pounds annually.

Pacific sardines were caught by purse seines for use in reduction plants from 1935 until the late 1940's. Landings were largest in the late 1930's, when Oregon-Washington production exceeded 80,000,000 pounds in some years.

Small amounts of Pacific herring are caught by seines, gill nets, and dip nets in the bays and inshore waters along the coasts of Oregon and Washington. Production from Oregon-Washington coastal waters in recent years has averaged less than 50,000 pounds annually.

Dense schools of anchovy are found in coastal waters throughout the year. Anchovies were the most important species used in the live-bait fishery for albacore in the late 1940's. Although practically unharvested now, anchovies perhaps could support a relatively large fishery.

The longline fishery for Pacific halibut is 1 of the oldest on the Pacific Coast: as early as 1885, commercial landings were made from Oregon waters. Large catches of several million pounds were taken from ocean banks off the Columbia River during the early years of the fishery. These heavy yields, which were derived from accumulated stocks of mature fish, were short-lived. The 1956-63 harvests of Pacific halibut from grounds between Willapa Bay, Washington, and Northern California averaged about 333,000 pounds annually.

A longline fishery for sablefish began off Washington in the 1890's and quickly expanded into Oregon waters. Since the early 1940's, an increasing share of the catch has been taken by otter trawls. Grounds between Tillamook Head, Oregon, and the Columbia River contributed annual catches estimated at about 250,000 pounds during the 1940's and early 1950's.

The otter trawl fishery became important in 1940, when World War II created an additional demand for fishery products. Species harvested include a variety of flatfishes, rockfishes, "cods," and elasmobranchs. The most intense trawling off Oregon occurs between the Columbia River and Tillamook Head. During 1950-63, Washington landings, excluding elasmobranchs, averaged about 39,200,000 pounds annually; during the same period, Oregon averaged about 23,100,000 pounds. The 1956-60 yields from a 33-mile strip adjacent to the mouth of the Columbia River averaged 10,750,000 pounds annually.

In response to demands for vitamin A, a large Pacific Northwest fishery for grayfish (spiny dogfish) livers developed during World War II. The fishery declined rapidly in postwar years when other vitamin sources were found. Most grayfish were harvested with otter trawls. Off Oregon, they were fished mainly in the fall, winter, and spring. Over 80 percent of the Oregon landings was made in Columbia River ports. Annual landings (equivalent round weights) during 1941-49 averaged 3,250,000 pounds in Oregon and over 21,000,000 pounds in Washington.

During and immediately following World War II, soupfin shark were sought for their livers, which have a high vitamin A content. Longlines and gill nets were the primary gear used. Largest landings were 2,250,000 pounds (equivalent round weight) in Oregon in 1943 and 5,250,000 pounds (equivalent round weight) in Washington in 1942.

A major trawl fishery for pink shrimp began in Oregon and Washington in 1957. The Oregon-Washington landings reached a peak in 1958 of over 8,000,000 pounds and in 1960 through 1963 ranged from 3,000,000 to 4,000,000 pounds annually. Grounds off Grays Harbor, Washington, historically have been the best producer, followed by those between the Columbia River and Cape Perpetua, Oregon.

An important pot fishery for Dungeness crabs occurs in ocean waters—mainly at depths of from 2 to 25 fathoms—off Oregon and Washington. The 1956-60 landings for Oregon-Washington coastal waters have averaged 19,000,000 pounds annually. Grounds adjacent to the mouth of the Columbia River have long been major producers of crabs.

Bay clams and razor clams support commercial fisheries in Oregon and Washington. Yaquina, Tillamook, and Coos Bays account for most of the bay clams dug in Oregon. Bay clams from Washington's coastal district are dug mainly in Willapa Harbor. The Oregon-Washington commercial take of bay-clam meats from coastal districts averaged 65,000 pounds annually during 1956-60. Over 90 percent of Oregon's razor-clam harvest has been taken from an 18-mile-long strip of ocean beach between the Columbia River and Tillamook Head. Razor-clam beaches stretch almost continuously from the Columbia River northward for some 60 miles along the Washington Coast. The Oregon-Washington commercial take of razor-clam meats averaged 358,000 pounds annually during 1956-60.

The Pacific oyster is the mainstay of the Pacific Northwest oyster-farming industry. In Oregon, Pacific oysters are grown primarily in Tillamook, Netarts, Yaquina, and Coos Bays. Willapa Harbor has been the largest producer in Washington. Production of Pacific-oyster meats from Oregon-Washington coastal districts averaged about 7,400,000 pounds annually during 1936-63, with over 90 percent coming from Washington beds.

Sea lions, particularly those inhabiting the rocks off the coast of Oregon, are of commercial value as a tourist attraction. Seal pups are taken in Tillamook Bay and sold to zoos.

A whaling operation was tried from 1911 to 1925 at Bay City, Washington. From 2 to 4 killer ships landed an average of 193 whales, mostly humpback and finback, annually. Occasional trips were made to Southern Oregon and Northern Vancouver Island; however, most whaling was done within a 135-mile radius of Grays Harbor, Washington. The first whaling venture out of the Columbia River began in 1961 and has continued on a limited scale since then. Relatively small killer vessels operate in waters within 100 miles of the coast in search of humpback and finback whales.

ACKNOWLEDGMENT

Although responsibility for the accuracy of this report is mine, its preparation was facilitated by advice and suggestions received from others, particularly the following: D. Demory, R. E. Loeffel, A. R. Magill, and C. D. Snow of the Fish Commission of Oregon; E. K. Holmberg, D. E. Kauffman, H. C. Tegelberg; D. Ward, and H. O. Wendler of the Washington State Department of Fisheries; F. H. Bell of the International Pacific Halibut Commission; and F. C. Cleaver, W. L. Peck, K. Weber, and P. D. Zimmer of the Bureau of Commercial Fisheries.

Photographs were furnished as indicated in the following:

From outside sources.—Figures 2, 10, 25, 31, and 32, Pacific Fisherman; Figure 3, H. A. Laney; Figures 11, 15, 29, 33, 35, 37 and 40, Washington State Department of Fisheries; Figure 16, Ivan Donaldson, United States Army Corps of Engineers; Figure 17, A. Pierce (courtesy of Ivan Donaldson); Figures 23 and 24, The Jones Photo Company, Aberdeen, Washington; Figures 38 and 39, The Seattle Times; Figure 41, Thomas W. L. Sanford; Figure 42, Bio-products, Inc., Warrenton, Oregon.

From United States Fish and Wildlife Service sources.—Figures 1, 7, and 8, R. Matheny.

From Bureau of Commercial Fisheries sources.—Figure 5, G. M. Kaydas; Figure 6, D. R. Orcutt; Figure 9, E. M. Maltzeff; Figure 12, R. L. Hacker; Figure 13, H. Heyamoto; Figures 14, 30, 34, and 36, F. Bruce Sanford; Figure 19, R. L. McNeely; Figures 20, 22, 26, and 28, unidentified; Figure 21, R. J. Wahle; Figure 27, A. T. Pruter.

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