Chemical Characteristics of Fish Caught in the Northeast Pacific Ocean

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INTRODUCTION

Vast differences in chemical composition are found in fish—not only between one species and another but also between one individual and another, or even between different parts of the same body. This paper will give the reader a general idea of the chemical makeup of the fishery resources of the waters off Oregon, Washington, and Alaska. Differences in the composition of the various species inhabiting these waters will be stressed.

Such differences in chemical composition are due to a variety of factors, most of which lead back to what and how much feed the fish has been consuming. Thus, fish taken during winter when feed may not be plentiful usually have a different chemical composition from individuals of the same species captured during the summer when feed is more plentiful. Similarly, fish that undergo protracted spawning migrations during which little or no feed is consumed will have a chemical composition quite different from fish of the same species taken at other times in their life cycles. Juvenile fish may have chemical compositions differing from those of adults, which in turn may be related to feeding habits—but such differences are apt to be small or inconsistent.

Composition of fish may also depend upon factors not related to feeding habits. For example, the temperature of the water in which the fish live determines the chemical makeup to some extent. This factor goes beyond the influence of environmental temperature upon feed conversion. The temperature of the fish's environment may result in the laying down within the fish of different types of components of which the best example is the type of fat. Fish inhabiting cold waters usually deposit fat of a more unsaturated type, having a lower melting point than fish of the same species living in warmer waters.

There is no doubt that, environmental conditions aside, the different species adapt their chemical composition to conditions which the species encounter during their life cycles. Species which must move about rapidly and over wide distances must provide energy sources to draw upon, and such species will contain much higher fat content (which can be drawn upon as an energy source) than is to be found in fish of more lethargic movements, such as bottom dwellers.

Because of the very wide variation in composition of fish (in order to have even an approximate idea of the effect of such variables as season or geographic area of catch upon composition), a tremendously large number of samples must be analyzed for us to be able to know with any certainty the effects of such variables. Such extensive analyses have not been made for species inhabiting the waters of the northeastern Pacific Ocean. Most of the data presented will be set forth in a species-oriented way to show the range of values encountered throughout the region.

The discussion of composition deals with adult finfish, shellfish, and crustaceans. Nearly all data have been collected in connection with their usefulness to the commercial fisheries. This means there are virtually no data on the composition of larval forms nor of plankton. Furthermore, since no commercial operations have ever been carried out in the region on utilization of seaweed, there are no data upon which we can draw to show the chemical composition of this class of sea life.

In presenting the information, the proximate composition (i.e., the content of moisture, oil (or fat), protein, and ash) will be discussed first. The available data are far more extensive in these types of analyses than for any others. This discussion will be followed by a consideration of the kinds of chemical compounds which make up the broader classes considered in proximate composition. This entails discussion of the amino acid makeup of the protein of fish, the fatty acids present in the oil or fat, and the mineral elements which are collectively reported as ash. Finally, a presentation will be given of chemical components such as vitamins which occur in only trace amounts.

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PROXIMATE COMPOSITION

General Considerations

Proximate composition has been widely used as a general assessment of the composition of foods for more than a century. Proximate composition of American foodfish was determined by Atwater and Wood in a very thorough way, the work being carried out during the early 1870's at Wesleyan University in Connecticut under the sponsorship of the U.S. Commission of Fish and Fisheries, the predecessor agency of National Marine Fisheries Service (Atwater, 1892). The work was exhaustive and complete for most species caught on the Atlantic coast; some species were included from inland waters, such as the Great Lakes. These data are still in general use in tables of food composition which include fish.

Unfortunately, these analyses included very few species taken in the waters off Oregon, Washington, and Alaska. From the early 1930's to the present time, several thousand analyses of the proximate composition of fish inhabiting the waters of the northeastern Pacific Ocean have been made in laboratories of the National Marine Fisheries Service (and predecessor agencies). Some of these analyses have been published by Thurston and others, (Thurston, 1958, 1961a, 1961b, and 1961c; Thurston and MacMaster, 1960; Thurston and Newman, 1962; Karrick and Thurston, 1964 and 1968; and Nelson and Thurston, 1964), but a considerable part of the available data has never been published. The data used in this section are taken from this published and unpublished reservoir of data of the National Marine Fisheries Service.

As has been indicated, although many thousands of analyses have been made of fish in the area of current concern, because of the high variability and many factors involved, the data are sufficient only to establish the general range of values for the different species.

The data are presented in Tables 1 and 2. Table 1 lists the species by common and scientific name. Table 2 gives an idea of the sample size as well as the values found for the proximate composition. The geographic area where the fish were caught, if known, is also given.

The sample size is indicated by giving the number of lots of fish, the number of individual fish, and the number of chemical analyses made. Sampling methods differed, depending upon the person(s) conducting the investigation under different circumstances over a span of more than 40 years. Anywhere from 1 to 50 or more individual fish were procured from some given areas. In some cases all the fish were mixed (after grinding and other preliminary work) together and a single analysis made. In other instances, individual analyses were made upon samples from each fish.

Table 1.—Species of fish analyzed for proximate composition.

Common name	Scientific name
Abalone	*Haliotis*
Albacore	*Thunnus alalunga*
Clam	
Butter	*Saxidomus nuttalli*
Cockle	*Cardium corbis*
Littleneck	*Protothaca staminea*
Cod, Pacific	*Gadus macrocephalus*
Crab	
Dungeness	*Cancer magister*
King	*Paralithodes camschatica*
Cucumber, red, sea	*Stichopus californicus*
Dogfish, spiny	*Squalus acanthias*
Eulachon	*Thaleichthys pacificus*
Flounder	
Arrowtooth	*Atheresthes stomias*
Starry	*Platichthys stellatus*
Geoduck	*Panope generosa*
Halibut, Pacific	*Hippoglossus stenolepis*
Herring, Pacific	*Clupea harengus pallasi*
Lingcod	*Ophiodon elongatus*
Octopus	*Paroctopus hongkongensis*
Oyster	
Japanese	*Crassostrea gigas*
Native	*Ostrea lurida*
Pollock, walleye	*Theragra chalcogramma*
Ratfish	*Hydrolagus colliei*
Rockfish	
Black	*Sebastes melanops*
Darkblotched	*Sebastes crameri*
Rougheye	*Sebastes aleutianus*
Bocaccio	*Sebastes paucispinis*
Chilipepper	*Sebastes goodei*
Flag	*Sebastes rubrivinctus*
Greenstriped	*Sebastes elongatus*
Shortspine thornyhead	*Sebastolobus alascanus*
Canary	*Sebastes pinniger*
Pacific ocean perch	*Sebastes alutus*
Yelloweye[1]	*Sebastes ruberrimus*
Rosy	*Sebastes rosaceus*
Yellowtail	*Sebastes flavidus*
Widow	*Sebastes entomelas*
Sablefish	*Anoplopoma fimbria*
Salmon	
Chum	*Oncorhynchus keta*
Chinook	*Oncorhynchus tshawytscha*
Pink	*Oncorhynchus gorbuscha*
Coho	*Oncorhynchus kisutch*
Sockeye	*Oncorhynchus nerka*
Seal, northern fur	*Callorhinus ursinus*
Sea lion, northern	*Eumetopias jubatus*
Shad, American	*Alosa sapidissima*
Shrimp, pink	*Pandalus borealis*
Skate	*Raja* sp.
Sole	
Dover	*Microstomus pacificus*
English	*Parophrys vetulus*
Flathead	*Hippoglossoides elassodon*
Petrale	*Eopsetta jordani*
Rex	*Glyptocephalus zachirus*
Rock	*Lepidopsetta bilineata*
Sand	*Psettichthys melanostictus*
Yellowfin	*Limanda aspera*
Starfish	
Mottled	*Evasterias troschelii*
Purple	*Pisaster ochraceus*
Sunflower	*Pycnopodia helianthoides*
Trout	
Cutthroat	*Salmo clarki*
Dolly Varden	*Salvelinus malma*
Steelhead	*Salmo gairdneri*

[1]Commonly but erroneously referred to as red snapper.

Analyses were mostly performed upon the edible flesh, by which is meant the skin- and bone-free flesh. Unless otherwise stated in Table 2, the analyses refer to such sampling which, in effect, are similar to the analysis of a skinned fillet. When other than edible flesh was analyzed, notation is given in Table 2, column 1. In some species, especially large fish like Pacific halibut, although skin- and bone-free flesh was used in the analyses, the fish was so large that only a portion was used. In such instances, comments are made under the sections discussing results of different classes of species.

In a general way, as has been found for species taken anywhere in the world, there are general types of fish flesh from the standpoint of protein and oil composition. For nutritional purposes, the species can be classified (Stansby, 1962) as: A) low oil-high protein, where the oil content is under 5 percent and the protein content 15-20 percent; B) medium oil-high protein content, with oil running from 5 to 15 percent and protein, 15-20 percent; C) high oil-low protein, in which oil content exceeds 15 percent and protein is under 15 percent; D) low oil-very high protein, where oil content is under 5 percent and protein is above 20 percent; and E) low oil-low protein, where oil content is under 5 percent and protein under 15 percent.

Category B corresponds to fish having composition comparable to meat. For low calorie diets (as for weight reduction), species of fish in category A are especially desirable because of low calorie content (low oil content—lower than in most meats—yet as high a protein content as in other flesh foods). Fish in category D are especially valuable for individuals requiring high protein content since the protein in these species is at higher levels than in other flesh foods. Most species taken in northeastern Pacific waters are in the desirable categories A, B, or D.

Oil and fat are used interchangeably; hereafter, we will use the term oil. The oil content varies to a greater extent

Table 2.—Proximate composition of fish and shellfish.

Species	Origin of sample	No. of lots	No. of fish	No. of anal.	Percent composition: Moisture Max.	Moisture Min.	Moisture Avg.	Oil Max.	Oil Min.	Oil Avg.	Protein Max.	Protein Min.	Protein Avg.	Ash Max.	Ash Min.	Ash Avg.
Abalone, Alaska	SE Alaska	3	72	3	77.5	76.6	76.9	0.7	0.6	0.7	17.5	16.3	17.1	1.8	1.7	1.7
Clam																
Butter	SE Alaska	21	525	21	87.3	79.1	80.0	1.8	0.8	1.23	16.0	9.4	13.0	2.08	1.0	1.7
Cockle	SE Alaska	1	10	3	86.0	79.8	82.4	1.4	0.8	1.0	13.5	10.1	11.8	2.2	1.2	1.6
Little neck	SE Alaska	1	1	1		(79.4)			(1.0)			(13.5)			(2.6)	
Cod																
Grey	Alaska, Wash., & Oreg.	12	113	113	83.2	79.7	81.1	1.10	0.21	0.66	19.1	16.3	17.9	1.65	0.96	1.20
Ling	Wash. & Oreg.	14	105	94	85.1	79.1	81.1	2.31	0.35	0.96	19.4	14.4	17.6	1.31	0.93	1.20
Crab, Dungeness																
(Body)	Wash., Oreg., & N. Calif.	8	84	8	81.3	76.0	78.1	0.92	0.80	0.87	20.4	16.9	19.3	2.02	1.65	1.81
(Leg)	" " " " "	8	84	8	81.8	77.3	78.9	0.89	0.72	0.82	20.0	16.3	18.4	2.12	1.78	1.95
Crab, King																
(Body)	Kodiak Isl.	4	?	4	88.8	83.1	86.1	1.10	0.38	0.60	13.9	8.7	11.6	2.64	1.98	2.34
(Leg)	Kodiak Isl.	4	?	4	90.8	78.9	86.0	1.29	0.44	0.69	—	—	13.5	—	—	—
(Composite)	Kodiak Isl.	12	?	12	80.5	78.2	79.6	1.46	0.94	1.16	19.6	16.8	18.2	2.20	1.64	1.89
Cucumber, Red, sea	SE Alaska	1	4	1		(86.2)			(0.6)			(10.6)			(1.7)	
Dogfish (Flesh)	Straits of Juan de Fuca	2	3	3	73.8	68.4	70.6	13.6	12.7	13.4	19.4	14.6	17.4	0.96	0.54	0.80
(Whole fish)	Lower Pug. Sd.	3	9	7	72.9	67.0	69.5	18.3	10.1	15.3	17.2	15.6	16.3	2.03	1.50	1.77
Eulachon	Col. River	1	16	16	81.3	76.5	79.6	8.98	4.59	6.25	15.3	13.2	14.6	1.40	1.12	1.25
Flounder																
Arrowtooth	SE Alaska, Wash., & Oreg.	3	31	31	81.7	76.1	79.5	4.52	0.78	2.30	18.8	16.3	17.7	1.20	0.99	1.11
Starry	SE Alaska, Wash., & Puget Sd.	9	40	31	85.7	78.4	80.3	3.40	0.40	1.40	20.6	13.4	17.3	1.24	1.06	1.12
Geoduck, Alaskan																
(Syphon)	SE Alaska	1	7	5	81.1	75.4	77.2	1.3	0.5	0.8	16.7	14.2	15.9	6.4	1.3	4.6
(Body)	SE Alaska	1	7	5	80.4	77.1	78.8	3.7	2.8	3.2	15.4	14.7	15.0	1.9	1.6	1.8
Halibut, Pacific	Oreg., Wash., & Alaska	26	29	29	81.2	76.5	78.3	3.32	0.39	0.79	22.5	18.1	20.7	1.52	1.22	1.35
Herring (Flesh)	Brit. Col. & Puget Sd.	2	14	2	70.9	70.0	70.7	13.1	10.8	12.5	—	—	16.0	1.37	1.09	1.28
(Whole)	Kodiak, Pr. Wm. Sd., SE Alaska, & Brit. Col.	13	210	69	80.3	59.8	70.8	23.7	2.2	12.8	19.5	14.2	16.4	2.8	1.6	2.4
Octopus	SE Alaska	2	2	2	85.7	84.0	84.9	0.86	0.80	0.83	14.0	12.3	13.2	1.90	1.26	1.58
Oyster																
Japanese	Alaska	2	46	2		(80.5)			(1.26)			(10.4)			(1.43)	
Native	SE Alaska	1	15	1		(86.3)			(0.5)			(10.6)			(1.9)	
Pollock, Pacific	Bering Sea & NE Pacific Ocean off Alaska	4	60	8	82.8	70.3	81.5	1.3	0.6	0.98	19.3	16.4	18.9	2.7	1.1	1.34
Porpoise	Unknown	1	4	4	66.6	63.8	65.2	5.03	3.24	3.86	27.5	25.6	26.4	3.79	3.37	3.56
Ratfish	SE Alaska	1	10	10	83.3	70.3	75.3	18.6	3.1	10.7	16.1	14.0	15.1	2.0	1.2	1.6
Rockfish																
Black	SE Alaska	2	32	32	82.6	75.0	81.0	3.62	0.57	1.84	18.9	16.2	18.7	1.35	1.01	1.17
Blackmouth	SE Alaska	1	12	2	77.4	76.9	77.1	2.28	2.09	2.19	18.9	20.6	19.8	1.23	1.22	1.23
Blacktip	SE Alaska	1	3	1		(79.6)			(1.27)			(19.3)			(1.63)	
Bocaccio	Wash.	1	15	15	81.2	78.6	80.0	1.62	0.80	1.04	19.5	17.6	18.6	1.25	1.15	1.20
Chilipepper	N. Calif.	1	12	12	78.7	75.8	76.5	2.90	1.55	2.35	21.6	19.6	20.8	1.20	1.04	1.10
Flag	Wash.	1	6	2	79.1	78.6	78.9	1.95	1.60	1.78	18.4	17.9	18.2	1.10	1.09	1.10
Greenstriped	Wash. & Oregon	2	30	16	79.5	77.5	78.5	0.74	20.2	0.73	20.8	19.6	20.3	1.35	1.13	1.21
Idiot	Wash. & Oregon	1	13	13	81.8	79.3	80.7	3.38	0.57	1.67	18.3	16.3	17.3	1.17	1.01	1.07
Orange	SE Alaska, Wash. & Oregon	13	110	93	83.1	75.2	79.6	4.10	0.25	1.39	20.6	16.4	18.7	1.47	1.00	1.15
Pacific ocean perch	Wash., Oregon & N. Calif.	17	210	200	81.9	76.1	79.2	4.03	0.36	1.43	20.7	15.1	19.0	1.43	1.00	1.16
Red	SE Alaska	4	9	4	83.0	79.8	51.4	0.23	0.19	0.20	18.1	16.4	17.2	1.20	0.86	1.02
Rosy	Wash.	1	13	2	79.1	79.0	79.1	0.88	0.79	0.84	19.4	19.2	19.3	1.09	1.09	1.09
Yellowtail	Wash. & Oregon	6	52	45	81.0	77.5	79.3	3.45	0.62	1.56	20.1	17.1	18.9	1.42	1.06	1.19
Widow	SE Alaska	1	9	9	79.4	77.3	78.7	2.02	1.08	1.60	20.4	18.8	19.6	1.22	1.14	1.16
Sablefish	SE Alaska, Wash. & Oregon	13	108	107	82.4	63.2	70.7	22.9	2.76	15.1	16.6	10.6	13.8	2.00	0.77	1.09
Salmon																
Chum	Puget Sd.	7	7	7	75.6	71.0	74.1	7.33	2.18	3.86	23.3	20.2	21.3	1.33	1.08	1.18
Chinook	Oregon	3	3	3	—	—	73.1	15.7	7.2	11.5	21.2	17.8	19.5	1.32	1.16	1.28
Pink	SE Alaska, Wash., & Puget Sound	15	73	44	80.1	70.3	75.6	12.1	7.4	4.76	23.2	15.2	19.0	1.90	0.80	1.20
Coho	Wash., Oreg. & Puget Sd.	14	86	86	77.2	67.2	72.6	12.5	1.63	5.31	22.8	20.0	21.7	1.30	1.07	1.21
Sockeye	Brit. Col., Wash., Oregon & Col. Riv.	12	42	42	81.9	61.7	70.0	13.7	1.26	8.55	23.4	17.2	21.3	1.28	1.02	1.18
Seal																
N. fur (Whole)	St. Paul Isl. and proc. (Brit. Col.)	2	9	9	67.3	59.4	64.0	20.0	8.8	14.7	21.6	18.6	20.4	5.48	2.46	4.22
(Meat)	St. Paul Isl.	2	3	3	72.8	71.7	72.3	3.71	2.75	3.23	24.6	24.6	24.6	1.42	1.29	1.36
Sea lion (Meat)	SE Alaska	2	5	5	75.0	74.0	74.3	3.5	1.4	1.66	24.5	21.8	23.2	1.3	1.1	1.16
Shad	Oregon	1	2	1		(71.4)			(7.9)			(18.8)			(1.48)	
Shrimp, pink	SE Alaska & Wash.	5	125	5	82.9	75.5	80.1	1.03	0.80	0.95	21.1	15.9	18.1	1.45	0.89	1.25
Skate	Unknown	1	1	1		(81.8)			(6.05)			(16.3)			(1.68)	
Sole																
Dover	Wash., Oreg. & N. Calif.	11	103	103	91.3	76.5	85.4	3.32	0.39	0.95	22.5	7.1	16.8	1.52	0.91	1.11

(Continued on page 4.)

Table 2.—Proximate composition of fish and shellfish, continued.

Species	Origin of sample	No. of lots	No. of fish	No. of anal.	Moisture Max.	Moisture Min.	Moisture Avg.	Oil Max.	Oil Min.	Oil Avg.	Protein Max.	Protein Min.	Protein Avg.	Ash Max.	Ash Min.	Ash Avg.
Sole																
English	Bering Sea, Brit. Col., Wash., Oreg. & Puget Sd.	12	98	12	86.3	75.5	81.4	5.41	0.38	1.36	19.3	12.6	16.8	1.34	0.91	1.12
Flathead	Bering Sea, Brit. Col., Wash., Oreg., & Puget Sd.	4	28	8	83.9	79.8	81.0	1.50	0.55	1.10	19.7	14.9	19.2	1.40	0.96	1.13
Petrale	Oregon	3	33	33	83.0	78.5	80.0	2.26	0.52	0.80	19.9	15.6	17.6	1.31	1.02	1.19
Rex	Wash. & Oregon	4	58	58	84.5	80.8	82.3	3.09	0.35	0.71	18.1	13.9	16.7	1.25	0.95	1.10
Rock	Bering Sea & Puget Sd.	4	15	15	83.3	78.8	80.7	1.30	0.49	0.77	19.8	15.9	19.2	1.30	0.99	1.15
Sand	Puget Sound	2	19	19	84.3	79.9	83.4	0.88	0.38	0.44	19.2	15.5	16.1	1.58	1.05	1.07
Yellowfin	Bering Sea	1	78	1		(82.66)			(1.25)			(17.0)			(1.46)	
Starfish																
Mottled	SE Alaska	1	8	8	71.9	67.9	70.6	1.6	0.6	1.2	14.5	11.0	11.8	19.0	13.2	15.9
Purple	SE Alaska	1	9	9	72.7	70.0	71.4	1.8	1.2	1.5	12.3	8.1	10.0	18.0	13.6	16.6
Sunflower	SE Alaska	1	4	4	88.9	86.5	87.6	0.9	0.6	0.7	6.8	3.9	5.7	6.3	3.8	5.0
Trout																
Cutthroat	Pr. of Wales Isl.	1	8	8	79.5	75.8	78.2	3.2	1.1	1.8	21.9	18.3	19.9	1.5	1.3	1.4
Dolly Varden	Bristol Bay (Lake on island)	2	25	19	79.5	67.6	74.1	10.7	2.0	5.4	21.1	17.5	19.8	1.3	1.2	1.2
Steelhead	SE Alaska	4	33	16	74.3	62.2	68.9	16.4	3.7	9.02	22.8	18.2	21.1	1.40	1.00	1.31
Tuna, albacore (Light meat)	Wash. & Oregon	3	28	28	69.5	59.6	64.9	16.1	5.1	10.3	27.1	21.0	25.0	1.56	1.04	1.26
Tuna, albacore (Dark meat)	Wash. & Oregon	3	28	28	72.0	63.3	68.6	13.9	4.3	8.25	24.0	21.0	22.8	1.29	1.11	1.18

than any other component. In the present work, oil content ranged among the species and samples from 0.2 percent to 23.7 percent. In species from other parts of the country, oil content has been measured as high as 85 percent in the edible flesh. These values thus can range up to more than 400 times.

The moisture content of fish tends to vary inversely with the oil content. The sum of the two usually approximates 80 percent. The protein content of fish usually ranges from 17 to 20 percent. The ash content of fish flesh approximates 1.25 percent, falling occasionally to 1 percent or a little less, sometimes rising to 1.5 percent. The ash content is sometimes erroneously found to be considerably higher where all fine bones have not been eliminated. A small proportion of bone can give rise to considerable error.

Discussion of the voluminous results appearing in Table 2 is according to an arbitrary listing by groups of fisheries in the following section.

Discussion of Results by Species

Salmon and Trout

Salmon species are usually priced in the marketplace proportionally to the intensity of their color, ranking in the following order: 1) chinook (king) and sockeye; 2) coho (silver); 3) pink; and 4) chum. Chinook and sockeye are of similar color; chinook salmon have some individuals with nearly colorless flesh which are known as white kings. The color of the different species is usually proportional to the oil content, species ranking for average oil content in the same order: chinook, 11.5 percent; sockeye, 8.6 percent; coho, 5.3 percent; pink, 4.8 percent; and chum, 3.9 percent. The relationship between oil and color is fortuitous and does not apply to white kings, which, although much lighter in color than their red counterparts, have equal oil content. Trout are of much lighter color than the salmon but may have considerable oil content (especially the steelhead trout which averages 9 percent).

The red pigment in salmon, astacin, is readily oxidized, and salmon stored for long periods (such as in the frozen state) gradually lose the red color as a result of such oxidation. Astacin and other pigments may also give rise to changes in color, e.g., red to orange or to brown as a result of oxidation.

The fatty acids of salmon oils of the different species have differing degrees of stability against oxidation, an important property for retaining higher quality during storage. Table 3 lists oils of several species of salmon and trout, showing two indices of such stability: 1) the sum of C22:6 and C20:5 fatty acids (the most highly polyunsaturated and, therefore, most unstable, which occur in fish oils), and 2) the iodine number, an arbitrary fat constant proportional to stability.

Table 3.—Stability of Pacific salmon and rainbow trout oils.

Species	Total % C22:6 and C20:5 fatty acids	Iodine #
Pink salmon	32.4	154
Coho salmon	25.8	139
Rainbow trout	24.0	unknown
Chum salmon	22.8	138
Chinook salmon	14.1	118
Sockeye salmon	unknown	118

Stability toward oxidation increases as one descends the list in Table 3. Pink salmon oil is so unstable that this species cannot be held successfully in the frozen state for more than a few weeks. On the other hand, chinook salmon oil at the bottom of the list is so stable that mild-cured (salted) chinook salmon can be held successfully at above-freezing temperatures for many months without objectionable rancidity problems.

The protein content of salmon and trout is somewhat higher than that of the average fish. Whereas most species of fish average about 16-18.5 percent protein, some falling as low as 15 percent or less, salmon and trout usually contain about 20 percent. Sockeye and coho salmon as well as steelhead trout are especially high, averaging above 21 percent protein.

Flatfishes

Chemical contents of halibut are perhaps less representative for this species than are those of any other. This is because halibut are often very large and a relatively expensive fish. In analyzing most species, the cost of grinding the edible flesh of each fish in the sample is not a major problem. With halibut, where a single fish may weigh up to 100 pounds, the sampling cost makes the usual procedure unfeasible. Thus, samples were procured by removing several small pieces from a halibut "fletch." A fletch is the meat from a halibut, somewhat analogous to a fillet. By taking a small portion of such a fletch from different parts, at least an approximation of the representative chemical composition was reached.

Halibut have a proximate composition of remarkably uniform range. With an average oil content of 0.79 percent, only 3 of the 29 fish analyzed had values more than 50 percent higher than this amount (1.20 percent, 1.73 percent, and 3.32 percent oil); only one fish had an oil content as little as one-half of the average. The protein content of halibut is higher than that for most species, averaging 20.7 percent for the 29 samples analyzed. Again, the range of protein content, as of oil, was quite uniform. None of the samples contained as much as one-tenth higher protein content than the average, and only one sample had a value this much lower.

Flatfish other than halibut (i.e., the flounders and sole) have proximate composition similar to halibut with respect to oil content but have considerably less protein. The protein content was about average for the species tested in general; for all of the species of flounder and sole analyzed, the protein content averaged 17.2 percent. The protein content for flounder and sole varied to a much greater extent than for halibut, with values ranging from 7.1 to 22.5 percent.

As a class, flatfish have a composition similar to that of most bottom-feeding fish in which the oil content is relatively low and protein content is generally average. Because such fish usually do not migrate over wide areas, there is not the need to store fat in their muscular tissue as an energy source. Hence, large variations in oil content are not found.

Table 4.—Comparison of composition of different varieties of rockfish with that of the average of all rockfish varieties.

Species[1]	Average composition	Significantly lower oil content	Significantly higher oil content
Shortspine thornyhead*	X	—	—
Canary*	X	—	—
Pacific ocean perch*	X	—	—
Yellowtail*	X	—	—
Bocaccio*	—	X	—
Chilipepper*	—	—	X
Darkblotched*	—	—	X
Black	—	—	X
Greenstriped	—	X	—
Yelloweye[2]	—	X	—
Rosy	—	X	—

[1]Asterisk opposite name indicates it to be one of the most abundant varieties commercially.
[2]Commonly but erroneously referred to as red snapper.

Rockfish

Rockfish include members of the Scorpaenidae family. Many genera have similar properties but differ rather widely in external appearance and sometimes in other properties. These fish were first extensively fished during World War II because of a protein shortage. Annual landings on the Pacific coast rose from a few million pounds to over 60 million pounds. After the war and protein shortages declined, the catch declined.

Volume of landings was bolstered, however, well above prewar levels owing to new marketing practices, whereby the most widely available variety, *Sebastes alutus,* began to be marketed under the name of Pacific ocean perch. The related species, *Sebastes marinus,* on the Atlantic Coast had been sold as ocean perch, attracting demand in the middle west where lake fish, such as yellow perch, had been widely known and highly prized. When the Food and Drug Administration permitted sale of this species to be sold as ocean perch, resulting in vast increases in its utilization, the fishing industry sought and obtained authorization to market *Sebastes alutus* as Pacific ocean perch. This halted the drastic downward trend in sale of rockfish and stabilized the market in subsequent years.

The average composition of the 14 species of rockfish, for which proximate composition values are available (Table 2), is moisture, 79.2 percent; oil, 1.42 percent; protein, 19.0 percent; and ash, 1.15 percent. Among the rockfishes, seven make up the bulk of the commercial catch, designated in Table 4 by an asterisk (*). Four of these have closely similar chemical composition to the average values, with Pacific ocean perch being very close to the average. Two others of the commercially common rockfishes have significantly more oil content and one has significantly less.

Pacific ocean perch is estimated to make up about 25 percent of the standing stock of rockfishes off the coasts of Alaska, Washington, Oregon, and northern California. It is less abundant in the waters of the Pacific Northwest than at the peak harvesting periods in past years. In Alaskan waters it, together with the shortspine thornyhead, makes up the vast predominance of rockfish. Pacific ocean perch remains by far the major species landed by American fishers. Canary and yellowtail rockfish are the two most important landed from off the continental shelf adjacent to Washington and Oregon, and each of these species has typical chemical composition. The shortspine thornyhead, also of typical composition, in addition to being abundant in Alaskan waters, is a major variety in the commercial catches in the continental shelf area off northern California and in the continental slope fishing area off Washington and Oregon. This latter fishery also has abundant stocks of Pacific ocean perch and of darkblotched rockfish. The latter variety is of significantly higher fat content than the average rockfish. Other important varieties taken in the northern California fishery include bocaccio—significantly less high in oil than average—and darkblotched rockfish, as well as chilipepper, both higher in oil content than average.

A species of rockfish highly prized in markets of the Pacific Northwest and Alaska by some is the yelloweye rockfish. It is widely (but erroneously) sold as red snapper and is sometimes referred to as red cod. It has, by far, the lowest oil content of any of the rockfish—around 0.2 percent. Perhaps partly because of this very low oil content it has a different texture, somewhat resembling that of crab meat.

Black rockfish was once one of the most abundant varieties but landings have declined in recent years. It has considerably higher oil content than most other rockfish.

Miscellaneous Finfish

In the group classified as miscellaneous finfish, two extreme types are included. One is the miscellaneous bottom fish: Pacific cod, lingcod, and walleye pollock. The other is a group consisting of Pacific herring, American shad, eulachon, and albacore, which are of a more pelagic type, resulting in a more variable composition, especially with regard to oil content. Sablefish, sometimes referred to as black cod, are often considered to be bottom fish, but because they spend a part of their lives off the bottom and migrate considerably, their composition is closer to that of the miscellaneous pelagic species. Thus, they will be considered here under this latter category.

The three bottom fish, Pacific cod, lingcod, and walleye pollock, have compositions fairly similar to that of the flatfish previously discussed. They have an average oil content of 0.87 percent, ranging from 0.21 to 2.31 percent. Protein content averages 18.1 percent, ranging from 14.4 to 18.1 percent.

In contrast to the latter group, the remaining species, Pacific herring, American shad, eulachon, albacore tuna, and sablefish, have wide ranges of oil content within species and a wide inter-species range of protein content. Oil content averages 10.5 percent, ranging from 2.20 percent to 23.7 percent. Protein content averages 17.7 percent, ranging from 10.6 to 27.1 percent. The oil content for this group is unusually high and the protein content about average.

Albacore is almost unique among the many species of fish inhabiting northeastern Pacific waters in regard to its extremely high protein content. The average protein content for the light meat (the variety of meat used for the canned product) is 25.0 percent, ranging from 21.0 to 27.1 percent. This is an unusually high value for any species, almost half again higher than for most others. The oil content of albacore is high for species of fish in general (just over 10 percent) but is unusually high for tuna. The oil content of other varieties of tuna (not generally found in the northeastern Pacific Ocean) usually is well under 5 percent, often as little as 1 percent. Tuna, except for albacore, is not a fat fish. The canned product contains added vegetable oil which leads the general public to think of it as a fairly fat variety of fish.

Sablefish flesh is near the top of the list with respect to oil content among all common species. Its average of 15.1 percent oil is exceeded to any great extent by only one rather unusual freshwater species of fish, the siscowet trout of Lake Superior, the average oil content of which exceeds 50 percent. Although sablefish is an extremely oily variety, this trait is not always recognized. High oil content species are usually highly susceptible to oxidation. Consumers generally recognize a fish as oily by the flavor, resulting from early stages of oxidation. But sablefish are remarkably stable against oxidation and the oil is almost tasteless. This lack of "oily flavor" sometimes makes it appear that sablefish contain much less oil than indicated by analysis.

Unutilized and Miscellaneous Trash Fish

Many marine fish are not used commercially, but we have only scattered information about most of them. Some efforts have been made to utilize such fish for human consumption or to land large quantities for manufacture of fish meal. A few such species are included in this section, for which limited analytical data are available.

Efforts have repeatedly been made in the Pacific Northwest to utilize the flesh of the spiny dogfish for food—a species extensively used in other countries. In the State of Washington, the dogfish is utilized to a limited extent, together with other species such as skate and ratfish, to manufacture fish meal. The flesh of dogfish in a small sample analyzed was found to contain about 13 percent oil and 17.4 percent protein; nonprotein nitrogen content was 1.7 percent urea and 0.14 percent trimethylamine. The presence of considerable urea in dogfish and other sharks is of concern, especially if it is not separately determined. The urea makes the shark appear to have a much higher protein content than actually present. Thus, in the analysis just cited for dogfish, ignoring the presence of urea would have indicated a protein content of 19.9 percent as contrasted to the actual 17.4 percent.

An analysis of 10 ratfish (analyzed as whole fish) showed an average protein content of about 15 percent, ranging from 14 to 16 percent; oil content averaged 10.7 percent, ranging from 3.1 to 18.6 percent. Analysis of a single whole skate showed 6.3 percent oil and 16.3 percent protein. In view of the inadequate sample size these values are atypical.

Efforts have been made to market the sea cucumber as food. Analyses of four such samples showed 10.6 percent protein and 0.6 percent oil.

Average protein contents of three species of starfish were 11.8 percent, 5.7 percent, and 10.0 percent, respectively, for the mottled, sunflower, and purple varieties. Oil content was low (0.7-1.5 percent).

Shellfish and Crustaceans

One would predict that, if there is to be any large differences composition of different species of marine organisms, these would show up most prominently between major classes such as shellfish and crustaceans as contrasted to finfishes. While there are indeed such differences, they are not as great as one might expect. In chemical composition, shellfish differ considerably compared with crustaceans; in this section these will, therefore, be considered separately.

Shellfish. Included in shellfish composition listings (for which sufficient analytical data are available) are oysters, several varieties of clams, abalone, and octopus. It is unfortunate that no data could be found on razor clams, a species of some importance in Oregon. Data available on oysters are also not as extensive as the importance of the species would warrant.

As a class, the chemical composition of shellfish of the northeastern Pacific Ocean is, as contrasted to that of finfish, much lower in protein content. The oil content is uniformly low. Protein averages 13.4 percent, ranging from 9.4 to 17.4 percent. Oil content averages 1.17 percent, ranging from 0.5 to 3.7 percent. Ash content is definitely higher than in finfish, with an average of 2.10 percent. The higher ash content could conceivably be due, at least in part, to small residue of shell not completely eliminated during the shucking process.

Clams, with a protein content around 13 percent have considerably higher proportions of this important component than do oysters, which average around 10.5 percent. Oil content is uniformly low in both oysters and clams with an average content near 1 percent. Geoduck, introduced in recent years as a commercial product, is somewhat higher in protein than other clams, averaging close to 16 percent. Oil content in its siphon portion was similar to that of other clams, but in the body meat oil was found to be much higher, or about 3 percent.

Limited analyses of Alaskan abalone and octopus, neither of which has much commercial importance in the Pacific Northwest or Alaska, indicate that abalone is higher in protein than either oyster or clam, with an average of 17 percent. Octopus seems to have about the same protein content (13 percent) as clam. Oil content for both species falls somewhat under 1 percent.

Oysters, both Japanese and native, have similar protein content, close to 10.5 percent. In the somewhat limited samples for which analytical data were available, the native oysters had lower oil content (0.5 percent) than did the Japanese variety (1.27 percent).

Crustaceans. Analyses were made on both king and Dungeness crab. Although there was no consistent difference in chemical composition between these varieties, king crab protein composition appeared to be much more variable than that of Dungeness crab. Dungeness protein content varied from 16.3 to 20.4 percent, while king crab meat protein content varied from 11.6 to 19.6 percent. The average protein content of Dungeness crab was 18.8 percent. With the limited sampling and high variation encountered in the king crab, estimation of typical protein content is very difficult, but it is undoubtedly lower than that of the Dungeness variety. The oil content of both Dungeness and king crab was uniformly low, near 1 percent.

The composition of pink shrimp indicated it was similar to that of Dungeness crab. Protein content of the shrimp averaged 18.1 percent, ranging from 15.9 to 21.1 percent. Oil content averaged 0.95 percent, ranging from 0.80 to 1.03 percent.

Marine Mammals

Marine mammals are taken rarely for their meat; ordinarily they are captured for some byproduct such as fur or oil. Need for information on the proximate composition of these animals has not been manifested. Hence, little data are available. A problem exists as to just what should be analyzed. As with other large animals, chemical compositions between different parts vary greatly. A layer of blubber has an entirely different composition from a layer of muscle or an organ. In considering proximate composition of marine mammals, we need especially to pay attention to how the sample was taken and to interpret the results in terms of to what aspect the results are to be applied.

The northern fur seal, whose fur is used commercially, has been analyzed for proximate composition from meat and whole carcass samples. The raw meat gave a proximate composition not much different from that of flesh from a typical lean finfish: moisture, 72.3 percent; oil, 3.23 percent; protein, 24.6 percent and ash, 1.36 percent. The protein content was somewhat higher than in most finfish. Whole carcasses of the northern fur seal, probably due to the presence of more blubber, gave drastically different proximate composition: moisture, 64 percent; oil, 14.7 percent; protein, 20.4 percent; and ash, 4.22 percent.

Meat from sea lion flesh had proximate composition similar to that of meat from the northern fur seal: moisture, 74.3 percent; oil, 1.66 percent; protein, 23.2 percent; and ash, 1.16 percent. Porpoise, analyzed from a composite of four muscle portions from the back (but including a girdle of blubber and the entire liver), gave a somewhat different composition than parallel meat analyses for other species sampled in a more conventional way: moisture, 65.2 percent; oil, 3.86 percent; protein, 26.4 percent; and ash, 3.56 percent.

Proximate Composition of Different Parts of Fish

In this section will be discussed the differences in proximate composition obtained, dependent upon what part of a fish was sampled. A fish may be ground up completely, employing for the sample the fish in its entirety including skin or shell. Alternately, only edible portions such as the meat or flesh may be used as the sample. Furthermore, fish flesh taken from different parts may vary to a considerable extent. This may be a matter of the kind of flesh throughout the fish. There are in most fish two different kinds of flesh, the light and the dark, both edible but often of rather different chemical composition. The same kind of flesh may have a considerably different chemical composition when taken from near the head, for example, as compared to near the tail.

Location of Oil in Fish Tissue

Oil is the component of fish flesh which varies to the greatest extent. If we consider first where the oil in fish tissue is located it may be easiest to understand factors controlling variation of composition from one part to another of the fish.

Some oil is closely associated with the cellular structure of all fish tissue. To the extent of about 0.2 percent, oil (occurring largely as phospholipid) exists throughout all of the fish flesh. In addition to this minimal amount, oil occurs to a greater or lesser extent either throughout the flesh or sometimes in fat deposits. Some of this fat occurs in most tissue, interspersed fairly uniformly with muscle. Oil also occurs in special locations in much larger amounts. Usually, immediately beneath the skin—especially beneath the lateral line—but also along the top of the back (dorsal area), there may be fatty layers. Another location where thick layers of primarily fatty tissue can be located is along the abdominal wall.

In addition to the locations outlined above, there is a general decline in the amount of oil dispersed in the flesh, decreasing from the head end of the fish toward the tail. Muscle used for extensive activity, such as swimming, in fish is concentrated at the tail. This muscle is apt to have considerably less oil dispersed in it than in less active muscle toward the head. Tissue in the head itself, e.g., in the flesh of the cheeks, are apt to be the tissue having a relatively high oil content.

If slices (steaks) are taken at intervals from head to tail of any fairly fat fish such as salmon, the oil content declines, with slices at the head end often having several times the oil content of slices at the tail end.

Muscle

The light muscle of fish is usually white (in salmon it is pink) while the dark muscle is grey to black. It has sometimes been believed that the oil content of dark muscle of fish is always higher than that of the light muscle. This is not necessarily true. In some circumstances the light muscle has somewhat higher oil content. Perhaps the illusion that dark muscle is always higher in oil stems from the fact that most of the dark muscle occurs immediately beneath the skin at points where there are apt also to be deposits of fat. In salmon, however, the dark muscle is apt to be of higher oil content than that of the light muscle. Sometimes this difference is very pronounced.

In one study of pink salmon, the dark meat contained 12.5 percent oil while the light meat contained only 2.1 percent. With other species the difference may be much less or even reversed. In one series of analysis of 28 albacore tuna, the light meat contained an average of 10.3 percent oil, compared to 8.25 percent oil in the dark meat. The ranges of oil were as follows: light meat, 5.1-16.1 percent; dark meat, 4.3-13.9 percent. Thus, there can be no generalization as to relative oil content between dark and light meat, although differences, such as cited above on pink salmon, may be very great in certain circumstances.

Bone and Shell

The bone and shell of fish have compositions quite different from that of the edible flesh, especially the mineral content. The percentage of ash is much higher in bone or shell. Whole fish will, therefore, have much higher ash content than the edible flesh. In preparation of the edible flesh, unless all fine bones or traces of shell are removed, deceptively high ash content may appear to be present in the flesh.

Although fish bone is higher in ash and lower in moisture than the flesh, it may be higher in protein than the flesh. Thus, the bone may be one of the richest sources of nutrients, high not only in calcium and other nutritionally important minerals, but also in protein. Actually, the bone protein is different from that in the flesh and, in some cases, may not have such a good distribution of amino acids.

Differences in proximate composition of whole fish, edible flesh, and trimmings are typified by the following analysis of Dover sole:

	Moisture	Oil	Protein	Ash
Edible flesh	83.6%	0.8%	15.2%	1.1%
Whole fish	81.9	3.5	12.7	2.7
Nonedible portion	81.2	4.4	11.7	3.5

Subcomponents of Major Constituents

In the preceding section have been discussed the several major classes of compounds which together comprise proximate composition. Most of these major classes consist of components having various subcomponents. The proteins, in addition to belonging to a number of separate protein classifications, are composed of different amino acids. The oil of fish consists of different classes, such as triglycerides and phospholipids, each of which contains different subcomponents such as fatty acids. Finally, the ash contains different elements, such as sodium, calcium, sulfur, etc., and these in turn were present in the fish in different chemical forms. This section will discuss these subcomponents.

We do not have nearly enough information about the chemistry of different species of fish to enable us to pinpoint information about these subcomponents by species specific to the northeastern Pacific Ocean. In this section, therefore, discussions will be on a general basis applicable to most species.

Proteins

Fish proteins are of many varieties, with the type being associated with the function it performs. Sometimes proteins are classified in a general way with respect to their solubility. On an overall basis most of the proteins (70-90 percent) in fish are soluble in salt solutions of the class known as globulins, while another 10-20 percent are water soluble of the type known as albumins. The remaining fish proteins are of the insoluble type such as collagens and keratins.

Muscle proteins of fish consist primarily of myosin (50 percent) and actin (20 percent) which, during muscle contraction, combine to produce actomyosin. Connective tissue, cartilage, and skin contain considerable quantities of collagens. Important proteins with which small quantities of iron are combined include the myoglobin of dark muscle and the hemoglobin of blood. Lipoproteins consisting of lipids combined with protein are important blood constituents and occur in roe. The classes of proteins in fish have been reviewed by Hamoir (1951).

All proteins are made up from amino acids of which at least 21 occur in significant amounts. Table 5 lists the content of amino acids in the flesh and in three common proteins of fish. Those amino acids followed by an asterisk (*) are essential amino acids, i.e., they are not synthesized in vivo and thus must be obtained from exogenous sources. Fish proteins have a good balance of essential amino acids and are not significantly deficient in any, as are many of the vegetable proteins.

Table 5.—Amino acids in fish flesh and protein (from Stansby, 1967).

Amino acid[1]	Percent flesh	Composition		
		Myosin	Actin	Collagen
Alanine	7.1	6.5	5.4	10.4
Arginine	6.9	6.7	7.4	9.1
Aspartic acid	11.2	11.5	9.7	7.5
Cystine	1.4	0.9	1.3	0.0
Glutamic acid	16.9	21.7	13.3	11.3
Glycine	5.1	3.4	5.0	28.2
Histidine	3.6	2.1	3.3	1.2
Hydroxylysine	0.0	0.0	0.0	1.0
Hydroxyproline	0.0	0.0	0.0	9.0
Isoleucine*	5.0	4.6	7.7	1.7
Leucine*	9.2	9.4	6.6	3.2
Lysine*	10.6	10.6	6.5	3.7
Methionine*	2.7	3.0	4.1	2.0
Phenylalanine*	4.7	3.9	4.6	2.0
Proline	4.4	3.5	6.0	12.4
Serine	5.8	4.9	5.9	7.9
Threonine*	5.5	4.3	6.9	0.6
Tryptophane*	1.4	0.8	1.6	0.0
Tyrosine	4.1	2.7	6.0	0.6
Valine*	5.8	5.3	5.9	2.3

[1]Asterisk indicates essential amino acid.

Oils

Fish oils consist for the most part of triglycerides and phospholipids, the former usually making up the bulk of the oil. Other classes of compounds may be present in small amounts except for a few species where the other classes may be considerable. In many elasmobranch fishes, alkoxydiglycerides may occur in considerable amounts. A few species of fish contain large quantities of wax esters. Many liver oils, especially of elasmobranch fishes, may contain large quantities of hydrocarbons, especially squalene and, in some cases, pristane.

Triglycerides, phospholipids, and several of the other less usual classes of lipids are made up with fatty acids as the most prevalent building block. Just as numerous amino acids make up the building blocks of protein, many fatty acids combine in different proportions in triglycerides or other components of fish oils. The fatty acids differ chiefly in two respects: 1) the chain lengths (i.e., number of carbon atoms), and 2) the extent of unsaturation (i.e., the number of double bonds). Fish oils have a much wider variety of fatty acids than occur in most other edible oils. Many vegetable oils may have only three or four major fatty acids with, in some cases, a single fatty acid comprising more than half of the oil. Fish oils, on the other hand, usually have about 16 major fatty acids and, often, hundreds of others which may occur in small or trace amounts.

The fatty acids of fish oils also differ from those in other fats and oils by being more unsaturated, i.e., in having more double bonds per molecule. Animal and vegetable oils, with only a few exceptions, have no more than four double bonds per molecule (there are ordinarily only small quantities of fatty acids with more than two double bonds). Fish oils may have one-fourth or more of these fatty acids with five or six double bonds; the proportion may run, in some cases, up to 50 percent. Seldom, if ever, is it under 10 percent. The carbon chain length in some fatty acids of fish oils is also somewhat longer than those commonly present in other oils. Lengths above 20 carbons rarely occur in any but fish oils where a chain length of 22 carbons is common.

Table 6 lists the fatty acid composition of the oils of some species of fish taken in the northeastern Pacific Ocean. The fatty acid composition has as yet been determined for only a part of the major species of commercial importance.

Inorganic Elements (Ash)

The ash reported under proximate composition of fish consists of oxides of the various inorganic elements, which may have been present in the fish. Some such elements (e.g., sulfer) may form volatile oxides and be lost during the ashing process so that the approximately 1.25 percent found in most fish flesh ash represents minimal amounts. A different and more complex analysis is needed to reveal the amounts of the different, individual elements present in fish. Such analyses are seldom performed so that we have little information to draw upon to consider the content of the chemical elements in various species. Table 7 lists average composition of various inorganic elements.

Because of interest in recent years in keeping the diet of certain patients low in sodium, there have been several papers published on the sodium and sometimes on the potassium content of fish flesh. Table 8 gives data on the content of these two elements in the flesh of 13 species of fish from the northeastern Pacific Ocean.

Much fish during preparation for marketing are treated with a weak brine at some stage of processing. Frozen fish are often dipped in brine to minimize drip formation during frozen storage. Canned fish often have salt added as a flavor component, making the sodium content of the canned products often more than double that in the fish as it comes from the water.

Not much is known about precisely what form inorganic elements are present in fish. Some components such as sodium and potassium doubtlessly occur largely as inorganic electrolytes. Others such as phosphorous occur both in the ionic form and organically combined, such as in phospholipids. Several

Table 7.—Inorganic elements in the edible flesh of fish (from Stansby, 1963).

Mineral element	Average content (mg %)	Mineral element	Average content (mg%)
Potassium	300	Iron	1.5
Chloride	200	Manganese	1
Phosphorous	200	Zinc	1
Sulfur	200	Fluorine	0.5
Sodium	63	Arsenic	0.4
Magnesium	25	Copper	0.1
Calcium	15	Iodine	0.1

Table 6.—Fatty acid composition (Stansby, 1967 and 1969) of some oils from fish of the northeastern Pacific Ocean.

	Fatty acid content (%)[1]															
Species	14:0	15:0	16:0	16:1	17:0	18:0	18:1	18:2	18:3	18:4	20:1	20:4	20:5	22:1	22:5	22:6
Clam, littleneck	3.2	0.8	23.8	9.6	1.3	5.4	10.8	1.4	1.6	3.0	3.5	1.7	10.0	2.6	1.7	14.5
Cod, Pacific	1.0	+[2]	18.2	3.6	NK[3]	4.7	14.5	1.0	[4]	NK	[4]2.0	[5]	17.9	[5]5.6	1.9	29.2
Dogfish, spiny	2.0	0.5	21.2	6.0	1.2	2.7	27.5	1.3	0.6	0.7	5.8	2.5	7.9	4.1	2.3	10.4
Dogfish, spiny	1.6	0.2	23.5	5.7	0.9	3.0	33.6	0.6	0.5	NK	6.4	2.8	6.5	3.5	1.7	7.0
Halibut, Pacific	2.8	0.3	15.1	8.9	0.7	3.4	25.7	0.9	0.3	3.6	8.0	2.5	10.1	5.1	1.6	7.9
Herring, Pacific	7.6	0.4	18.3	8.3	0.5	2.2	16.9	1.6	0.6	2.8	9.4	0.4	8.6	11.6	1.3	7.6
Oyster, Pacific	2.7	0.9	21.4	4.6	1.4	4.0	8.5	1.2	1.6	4.3	+	1.9	21.5	2.6	1.0	20.2
Rockfish	4.1	0.6	14.9	6.6	2.6	6.0	20.8	1.6	0.8	1.3	1.4	1.5	11.7	0.8	1.6	17.4
Sablefish	4.1	0.5	14.8	11.6	1.0	3.8	38.0	2.1	1.3	NK	6.6?	1.0	4.6	4.1?	NK	2.2
Salmon																
Chinook	3.7	0.4	16.6	9.2	1.1	5.8	29.1	1.1	0.9	1.5	4.7	0.5	8.2	3.6	2.4	5.9
Chum	2.2	0.6	17.0	4.1	1.1	3.2	21.4	2.0	1.0	2.0	5.4	0.9	6.7	9.4	2.3	16.1
Coho	3.7	0.5	10.2	6.7	0.9	4.7	18.6	1.2	0.6	2.1	8.4	0.9	12.0	5.5	2.9	13.8
Pink	3.4	1.0	10.2	5.0	1.6	4.4	17.6	1.6	1.1	2.9	4.0	0.7	13.5	3.5	3.1	18.9
Trout, rainbow	2.1	0.8	11.9	8.2	1.5	4.1	19.8	4.6	5.2	1.5	3.0	2.2	5.0	1.3	2.6	19.0
Albacore	3.7	1.0	29.3	6.3	1.2	6.1	16.6	0.7	0.6	2.2	2.7	1.2	6.5	2.0	0.8	17.6

[1]The figure before the colon is chain length; that after is the number of double bonds.
[2]+ = Trace amounts.
[3]NK = Not known.
[4]Combined 18:3 and 20:1 acids.
[5]Combined 20:4 and 22:1 acids.

Table 8.—Sodium, potassium, and ash content of certain species from northeastern Pacific Ocean (from Thurston, 1958).

Species	Place of capture	No. of fish in sample	Ash (%)	Sodium[1]	Potassium
Albacore	Washington coast	6	1.18	34	293
Pacific halibut	Alaska coast	10	1.50	53	379
Lingcod	Washington coast	6	1.23	62	352
Yellowtail rockfish	Washington coast	6	1.20	50	358
Yelloweye rockfish	Washington coast	6	1.28	66	413
Black rockfish	Washington coast	6	1.28	66	432
Canary rockfish	Washington coast	6	1.26	71	347
Pink salmon	Burroughs Bay, Alaska	12	1.15	76	290
Pacific cod	Washington coast	6	1.22	76	372
Pacific ocean perch	Washington coast	6	1.03	79	324
Starry flounder	Washington coast	6	1.14	85	285
English sole	Vancouver Island	6	1.21	91	330
Petrale sole	Vancouver Island	6	1.12	96	268

[1]Data in mg/100 g.

of the trace elements, such as iron, copper, and arsenic are probably organically combined for the most part. Mercury in fish occurs largely as methyl mercury.

Trace Components

In addition to the major components of water (moisture), protein, oil, and mineral water (ash), fish contain innumerable substances ranging in amounts from a few parts per billion up to a few tenths percent, which we can classify as trace components. It is not possible to even mention many of these substances, but some discussion is included here on three important groups of these components: nonprotein nitrogen, vitamins, and pigments.

From the standpoint of the amounts present, nonprotein nitrogen components are the most important of the classes not already discussed. The nonprotein nitrogen compounds occurring in fish which have been reviewed by Shewan (1951) occur in teleost fishes around 10-15 percent of the total nitrogen in the fish (a little more in herring types of fish). In the elasmobranch fishes these compounds make up a far larger proportion, up to 40 percent, of the total nitrogen. This is due to the occurrence in the elasmobranch fishes of considerable quantities (around 2 percent) of urea.

One of the most important nonprotein nitrogen components of most fish is trimethyl amine oxide which plays an important role in nitrogen metabolism. In marine teleost fishes, this compound is believed to be involved in mechanisms for regulating osmotic pressure. Groninger (1959), who reviewed the occurrence and significance of trimethyl amine oxide, gives the values shown in Table 9 for the content of this substance in various classes of fishes. The elasmobranch fishes contain the most (0.66 percent), about 2 to 4 times as much as other classes of marine fishes and about 20 times as much as freshwater teleosts.

Another important nonprotein compound occurring in considerable quantity in the muscle of fish is creatine. Data compiled by Shewan (1951) indicates that this substance makes up from 0.3 to 0.7 percent of the muscle tissue of a wide variety of fishes (elasmobranch teleosts, molluscs, and crustacea). Urea, which has been noted above as occurring in high concentrations in elasmobranch fishes, is present in only small amounts in teleost fishes, the amounts ranging from 0.5 to 14.5 mg per 100 g (Shewan, 1951).

Table 9.—Content of trimethylamine oxide in different classes of fishes according to Groninger (1959).

Type of fish or shellfish	No. of species	Concentration (mg/100 g) Range	Mean
Molluscs	35	0.0- 955	172
Crustacea	18	14.7- 515	211
Elasmobranch	19	142.0-1,340	659
Marine teleosts	72	0.0- 700	269
Freshwater teleosts	21	0.0- 83	37

In an earlier section the amino acid content of protein was discussed. It should be pointed out here that in all fish, small amounts of amino acids occur in the free state uncombined as protein. The amino acids arginine und histidine have been reported to occur in the free state, the latter at levels around 200 mg per 100 g of wet tissue (Yudaev, 1950).

Vitamins occur in fish associated either with oil (vitamins A, D, and E) or in the case of water-soluble vitamins, with the flesh. The fat-soluble vitamins generally occur in a species of fish in proportion to the fat content of the tissue and are, therefore, higher in amount depending on the oil content of the particular sample. Table 10 gives an indication of the average amounts of vitamins contained in fish.

The pigments of fish are largely carotenoids which are also the principal pigments in plants and animals. Carotenoids are of two chemical types: carotenes, which are hydrocarbons; and xanthophyls which, in addition to hydrogen and carbon, also contain oxygen. The pigments of fish are primarily three compounds of the xanthophyl type: astaxanthine, taraxanthine, and lutein. Most species contain

Table 10.—Vitamin content of edible flesh of fish (Stansby, 1963).

Vitamin	Units	Content per 100 grams: Average	Usual range: Low	High
Vitamin A[1]	Micrograms	25	10	100
B vitamins				
Thiamine	Micrograms	50	10	100
Riboflavin	Micrograms	120	40	700
Nicotinic acid	Milligrams	3	0.5	12
Vitamin B12	Micrograms	1	0.1	15
Panthothenic acid	Milligrams	0.5	0.1	1
Pyridoxine[2]	Micrograms	500	50	1,000
Biotin[2]	Micrograms	5	0.001	8
Folic acid[2]	Micrograms	80	71	87
Ascorbic acid (vitamin C)	Milligrams	3	1	20
Vitamin D	Micrograms	15	6	30
Vitamin E (total tocopherol)[1,2]	Micrograms	12	4	35

[1]For fish of medium or high oil content.
[2]Based on very scanty data.

lutein and either astaxanthine or taraxanthine but not both.

Astaxanthine is the pigment responsible for the color of salmon flesh. It is also present in crustaceans where it is generally combined with protein in which form it has a blue or green color. Upon heating with water, the protein bond is broken, releasing the red astaxanthine. These pigments are found in nearly all fish in the skin where they occur inthe esterified forms. Goodwin (1951) reviewed the occurrence and function of carotenoids in fish.

Composition and Nutritional Properties

In foregoing sections emphasis was placed on chemical composition with some incidental mention of its relationship to nutritional properties. Some of the main features of nutritional properties of fish will be summarized here, both with respect to constrasting these properties of fish with that of other foods and with some reference to these properties as they occur in fish of the northeastern Pacific Ocean.

Fish have protein composition in general similar to that of other flesh foods such as meat rather than that in vegetables. The protein is well-balanced with respect to amino acids. Lipids, containing essential fatty acids, are present, but there are little or no carbohydrates. From these standpoints all species of fish are similar.

Some species of fish have characteristics somewhat different from those of other flesh foods which make them more desirable for certain nutritional needs. These relate to: 1) the selection of a food high in protein yet low in calories; and 2) as a source of high quality protein combined with a source of polyunsaturated oil, desirable when serum cholesterol level must be minimized—such as for patients with heart ailments. These properties have been reviewed in a recent report (Stansby, 1973). A variety of species are available with high protein of good nutritional properties, yet having such low oil content that the calories per pound are considerably less than is the case with other flesh foods. Other species of fish serve the second-mentioned dietary need by providing high quantities of highly polyunsaturated oil, which can lower or control serum cholesterol levels (Pfeifer, 1967; Stansby, 1969).

Fish in the northeastern Pacific Ocean provide species for both nutritional needs. Flatfishes, crab, and cod have excellent combinations of low calorific content with high protein. Of fish containing high cholesterol-lowering properties, the various species of salmon are unexcelled. Nelson (1972) provided dramatic evidence of the ability of heart patients to prolong life by adhering to dietary regimens where salmon was a principal source of polyunsaturates.

ACKNOWLEDGMENT

A considerable proportion of the unpublished data upon which results reported here are based were obtained by the late William Clegg, who ran proximate composition of many thousands of fish samples. Much of this work was carried out in the late 1930's and 1940's. We are greatly indebted to Mr. Clegg for his meticulous analytical work and for the fine records he kept which enables the belated publication on his important work.

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