TESTS OF HATCHERY FOODS FOR BLUEBACK SALMON 1944 - 48

SPECIAL SCIENTIFIC REPORT: FISHERIES No. 59

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Explanatory Note

The series embodies results of investigations, usually of restricted scope, intended to aid or direct management or utilization practices and as guides for administrative or legislative action. It is issued in limited quantities for the official use of Federal, State or cooperating agencies and in processed form for economy and to avoid delay in publication.

Washington, D. C.
March, 1951

United States Department of the Interior - - Oscar L. Chapman, Secretary
Fish and Wildlife Service - - Albert M. Day, Director

TESTS OF HATCHERY FOODS FOR BLUEBACK SALMON (ONCORHYNCHUS NERKA) 1944-1948

by

Roger E. Burrows, Leslie A. Robinson and David D. Palmer

Special Scientific Report: Fisheries No. 59

CONTENTS

ILLUSTRATIONS

INTRODUCTION

Feeding trials are a necessary adjunct to other other forms of nutritional research. Such trials are of particular importance in investigations concerned with the nutritional requirements of salmon and trout. Research in this field has not progressed to the point where the dietary essentials are known and therefore, purified rations cannot be fed. For this reason, feeding trials serve not only for the determination of the comparative value of various proteins as measured by the growth response of the fish but serve also as a measure of the nutritional adequacy of experimental rations as indicated by the presence or absence of recognizable deficiency symptoms.

In view of the fact that more and more reliance is being placed on artificial propagation to maintain the salmon runs of the Pacific Northwest, it is essential that both an adequate and available diet be developed to rear the fingerling to the time of liberation. The purpose of the feeding trials conducted at the Leavenworth Laboratory of the Fish and Wildlife Service during the years 1944, 1945, 1947, and 1948 was to evaluate available food supplies and to develop adequate diets for blueback salmon (*Oncorhynchus nerka*). Experimentation was limited to this species because proper facilities were not available to test diets on the other species of salmon native to the Upper Columbia River watershed.

Certain variables such as fish size, water temperature, and slight alterations in the experimental techniques, exist between the different years of experiment, but, because the design of the experiments was such as to include two standard control diets in each group, it is possible to compare the individual diets with the controls of that group and thus determine whether they were inferior or superior to these diets. Comparisons of different diets fed in different years may be made by the determination of their relative positions with reference to the controls.

A detailed description of the experimental techniques used in the diet studies has been included in this report because the procedures employed have a significant effect on the accuracy of results. The data for each group of experiments have been summarized in a series of tables. The discussion of the results of the feeding trials, however, has not been segregated according to the invividual years but rather according to the type of diet tested and covers the results of the experimentation for the four-year period.

METHODS

A review of the literature on the nutrition of salmon and trout such as was conducted by Karrick (1948) reveals the many divergent results attained by different investigators and often reversals in different years by the same investigators. These contradictory results may be due to several factors but, principally, to variations in methods of diet preparation and diet presentation. As pointed out by Phillips and Hewitt (1945), otherwise adequate diets may be prepared and presented in such manner as to be only partially available to the fish and, as a consequence, a reduction in growth or a nutritional deficiency may result. Another reason for a misinterpretation of results is faulty experimental design in which it is impossible to segregate the differences due to biological variation and experimental error from the differences due to diet. The experimental techniques employed in the feeding trials at the Leavenworth Laboratory were designed to eliminate as many of these as possible and to measure those which were unavoidable.

The fish used in each year's experiments were selected from a single day's take. During 1944 and 1945 the thoroughly mixed population of fingerlings was distributed into the troughs by the selection of random numbers. In this manner two adjacent troughs could be used for a single diet while still retaining a random selection. Previous experiments had determined that no significant difference existed due to the placement of the troughs in the experimental section. In 1947 and 1948 the use of the Leavenworth sampler (Hewitt and Burrows, 1948), in which all four pockets were closed, made possible the elimination of the above procedure. The use of the sampler insured a random distribution from a homogeneous population into all the experimental troughs. In this procedure the required poundage of fish for the entire experimental group was divided by the sampler into four equal portions. These divisions were further subdivided until the approximate weight of each individual trough of fish was attained, at which point the exact distribution was made by weight.

In order to retain a representative population in each trough throughout the experimental period, which is necessary for the use of analysis of variance, the initial stocking of the individual troughs was at 1,000 grams (2.2 pounds) for the 12 or 14 week experiments (1944, 1945, and 1947) and 500 grams (1.1 pounds) for the experiments of 24-weeks duration (1948). When experimental groups are arbitrarily reduced to a fixed weight at intervals within an experiment and a portion of the fish discarded, it is the opinion of the authors that the fish retained on experiment are no longer representative of the original population and, therefore, are not comparable to groups fed other diets in which reductions in the original population have been made at more or less frequent intervals and by different amounts.

It has been demonstrated by Hewitt and Burrows (1948) that it is practically impossible to secure an unbiased sample of a population when but a portion of the population is selected by weight due to the effect of stratification in the net during the necessary draining period. To avoid the necessity for reductions in weight due to the possible overcrowding of the fish, the troughs were stocked at reduced weights so that the initial population, less mortality, could be retained throughout the experimental period.

The equipment used in the experiments duplicated that in use in production procedures as nearly as possible. The troughs were the standard, concrete troughs of the Grand Coulee Project, 16 feet long, 16-1/2 inches wide, and with an average water depth of 10 inches. The food was presented to the fish by means of a specially designed ricer of a more limited capacity than that described by Mitchell (1941). The size of the food particle fed was varied by differences in the hole diameter of the perforations in the bottom plate of the ricer. These diameters varied from 1/16 to 5/32 inch dependent on the size of the fish.

At the beginning of each series of trials, sample groups representing 10 per cent of the fish in the entire group of experiments were counted to determine the average number of fish per trough. At biweekly intervals throughout the experimental period, the fish in each trough were weighed on a solution balance sensitive to one gram. A standard, 15-second draining interval was used before the fish were introduced into the weighing container. The total weight of each pair of troughs on a single diet and the total number of surviving fish at the end of the period were used to determine the size of the fish and the total weight of the lot. With these data and the expected average water temperature for the next bi-weekly period, the amount of food to be fed per day was established by reference to feeding charts prepared for blueback salmon (Table 1). The ration for each diet was weighed but distribution to the individual troughs was made by eye. To avoid the possibility of an accumulative error in the food distribution between troughs, the order of feeding was alternated so that first one then the other was fed first. On short term experiments (12-14 weeks) the fish were fed twice a day, 6 days per week. On long term experiments (24 weeks) the fish were fed 3 times per day, 7 days per week for the first 12 weeks and 2 times per day, 6 days per week thereafter.

During 1944 and 1945, the diets were ground one day in quantity sufficient for two rations, mixed by hand, and fed the following two days. In 1947 and 1948, the diets were ground, mechanically mixed, and fed within an eight-hour period. In each group of experiments, the raw products were held in frozen storage until required, ground while still frozen, and held under refrigeration until fed. The prepared diets were held at temperatures which would not allow them to

TABLE 1.--Feeding chart for blueback salmon expressed as the percentage of the body weight to be fed per day

Average water temperature °F.	Number of fish per pound						
	Over 2,500	2,500-1,400	1,400-300	300-150	150-90	90-40	40-10
40	8.1	7.1	6.1	5.1	4.1	3.0	2.0
41	8.4	7.4	6.3	5.2	4.2	3.2	2.1
42	8.7	7.6	6.5	5.4	4.4	3.3	2.2
43	9.0	7.9	6.8	5.6	4.6	3.5	2.3
44	9.3	8.2	7.0	5.8	4.8	3.6	2.4
45	9.6	8.5	7.3	6.1	5.1	3.8	2.5
46	9.9	8.7	7.6	6.3	5.3	4.0	2.6
47	10.3	9.1	7.9	6.5	5.5	4.1	2.8
48	10.7	9.5	8.2	6.8	5.8	4.3	2.9
49	11.0	9.8	8.5	7.0	6.0	4.5	3.0
50	11.4	10.2	8.9	7.3	6.3	4.7	3.2
51	11.9	10.6	9.2	7.6	6.6	4.9	3.3
52	12.4	11.0	9.6	7.9	6.9	5.2	3.5
53	12.8	11.4	10.0	8.2	7.2	5.4	3.6
54	13.4	11.9	10.4	8.5	7.5	5.6	3.8
55	13.8	12.3	10.8	8.9	7.9	5.9	3.9
56	14.4	12.8	11.2	9.2	8.2	6.1	4.1
57	15.0	13.3	11.6	9.6	8.6	6.4	4.3
58	15.5	13.9	12.2	10.0	9.0	6.7	4.5
59	16.0	14.3	12.6	10.4	9.4	7.0	4.7
60	16.7	15.0	13.2	10.8	9.8	7.3	4.9
61	17.4	15.6	13.8	11.2	10.2	7.6	5.1
62	18.1	16.2	14.4	11.6	10.6	7.9	5.3

freeze solid but would still preserve the optimum feeding consistency. Because of variations both in diet composition and the refrigeration temperature, a two-day storage period was not found satisfactory for the maintenance of optimum feeding consistencies.

Every effort was expended to present the food in a form which would be available to the fish. Salt, when combined with certain raw products, causes a change in the physical consistency of the diet. The addition of salt at the rate of 2 grams per 100 grams of mixed food containing an adequate binding agent causes the diet to assume a rubber-like consistency which does not leach out readily when introduced into the water. When binding agents such as hog liver and hog spleen were included in the diets, salt was added to produce this bound quality. When no binding action was present in the diet components and the product to be tested leached badly in the water when fed, absorbent meals, sufficient to prevent leaching, were added.

At the conclusion of each series of feeding trials, the data were analyzed statistically by use of analysis of variance for paired experiments as outlined by Snedecor (1940, 1946). In this manner it was possible to measure the differences which existed between the troughs on each diet and isolate the effect of biological variation and experimental error. By the establishment of the fiducial limits of these errors, it was possible to determine the significance of the differences which existed between the mean weights of the groups of fish fed different diets.

SUMMARIZED DATA

The results of the feeding trials for the individual years are summarized in Tables 2, 3, 4, and 5. Two control diets were included in each group of experiments: the first consisted of 100 per cent of flukey beef liver, and the second of the standard Leavenworth production diet which contained 20 per cent each of beef liver, hog liver and hog spleen, 30 per cent Columbia River salmon viscera, and 10 per cent flame-dried, salmon offal meal. In each table the diet number representing a control diet is underlined.

The mean lot weight represents the mean weight of the two groups of fish fed each diet. No compensation has been made for the mortality which occurred during the experimental period. The mean lot weight serves to weight the gain of the fish against the mortality and, therefore, is believed to be a better measure of the diet than is the average weight of the surviving fish.

The per cent mortality represents the percentage loss for the entire experimental period. Where the data are broken into 12 and

TABLE 2.—Summary of 1944 feeding trials with blueback salmon

Initial number per trough: 5,778 fish Initial average weight per fish: .173 gr Period: June 6 to September 12, 1944 Average water temperature for the 14 week period: 54.4° F.
Initial weight per trough: 1,000 gr Initial number per pound: 2,631 fish

Diet No.	Components		Percentage Composition	Mean diet weight at the end of 14 weeks in grams	Per cent mortality 14 weeks	Per cent gain 14 weeks	Mean mortality 14 weeks	Conversion	Deficiency symptoms
1	Beef liver		100	8,493	6.8	749	394	3.8	None
2	Beef liver Hog spleen	S[1]	50 50	8,293	5.1	729	296	3.9	None
3	Beef liver Hog liver	S	50 50	9,970	3.3	897	190	3.6	None
4	Hog liver Hog spleen	S	50 50	7,125	6.0	612	346	4.3	Acute anemia 9/12/44
5	Hog liver	S	100	8,057	4.9	706	281	3.9	None
6	C.R. [2] salmon viscera Apple pomace	S	95 5	14,311	28.3	1,331	1,637	2.9	Anorexia first six weeks. Hemorrhagic areas, body surface 9/12/44.
7	C.R. salmon viscera Flame-dried salmon offal meal		90 10	13,497	38.3	1,250	2,212	2.9	Anorexia first six weeks. Hemorrhagic areas, body surface 9/12/44.
8	C.R. salmon viscera Hog spleen	S	50 50	10,437	20.3	944	1,170	3.3	Anorexia first six weeks.
9	C.R. salmon viscera Hog spleen Flame-dried salmon offal meal	S	70 20 10	11,360	23.6	1,036	1,361	3.1	Anorexia first six weeks.
10	Beef liver 12.5%; Hog liver Hog spleen C.R. salmon viscera Salmon carcass Flame-dried salmon offal meal	S	12.5 25 20 20 10	12,470	3.3	1,147	192	3.0	None
11	Beef liver Hog liver Hog spleen C.R. salmon viscera Flame-dried salmon offal meal	S	20 20 20 30 10	12,447	1.9	1,145	110	3.0	None
12	Beef liver Hog liver Hog spleen C.R. salmon carcass Flame-dried salmon offal meal	S	20 20 20 30 10	10,826	2.1	983	119	3.2	None
13	Beef liver Hog liver Hog spleen C.R. salmon viscera Flame-dried salmon offal meal	S	12.5 12.5 25 40 10	11,995	2.1	1,100	123	3.0	None
14	Canned beef liver		100	3,147 Diet discontinued 7/28/44	1.9	Diet discontinued 7/28/44 215	111	3.8	Loss of equilibrium, nervous convulsions, no anemia, 7/28/44.
15	Beef liver Hog spleen Canned salmon Apple pomace	S	12.5 12.5 70 5	4,397	2.2	340	128	5.6	Acute anemia, 9/12/44
16	Beef liver Hog spleen Canned salmon Apple pomace	S	25 25 45 5	7,037	2.3	604	135	4.1	None
	Least difference at 5% confidence level:			594 gr	3.0%	59%	172 fish		

1/ S: Salt added at the rate of 2 grams per 100 grams of ration
2/ C.R.: Columbia River

TABLE 3.—Summary of 1945 feeding trials with blueback salmon

Initial number per trough: 1,432 fish
Initial weight per trough: 1,000 gr

Initial average weight per fish: .698 gr
Initial number per pound: 650 fish

Period: June 27 to October 2

Average water temperature for the 14 week period: 54.0° F.

Diet No.	Components		Percentage composition	Mean diet weight at the end of 14 weeks in grams	Per cent Mortality 14 weeks	Per cent gain 14 weeks	Mean mortality 14 weeks	Conversion	Deficiency symptoms
1	Beef liver		100	4,760	5.3	376	76	4.1	None
2	C.R.[1] salmon viscera Apple pomace		90 10	6,403	3.6	540	52	3.5	None
3	Tuna viscera Apple pomace		90 10	2,068 Diet discontinued 9/4/45	5.4	Diet discontinued 9/4/45 107	77	6.0	Acute anemia 9/4/45
4	Hog liver C.R. salmon viscera Apple pomace	S[2]	20 70 10	5,717	2.1	472	30	3.7	None
5	Hog liver Tuna viscera Apple pomace	S	20 70 10	2,311 Diet discontinued 9/4/45	8.0	Diet discontinued 9/4/45 131	65	5.1	Acute anemia 9/4/45
6	Hog liver C.R. salmon viscera Apple pomace	S	45 45 10	5,635	1.9	463	27	3.7	None
7	Hog liver Hog spleen C.R. salmon viscera Apple pomace	S	30 20 40 10	6,100	2.5	510	36	3.6	None
8	Hog liver Hog spleen C.R. salmon viscera Flame-dried salmon offal meal	S	30 20 40 10	6,521	2.8	552	40	3.5	None
9	Meat-viscera mixture[3] Flame-dried salmon offal meal	S	90 10	6,415	2.8	541	40	3.5	None
10	Meat-viscera mixture Apple pomace	S	90 10	6,121	1.5	512	21	3.6	None
11	Meat-viscera mixture Tomato pomace	S	90 10	5,772	1.1	317	16	3.7	None
12	Meat-viscera mixture Diatomaceous earth	S	90 10	4,549	2.0	355	29	4.1	None
13	Beef liver Hog liver Hog spleen Tuna viscera Flame-dried salmon offal meal	S	20 20 20 30 10	3,306 Diet discontinued 9/18/45	4.2	Diet discontinued 9/18/45 231	60	4.2	Acute anemia 9/18/45
14[4]	Meat-viscera mixture Flame-dried salmon offal meal	S	90 10	6,383	2.4	538	34	3.5	None
15[4]	Beef liver Hog liver Hog spleen Tuna viscera Flame-dried salmon offal meal	S	20 20 20 30 10	2,799 Diet discontinued 8/21/45	3.0	Diet discontinued 8/21/45 180	43	3.4	Acute anemia 8/21/45
16[4]	Beef liver Hog liver Hog spleen Salmon carcass Flame-dried salmon offal meal	S	20 20 20 30 10	4,156 Diet discontinued 9/18/45	5.3	Diet discontinued 9/18/45 316	76	3.8	Acute anemia 9/18/45
	Least difference at 5% confidence level			482 gr	2.0%	48%	28 fish		

1/ C.R.: Columbia River
2/ S: Salt added at the rate of 2 grams per 100 grams of ration.
3/ Meat-viscera mixture: beef liver 22.2%; hog liver 22.2%; hog spleen 22.2%; salmon viscera 33.4%.
4/ Frozen storage diet.

TABLE 4.—Summary of 1947 feeding trials with blueback salmon

Initial number per trough: 357 fish
Initial weight per trough: 1,000 gr
Initial average weight per fish: 2.801 gr
Initial number per pound: 163 fish
Period: July 9 to September 30
Average water temperature for the 12 week period: 54.9° F.

Diet No.	Components		Percentage composition	Mean diet weight at the end of 12 weeks in grams	Per cent mortality 14 weeks	Per cent gain 14 weeks	Mean mortality 14 weeks	Conversion	Deficiency symptoms
1	Beef liver		100	2,631	1.8	163	6	5.0	None
2	Beef liver Hog spleen Cortland No.6 Meal Mix 2/	S 1/	15 35 50	4,602	1.0	360	4	2.7	None
3	Hog spleen Cortland No.6 Meal Mix	S	50 50	4,751	.8	375	3	2.6	None
4	Meat-viscera mixture 3/ 145° C.R. 4/ salmon viscera meal	S	90 10	4,637	1.0	364	4	2.7	None
5	Meat-viscera mixture Flame-dried A. 5/ salmon offal meal	S	90 10	4,318	1.2	331	4	2.9	None
6	Meat-viscera mixture Acetone-extracted C.R. salmon viscera meal	S	90 10	4,593	1.5	359	6	2.7	None
7	Meat-viscera mixture Kelp meal	S	90 10	3,719	1.3	272	4	3.5	None
8	Meat-viscera mixture 145° C.R. salmon viscera meal Diatomaceous earth	S	90 5 5	4,221	1.4	322	5	3.0	None
9	Meat-viscera mixture Apple pomace	S	90 10	3,767	2.2	277	8	3.4	None
10	Meat-viscera mixture	S	100	3,656	.4	266	2	3.6	None
11	C.R. salmon viscera Apple pomace		90 10	3,678	.7	268	2	3.5	None
12 6/	C.R. salmon viscera Apple pomace		90 10	4,046	.1	305	1	3.1	None
13	Salmon trimmings		100	1,710	7.6	71	27	9.9	Acute anemia 9/20/47
14	Hake		100	3,557 Diet discontinued 9/2/47	1.4	Diet discontinued 9/2/47 256	5	2.3	Acute anemia 9/2/47
15	Whole Rockfish		100	1,705 Diet discontinued 9/2/47	4.5	Diet discontinued 9/2/47 71	16	6.9	Acute anemia 9/2/47
16	Rockfish offal		100	1,200 Diet discontinued 9/2/47	3.6	Diet discontinued 9/2/47 20	13	22.3	Acute anemia 9/2/47
	Least difference at 5% confidence level			292 gr	2.5%	29%	9		

1/ S: Salt added at the rate of 2 grams per 100 grams of ration.
2/ Cortland No. 6 Meal Mix: Cottonseed meal, 25%; wheat middlings, 25%; dried skim milk, 25%; and 145° C.R. salmon viscera meal, 25%.
3/ Meat-viscera mixture: beef liver, 22.2%; hog liver, 22.2%; hog spleen, 22.2%; and salmon viscera 33.4%.
4/ C.R.: Columbia River.
5/ A.: Alaska.
6/ Frozen-storage diet.

TABLE 5.—Summary of 1948 feeding trials with blueback salmon

Initial number per trough: 890 fish
Initial weight per trough: 500 gr
Initial average weight per fish: .5618 gr
Initial number per pound: 809 fish
Period: April 6 to September 21
Average water temperature: 0 to 12 weeks, 44.9° F.; 12 to 24 weeks, 54.3° F.; 0 to 24 weeks 49.6° F.

Diet No.	Components		Percentage composition	Mean diet weight at the end of 12 and 24 weeks in grams: 12 wks.	24 wks.	Per cent mortality 12 wks.	24 wks.	Per cent gain 12 wks.	24 wks.	Mean mortality 12 wks.	24 wks.	Conversion	Deficiency symptoms
1	Beef liver		100	1,566	5,950	3.8	6.8	219	1,090	34	61	3.9	None
2	Meat-viscera mixture[1/] 145° C.R.[3/] salmon viscera meal	S[2/]	90 10	1,889	10,692	11.8	14.4	278	2,039	105	128	2.5	None
3	Beef liver Hog liver Hog spleen Hake 145° sal. viscera meal C.R.	S	20 20 20 30 10	1,914	8,294	12.2	14.6	283	1,559	109	130	3.2	None
4	Beef liver Hog spleen Cortland No.6 meal mix[4/]	S	15 35 50	1,592	7,500	17.0	20.0	218	1,400	152	179	3.1	None
5	Hog spleen Cortland No. 6 meal mix	S	50 50	1,370	6,400	27.3	32.4	174	1,179	243	288	3.2	None
6	Hog liver C.R. salmon viscera 145° C.R. salmon viscera meal	S	40 40 20	1,938	10,285	17.7	28.3	288	1,957	158	252	2.4	Acute anemia 9/21/48
7	C.R. salmon viscera Hake 145° C.R. salmon viscera meal		50 40 10	1,724	7,193	18.4	26.5	245	1,338	164	235	3.3	Acute anemia 9/21/48
8	Meat-viscera mixture	S	100	1,862	9,128	7.4	8.7	272	1,726	66	78	2.8	None
9	Meat-viscera mixture 145° A.[5/] salmon viscera meal	S	90 10	1,791	9,684	14.6	17.1	258	1,837	130	152	2.6	None
10	Meat-viscera mixture 100° A. salmon viscera meal	S	90 10	1,890	10,677	11.9	16.1	278	2,035	106	143	2.5	None
11	Meat-viscera mixture 100° Spoiled A. salmon viscera meal	S	90 10	1,740	9,330	12.6	17.9	248	1,766	112	160	2.5	None
12	Meat-viscera mixture 100° A. salmon offal meal	S	90 10	1,803	9,779	13.0	16.2	261	1,856	116	144	2.7	None
13	Meat-viscera mixture 145° A. salmon offal meal	S	90 10	1,796	9,214	17.1	21.1	259	1,743	152	188	2.7	None
14	Meat-viscera mixture Flame-dried A. salmon offal meal	S	90 10	1,878	8,965	10.4	12.8	276	1,693	93	112	2.8	None
15	C.R. salmon viscera 145° C.R. salmon viscera meal		90 10	1,469	6,195	19.5	30.2	194	1,139	174	268	3.3	Fused gill lamellae, filaments 6/29/48. No deficiency symptoms 9/21/48.
16	A. salmon viscera 145° C.R. salmon viscera meal		90 10	1,400	5,390	22.7	34.6	180	978	202	308	3.6	Fused gill lamellae, filaments 6/29/48. No deficiency symptoms 9/21/48.
17	A. salmon offal 145° C.R. salmon viscera meal		90 10	800	Diet discontinued at the end of 10 weeks.	Diet discontinued at the end of 10 weeks (6/15/48) 16.3	....	60	.....	290	...	10.2	Fused gill lamellae, filaments; pale spleen 6/15/48.
18	C.R. salmon viscera 145° C.R. salmon viscera meal		50 50	871	Diet discontinued at the end of 8 weeks.	Diet discontinued at the end of 8 weeks (6/1/48) 16.4	....	74	.....	292	...	6.8	Fused gill lamellae, filaments; pale spleen 6/1/48.
19[6/]	Meat-viscera mixture 145° C.R. salmon viscera meal	S	90 10	1,631	1628 at the end of 16 weeks.	Diet discontinued at the end of 16 weeks (7/27/48) 13.0	37.3	226	225	232	689	7.0	Acute anemia 7/27/48
20[6/]	C.R. salmon viscera 145° C.R. salmon viscera meal		90 10	443 gr at the end of 12 wks.; 470 gr at the end of 18 wks.		Diet discontinued at the end of 18 weeks (8/10/48) 14.0	24.4	-11.4	-5.9	249	434	...	Fused gill lamellae and filaments 8/10/48
	Least difference at 5% confidence level			144 gr at 12 wks.	841 gr at 24 wks.	5.4%	7.6%	29%	168%	48	68 fish		

1/ Meat-viscera mixture: beef liver, 22.2%; hog liver, 22.2%; hog spleen, 22.2%; and salmon viscera, 33.4%.
2/ S: salt added at the rate of 2 grams per 100 grams of ration.
3/ C.R.: Columbia River.
4/ Cortland No. 6 meal mix: cottonseed meal, 25%; wheat middlings, 25%; dried skim milk, 25%; and 145° C.R. salmon viscera meal, 25%.
5/ A: Alaska.
6/ Frozen-storage diet.

24-week periods (1948) the figures for the 24-week period include the loss for the first 12 weeks. This same procedure is applied when computing the per cent gain.

The conversion is derived from the total weight of food fed a given lot divided by the total gain in weight made by the surviving fish on the diet. Here, again, no compensation is made for mortality.

Whenever a high mortality occurred in a lot, the fish were checked for demonstrable deficiency symptoms. At the conclusion of the experimental period, all lots of fish were examined for evidence of dietary deficiencies. During 1944 and 1945, erythrocyte counts were made on samples of fish taken from key diets. Because time did not permit the sampling of more than four fish from each diet, this procedure was abandoned in favor of cursory examinations of large samples of 50 to 100 fish for gill color as being more indicative of the true condition of the entire group.

Diets, which were discontinued, were abandoned due to an avitaminosis or an acute anemia in the fish which precluded the possibility of their survival until the conclusion of the experiment. Other diets in which deficiency symptoms were recognizable but were not acute were continued throughout the experimental period. In some cases, the deficiency symptoms of the fish on the various diets are listed in the tables giving the time of their occurrence and the condition of the fish at the conclusion of the experiment. Unquestionably, some deficiency symptoms were present which were not recognized either because the symptoms were not clear cut or they had not been previously described. The presence of pale spleens, which occurred in fish on several diets, may be an example of the latter case.

It will be noted that the per cent gains in weight varied tremendously from year to year. The initial average weight of the fish at the start of the experimental periods showed a similar variation. As larger fish gain at a reduced rate, the initial size variation in the fish between years explains the differences that exist in the percentage gains of fish fed comparable diets in different years when the water temperatures were similar.

The least difference for significance at the 5 per cent confidence interval was computed from the fiducial limits of the mean difference as determined by analysis of variance for paired experiments (Snedecor 1946). The least difference is expressed as twice fiducial limits of the mean difference. As the data presented in the tables, with the exception of the conversion factors, are the means of the two groups of fish fed each diet, it is possible to determine if the differences which exist between the fish fed any two diets is statistically significant merely by noting whether the difference is greater or less than the least difference.

EXPERIMENTAL RESULTS

In the selection of products for test, several factors were considered. First and foremost was the availability of the product. Little or nothing would be gained from the biological assay of products which could not meet the demand of the greatly expanded program for artificial propagation contemplated on the Lower Columbia River. The initial cost of the item was considered to be of secondary importance to its availability although low cost was highly desirable. Cost cannot be regarded as the only criterion for the evalulation of a product. Not only do prices vary with the demand but low cost items of inferior quality may prove more expensive than items of higher initial cost because of the higher conversion factors and increased mortalities which may result from their use.

The discussion of the results of the feeding trials has been organized into five major groups according to the types of diets tested. The groups consist of (1) meat products, (2) fish products, (3) dry meal supplements, (4) potential production diets, and (5) evaluations of the effect of cold storage on prepared diets. Because evaluations of a single type of product were not confined to a single year, the discussion covers the results of the four series of experiments.

Meat Products

The meat products used in salmonoid diets are limited to those which are not used extensively for human consumption, either because they are unfit or undesirable. Of this group of meats, flukey beef liver, flukey hog liver, and hog spleen were used in the feeding trials because they were the most generally available in this area and the work of other investigators indicated they offered the greatest possibilities for the vitamin fortification of otherwise deficient diets.

Flukey Beef Liver

Flukey beef liver was used as a standard control in all the feeding trials. The 100 per cent beef liver diet invariably produced higher mortality rates than did the standard production diet when fed at water temperatures above 50 degrees F. In 1944 and 1945 these differences were significant and the trend is present in both the 1947 and 1948 feeding trials. For comparisons, reference may be made to the underlined control diets in the four tables. Beef liver has not proved entirely adequate when used as the sole diet component in the ration of blueback salmon. It is indicated, however, to be an excellent source of the anti-anemic factor and serves as a fortifying agent in otherwise deficient diets.

Diets 15 and 16 in Table 2 demonstrate that 12.5 per cent of beef liver is not adequate for the prevention of anemia during a 14-week period when fed in conjunction with a comparable amount of hog spleen and a high level of canned salmon. An increase of the beef liver content of the diet to 25 per cent provides adequate fortification. The inclusion of 15 per cent beef liver in the Cortland diet resulted in a significant reduction in mortality at water temperatures below 50 degrees F. when compared with the 50 per cent spleen combination (Table 5, Diets 4 and 5). Such an effect is not apparent at temperatures above 50 degrees (Table 4, Diets 2 and 3).

Canned Beef Liver

Beef liver, preground and canned under 25 pounds of vacuum, was fed at the 100 per cent level in 1944 (Table 2, Diet 14). Contrary to expectations these fish did not develop an anemia during the course of the experiment. After 6 weeks of feeding, however, the fish showed indications of an acute avitaminosis, probably a thiamin dificiency and the experiment was abandoned at the end of a 52-day period. Whether beef liver, preserved in this manner, retains the anti-anemic factor in sufficient quantity to support blueback salmon is problematical, but in view of the indicated reduction in vitamin content, it is deemed unlikely.

Flukey Hog Liver

Flukey hog liver, when fed as the sole diet component for a 14 week period, will maintain blueback salmon without anemia and with a comparable growth rate to that of fish fed beef liver. Erythrocyte counts taken of fish fed exclusively on either beef or hog liver (Table 2, Diets 1 and 5) indicate no difference in red blood cell content between the two groups. Sample counts of four fish fed beef liver gave an average count of 1, 154, 000 red cells per cubic milliliter of blood while those fed hog liver averaged 1, 140,000. In view of the variation that exists between fish within a lot, these cannot be considered significant differences.

It is indicated, however, that hog liver apparently does not contain as great an amount of the anti-anemic factor as does beef liver. The results of feeding trials with diets in which 50 per cent hog spleen was combined with either beef liver or hog liver at the 50 per cent level (Table2, Diets 2 and 4) form the basis for this statement. At the end of 14 weeks, the hog liver-hog spleen fed fish showed positive evidence of an acute anemia while the beef liver-hog spleen fish had no such symptoms.

Hog Spleen

Hog spleen in combination with beef or hog liver (Table 2, Diets 2 and 4) made no measurable contribution to the growth of the fish in excess of that made by either beef or hog liver fed separately. In the case of the hog liver-hog spleen combination the final weight was significantly below that of hog liver. The anemia which developed in the hog liver-hog spleen fish indicates that hog spleen is inferior to hog liver in its content of the anti-anemic factor. Karrick and Edwards (1948) found that hog spleen was inferior to either beef liver or hog liver in its protein content. Both the vitamin assays of the Cortland Laboratory (Cortland Hatchery Reports 1944, 1945, 1946, and 1947) and those of Karrick and Edwards (1948) indicate that hog spleen contains a reduced amount of the B-complex vitamins when compared with beef liver. The low protein content, the deficiency in the anti-anemic factor, and the low content of certain of the B-complex vitamins, all combine to make hog spleen a rather undesirable diet component particularly since the cost per pound now approximates that of either flukey beef or hog liver. Hog spleen, however, is one of the best binding agents known when combined with salt and for this reason can be used to advantage in minimal amounts in composite diets.

Beef Liver - Hog Liver

A combination of equal parts of beef liver and hog liver (Table 2, Diet 3) resulted in a significant increase in growth over any other all-meat diet tested. As beef liver and hog liver have approximately the same protein content, the acceleration in growth rate may be attributed to the complementary nature of the proteins.

The feeding trials conducted with all-meat diets indicate that a beef liver-hog liver combination is superior in growth potential to either product fed separately or when combined at the 50 per cent level with hog spleen. The anti-anemic factor is present in the greatest amount in beef liver and to a lesser extent in hog liver. Hog spleen is inferior to either beef or hog liver in the amount of the anti-anemic factor it contains.

Fish Products

Fish products, particularly those which are not utilized for human consumption, such as the offal from canning or filleting operations or undesirable fish taken incidentally in a fishery, offer a cheap source of fish food. One of the objectives of the feeding trials was to evaluate the growth potential and nutritional adequacy of the fish products which were available in quantity on the Pacific Coast.

The offal from salmon canneries offers a relatively untapped source of fish food. Although the hatcheries, located close to cannery operations in the United States, utilize the bulk of the local product, Jones et al. (1948) estimate that 100,000,000 pounds of salmon offal annually goes to waste in Alaska.

Two products are prepared from salmon cannery waste for fish food. The entire offal consisting of the heads, collars, tails, fins and viscera is one preparation, and the salmon viscera, alone, which contains the gastro-intestinal tract, the gonads, and a portion of the liver is the other.

Salmon Viscera

Experiments conducted by Donaldson and Foster(1939) and Phillips and Hewitt (1945) indicated that high levels of salmon viscera in the diet were capable of maintaining chinook salmon fingerling for considerable periods. Phillips and Hewitt were of the opinion that beef liver was a necessary supplement to salmon viscera if anemia was to be prevented. Donaldson and Foster found that they could rear fingerling for a 20-week period on a diet composed of 100 per cent salmon viscera.

Salmon viscera proved to be one of the most promising products tested in the Leavenworth feeding trials. To overcome the feeding difficulties encountered by Phillips and Hewitt (1945), salmon viscera was fed in conjunction with dry meals to serve as absorbing agents or in diets which included a binding agent, to prevent the loss of the water-soluble components. In no trial was salmon viscera fed at the 100 per cent level. When fed at water temperatures above 50 degrees F., high levels of salmon viscera (90 per cent or more in the diet) exhibited an excellent growth potential, in every instance superior to the beef liver control (Table 2, Diets 6 and 7; Table 3, Diet 2; and Table 4, Diet 11).

The high mortalities encountered in lots fed salmon viscera diets during 1944 and 1948 stemmed from two entirely unrelated sources. In 1944, mechanical factors and partially spoiled viscera were the two primary causes of mortality. The extremely small fish used in the experiment (2,631 per pound) did not adjust readily to the abrupt change in diet consistency, color, and particle size encountered in the high viscera diets. The high mortality encountered in the first six weeks of the 1944 experiments consisted of emaciated fish which showed every evidence of starvation. During the last two weeks of this experiment the mortality showed another upswing. In this instance the presence of hemorrhagic areas beneath the skin indicated a nutritional deficiency very probably an avitimonosis. This condition is believed to have been created by viscera which had been allowed to partially decompose before freezing. Attempts to duplicate the breakdown using properly prepared viscera were unsucessful in subsequent trials.

In the 24-week experiments conducted in 1948, the high level salmon viscera diets again showed evidence of an excessive mortality in the stock (Table 5, Diets 15 and 16). In this instance the mortality was correlated with a vitamin deficiency during the cold-water period. The losses in these lots were normal for the first four weeks and then accelerated until they peaked between the tenth and twelfth weeks of feeding from which point they rapidly declined and remained normal for the remainder of the experimental period. Examination of moribund fish during and prior to the peak of the mortality showed no indication of an anemia but symptoms of a pantothenic acid deficiency as demonstrated by excessive fusion of both the gill lamellae and filaments. According to Phillips, et. al. (1946), the pantothenic acid requirement of trout is a function of body weight and is not affected by water temperature. The food intake of salmon and trout is also a function of body weight in that as the weight of the fish increases the percentage of food ingested decreases. The food intake is affected by another factor--water temperature. As the water temperature increases the food intake of the fish also increases (see Table 1). During periods of relatively-constant, cold-water temperatures, a diet which contained minimal amounts of pantothenic acid would be adequate while the fish were small and the food intake was high in proportion to the body weight. As the fish increased in size, the requirement would increase but the percentage of food intake would be reduced providing no increase in water temperature occurred to accelerate the intake. Thus a deficiency could develop in fish fed diets containing the minimal pantothenic acid requirement during periods of prolonged cold water temperatures. This deficiency could correct itself as the water temperature rose with a resultant increase in the food intake of the fish, sufficient to meet the vitamin requirement.

Figure 1 demonstrates the relationship between water temperature, food intake, and mortality in a diet containing a high level of salmon viscera fed during 1948. It will be noted that the mortality peaked during the period of cold water temperatures while the food intake was practically constant and declined sharply with the advent of warmer water and an acceleration in the food intake.

Although the symptoms of a pantothenic acid deficiency were the only ones recognized, it is very probable that other vitamin deficiencies were present in these fish. According to Karrick and Edwards (1948), salmon viscera contains a reduced amount of thiamin, riboflavin, and niacin when compared with either beef of hog liver. Using the requirements of trout for these vitamins as reported by Phillips

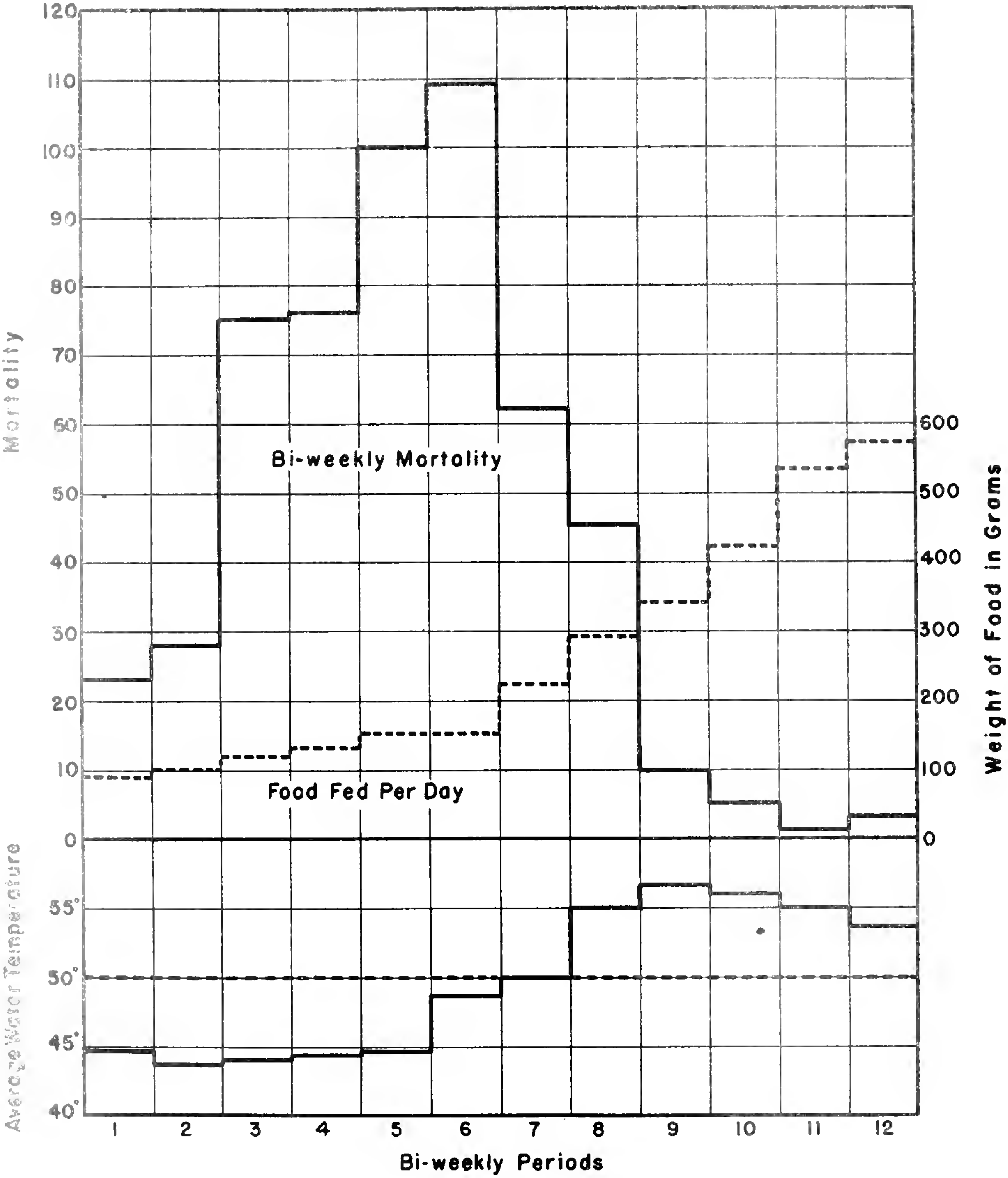

Figure 1. Relationship of Water Temperature, Food Fed and Mortality--1948 Salmon Viscera Diet.

and Brockway (1948), these fish, during the sixth bi-weekly period, were receiving insufficient amounts of both thiamin and niacin to maintain maximum storage in the livers. Neither the work of Phillips and Brockway (1948) nor that of McLaren et. al. (1947) make it possible to determine whether the amount supplied was below the minimal requirements of the fish for these vitamins.

The composition of salmon viscera is not stable. Viscera secured during the forepart of a season will contain a smaller percentage of eggs and milt than will that obtained during the later portion when the sexual products are more fully developed. It will be noted that the proportionally greater gains made by the fish fed high levels of salmon viscera used in these feeding trials was procured from a late run of fall chinook of the Columbia River in which the sexual products were well developed. Later experiments did not utilize salmon viscera in which sexually maturity was as far advanced. It is believed that the preponderance of sexual products in the salmon viscera used during the 1944 feeding trials is responsible for the proportionally greater gains made by the viscera-fed fish during these experiments.

A comparison was made between salmon viscera collected in Alaska and that derived from the Columbia River during the 1948 feeding trials. Two additional variables, different species and probably different stages in the maturity of the viscera, were present in this experiment. The Alaska salmon viscera was secured from pink salmon (O. gorbuscha) collected from Southeastern Alaska under conditions as described by Dassow (1948). The Columbia River salmon viscera was collected on a commercial basis as part of the production supply and consisted principally of the viscera of chinook salmon. No comparisons were made as to the proportions of sexual products contained in either lot. Under the conditions of this experiment no difference was demonstrated to exist between salmon viscera derived from Alaska or the Columbia River (Table 4, Diets 15 and 16).

The growth potential of salmon viscera excels that of any other product tested in these feeding trials. In every instance the addition of salmon viscera to a diet at levels of 30 per cent or over resulted in an acceleration of the growth rate over and above that which could be attributed to the other diet components.

Salmon viscera contains the anti-anemic factor in amounts sufficient to maintain blueback salmon when fed at levels of 90 per cent or more in the diet. Such a ration will maintain the fish for a 24-week period with no symptoms of an amemia (Table 5, Diets 15 and 16). The amount of the anti-anemic factor contained in salmon viscera, however, is indicated to be less than that of beef liver. When fed in conjunction with other products which are deficient in this factor, salmon viscera does not provide adequate fortification. Equal parts of hog liver and salmon viscera in combination with 20 per cent salmon viscera meal did not prevent an anemia from developing in blueback salmon during a 24-week experimental period (Table 5, Diet 6). Both salmon viscera and hog liver contain the anti-anemic factor but not in sufficient quantity to fortify the high level of meal used in the diet. Salmon viscera at the 50 per cent level when fed with 40 per cent hake and 10 per cent meal resulted in an anemic condition in the fish at the close of the experiment (Table 5, Diet7). Hake is known to be deficient in the anti-anemic factor but, according to Wales (1944), the addition of 50 per cent beef liver to a diet of ocean fish consisting principally of hake produced an adequate diet for trout. Because the substitution of salmon viscera for beef liver produced an anemia it may be concluded that salmon viscera does not contain amounts of the anti-anemic factor comparable to beef liver.

The results of these feeding trials indicate that salmon viscera produces an excellent growth response in blueback salmon, superior to any meat product tested, but is a less potent source of the anti-anemic factor than is beef liver and contains but minimal amounts of pantothenic acid, sufficient only to support blueback salmon when the food intake is high. Salmon viscera, therefore, should be fed in conjunction with other products which will supply adequate vitamin fortification, particularly during periods of low water temperature.

Salmon Offal

Salmon viscera represents but 30 per cent of the entire salmon offal. The remainder, consisting of the heads, collars, tails, and fins, represents a large potential source of fish food. Two feeding trials were conducted to evaluate this material. In the first trial, salmon trimmings, the offal from which the viscera was excluded, were fed at the 100 per cent level (Table 4, Diet 13). The growth rate on this diet was very poor and the fish showed an acute anemia at the conclusion of the 12-week, experimental period. In the second trial, the entire offal, in conjunction with 10 per cent salmon viscera meal, was fed (Table 5, Diet 17). At the end of 10 weeks the experiment was discontinued due to an excessive mortality. Although the fish were not anemic there were pronounced symptoms of a pantothenic acid deficiency. The growth rate on this ration was very low--one of the poorest tested during the 1948 season. By deduction it may be concluded that the factor responsible for the reduced growth rate in the entire salmon offal was the salmon trimmings.

Salmon Carcass

Spawned-out salmon carcass has been used as food for salmon fingerlings for many years in some hatcheries. Although available in limited amounts, not sufficient to serve as an adequate supply of fish food, it does offer a cheap source of food, the only cost being that of filleting. This process does increase the manpower requirements of fish food preparation but in small-scale operations the increase is insignificant. Comparisons were made between diets containing varying amounts of salmon viscera and salmon carcass in combination with beef liver, hog liver, hog spleen, and salmon offal meal (Table 2, Diets 10, 11, 12, and 13). Where salmon carcass was substituted for salmon viscera at the 30 per cent level there was a significant reduction in the total gains of the fish (Table 2, Diets 11 and 12). Salmon viscera and salmon carcass in combination at 20 per cent, each, did not produce a significantly greater gain than did salmon viscera alone at the 40 per cent level (Table 2, Diets 10 and 13). The feeding consistency of the salmon carcass-salmon viscera diet was superior to that of the ration containing 40 per cent salmon viscera. As these diets were held for a two-day period under variable refrigeration temperatures and salmon viscera liquefies at temperatures above 29.5 degrees F., the bound quality of the 40 per cent viscera diet was not comparable to that of the salmon carcass rations in which the bind was more stable. It is believed that the improved feeding quality of the salmon carcass-salmon viscera diet was responsible for the production of a growth rate comparable to that produced by salmon viscera. Although no symptoms of vitamin deficiencies were apparent in these short term experiments, when the salmon carcass-salmon viscera combination was fed on a production basis, evidence of a thiamin deficiency was noted after 30 weeks of feeding. The elimination of salmon carcass from the diet corrected the deficiency symptoms.

Canned Salmon

Condemned canned salmon is available, at times, in considerable quantities on the Pacific Coast. This salmon, usually canned in one pound talls, has been condemned as unfit for human consumption. Although not a reliable source of food, this product is available in sufficient quantity to justify an evaluation of its potentialities. Two experimental diets, in which canned salmon at the 70 and 45 per cent levels were fed in conjunction with beef liver, hog spleen, and apple pomace (Table 2, Diets 15 and 16), demonstrated that salmon carcass has an extremely low growth potential. Diet 15, which contained 70 per cent of canned salmon and 12.5 per cent, each, of beef liver and hog spleen plus 5 per cent apple pomace, caused an acute anemia at the conclusion of the feeding trial. An increase in the beef liver content to 25 per cent in Diet 16 prevented the development of an anemic condition in the fish. It is obvious from these experiments that condemned canned salmon does not compare favorably with salmon viscera when included at levels of 45 per cent or over in the diet of blueback salmon.

Tuna Viscera

Tuna viscera would be available in sufficient supply on the Pacific Coast to form a reliable source of fish food should it prove of value. Evaluations of this product were made during the 1945 feeding trials. Three separate combinations of tuna viscera were included in the experiments (Table 3, Diets 3, 5, and 13). In every instance the growth rate was poor and an anemia developed before the conclusion of the 14-week experimental period. Tuna viscera should not be included in the diets of blueback salmon because of its poor growth potential and apparent deficiency in essential vitamins.

Hake

Hake (Merluccius productus) occur in large numbers in the trawl fishery of the Pacific Coast. There is so little commercial demand for this species that it is regarded as a scrap fish in this area. For this reason, the cost per pound is low, and a cheap, adequate source of fish food is available. The preliminary feeding trial conducted in 1947 (Table 4, Diet 14), in which hake was fed at the 100 per cent level, indicated that this product had an excellent growth potential but was deficient in the anti-anemic factor. Although an acute anemia developed in the stock after eight weeks of feeding, the growth rate was such as to exceed that of the beef liver control at the conclusion of the experimental period (see Table 4). Wales (1944) used hake in combination with 50 per cent beef liver and produced an adequate diet for trout. This high level of liver was considered impracticable in view of the difficulties encountered in the procurement of this product.

Two composite diets including hake were tested in 1948 to determine if an adequate diet could be produced with hake which still retained a growth rate comparable to that of diets in which salmon viscera was fed. In one test, hake was substituted for salmon viscera in the standard meat-viscera-meal combination and compared with the diet in which salmon viscera was included (Table 5, Diets 2 and 3). The substitution of hake resulted in a significant reduction in the growth rate of the fish although the gains were greater than the beef liver control. In the second trial, salmon viscera, hake and salmon viscera meal were fed in combination (Table 5, Diet 6). While the gain in weight was below that of the first combination it was still superior to the gains made by the beef liver control and comparable to those made on the best Cortland diet. The fish, however, were acutely anemic at the conclusion of the feeding trial. Because of the excellent growth response attained from hake-fed salmon, further experimentation is proposed to determine a combination of foods which will produce optimum results.

Rockfish

Rockfish, a term used to define several species of the genus Sebastodes, are abundant in the trawl fishery of the Pacific Coast. The market for these fish is not well developed and a cheap source of fish food is available. Both the whole rockfish and the offal from filleting operations were tested at the 100 per cent level to evaluate the potentialities of these food sources in the diet of blueback salmon (Table 4, Diets 15 and 16). Although the whole rockfish produced a greater gain in weight in the fish than did the offal, neither trial indicated that these products had a growth factor sufficient to warrant their inclusion in the diet of blueback salmon. At the end of eight weeks of feeding the fish were acutely anemic and the experiments were terminated.

Of the various fish products tested only hake and salmon viscera offer sufficient promise to warrant further experimentation. Numerous fishery products remain to be explored, however, which, as time permits, will be included in the feeding trials.

Dry Meal Supplements

In the Leavenworth feeding trials, dry meals were used both as absorbing agents to improve the feeding consistency and as nutritional supplements. In these evaluations it was found that the type of meal used, the source from which it was derived, the method by which it was prepared, and the water temperature at which it was fed, all were factors which affected the utilization of dry meal supplements by blueback salmon.

Certain types of mineral, vegetable, and animal meals were incorporated into the experimental diets. The mineral and vegetable meals were used primarily as absorbing agents to improve the feeding consistency and secondarily as vitamin and mineral supplements. The animal meals which were derived exclusively from fish products were used as protein supplements.

If the addition of either mineral or vegetable meals were to compensate for a vitamin or mineral deficiency in the diet, an acceleration in growth rate such as was reported by Donaldson and Foster (1947) for the addition of kelp meal might be expected. No such results were noted when apple pomace, tomato pomace, kelp meal, or diatomaceous earth were incorporated in the diet in combination with beef liver, hog liver, hog spleen and salmon viscera.

Apple Pomace

Apple pomace, the residue from vinegar production, proved to be an excellent absorbing agent. The effect of this absorbent action is brought out clearly in the 1945 experiments in which the diets were held for a two-day interval while being fed. In this case the improvement in the feeding consistency made by the addition of apple pomace to the diet equaled the contribution made to the growth rate of a high-protein fish meal (Table 3, Diets 9 and 10). A repetition of these trials in 1947, when all diets were ground, mixed, and fed within an eight-hour period, which eliminated the breakdown in the bound diets due to storage, disclosed that apple pomace in the 1945 trials made no contribution to the meat and viscera mixture other than to improve its feeding consistency (Table 4, Diets 5, 9, and 10.

Tomato Pomace

Tomato pomace, the dried pulp remaining after juice extraction, was about comparable to apple pomace as an absorbing agent (Table 3, Diets 10 and 11) and did not appear to offer much possibility as a dietary supplement. As its contribution to the growth rate was not significantly different from that of apple pomace in the 1945 experiments and the 1947 trials indicated that the contribution of apple pomace was negligible in diets of good feeding consistency, it may be deduced that tomato pomace, also, would have no significant influence on the growth rate when fed in conjunction with the meat and viscera mixture.

Kelp Meal

In the 1947 feeding trials, kelp meal was fed at the 10 per cent level in the combination described above and compared with this meat and viscera mixture when fed at the 100 per cent level (Table 4, Diets 7 and 10). The results indicate that kelp meal made no measurable contribution to the growth rate of blueback salmon.

Diatomaceous Earth

Diatomaceous earth, the only meal of the mineral type fed, was tested in both the 1945 and 1947 trials but at different levels in the diet. In the 1945 experiments, this meal, when fed at the 10 per cent level in combination with the meat and viscera mixture, displayed an extremely low growth potential in comparison with either vegetable or animal meals (Table 3, Diet 12) but the fish on this diet were highly colored. As high coloration is considered desirable in trout production, it was decided to determine if this effect could be produced by feeding diatomaceous earth at a lower level in the ration. In 1947, 5 per cent of diatomaceous earth and 5 per cent salmon viscera meal were fed in conjunction with the standard meat and viscera mixture. This ration produced no noticeable increase in the coloration of the fish and the growth rate was significantly below that of fish fed an identical viscera meal at the 10 per cent level (Table 4, Diets 4 and 8). From these experiments it was concluded that diatomaceous earth because of its low growth potential was impracticable for use in combination diets.

Salmon Waste Meals

The design of these experiments did not include an evaluation of vegetable as contrasted to animal type protein supplements. Rather, this phase of the investigation was concentrated on the exploration of salmon waste meals. The only comparatively high protein, vegetable meals fed were cottonseed meal and wheat middlings combined with salmon viscera meal and dried skim milk in equal proportions to form the Cortland No. 6 meal mixture. In these diets (Table 4, Diets 2 and 3; and Table 5, Diets 4 and 5), the effects of the vegetable proteins were obscured by the addition of animal proteins to the mixture.

In the short-term experiments of 1944, 1945 and 1947 the addition of salmon waste meals to otherwise adequate diets resulted in a significantly greater gain in weight in the fish fed these diets. This conclusion is confirmed in the 1947 feeding trials (Table 4) in which a control diet consisting only of the standard meat and viscera mixture exhibited a significantly lower growth response than any diet in which 10 per cent of a salmon waste meal was used to supplement the mixture.

From these experiments it may be concluded that vegetable meals of a low protein content but of a highly absorbent nature make no measurable contribution to the diet of blueback salmon when fed at the 10 per cent level in combination with the meat mixture providing that the feeding consistency of the diet is not improved. The high mineral content of kelp meal and diatomaceous earth, likewise, make no significant contribution to the diet when fed in similar combinations. High protein, dehydrated, salmon waste products do make a marked contribution to this ration under certain environmental conditions.

Effect of Source on Utilization of Salmon Waste Meals

As the biological values of animal proteins from different sources vary, evaluations were made of meals derived from two segments of the salmon waste and from two localities -- Southeastern Alaska and the Columbia River. This investigation was conducted during 1947 and 1948 in cooperation with the Seattle Technological Laboratory of the Branch of Commercial Fisheries and financed in part by the Industrial Research and Development Division of the Department of Commerce.

The preliminary trials conducted in 1947 indicated that meals prepared from the whole waste did not have as high a growth potenial as did those derived from salmon viscera (Table 4, Diets 4 and 5). There were, however, several variables such as the procurement of the meals from two sources and variations in the methods of preparation which could have produced these differences.

In 1948, salmon offal and salmon viscera meals, derived from the same source and prepared by an identical method under controlled conditions, were tested to evaluate the protein quality of the two salmon waste products. Two such sets of evaluations were used employing two methods of preparation (Table 5, Diets 9 and 13, and Diets 10 and 12). In both groups the trend was the same, favoring the meal derived from salmon viscera, but only in the group in which the meal was most efficiently utilized were the differences statistically significant. It may be concluded, however, that salmon viscera tunnel-dried at 100 degree temperatures produces a greater growth response than does the complete salmon offal prepared by the same process.

Salmon wastes from different species vary in their proximate analysis. To determine if these differences affected the growth potential of the meals a comparison was made in the 1948 feeding trials. Two meals prepared in an identical manner but one derived from the viscera of Columbia River chinook salmon and the other from Southeastern Alaska pink salmon were tested at the 10 per cent level in combination with meat and viscera mixture (Table 5, Diets 2 and 9). The diet which contained the chinook salmon viscera meal produced significantly greater gains than did that which included meal derived from pink salmon viscera. There was one variable, the stage of maturity of the fish from which the viscera was obtained, which was not excluded from the experiment. As the season progresses, the proportions of eggs, milt, and gastro-intestinal tract change with the sex products occuring in greater proportions as the fish approach maturity. If both meals were derived from fish at comparable stages of maturity it was by pure chance. Because varying proportions of the sex products in the viscera may alter the biological value of the protein without materially changing the crude protein content, this variable may invalidate the results of the experiment.

Effect of Method of Preparation on Utilization of Salmon Waste Meals

That the biological value of proteins may be altered by excessive heat has been demonstrated, repeatedly, in feeding trials with other animals. Because of the cooperative agreement with the Seattle Technological Laboratory, it was possible to prepare meals derived from exactly comparable sources, using standard techniques of preparation, but employing different drying temperatures. In this manner, all variables other than that of drying temperature were eliminated. Two such series of experiments were included in the 1948 feeding trials. The meals were prepared by tunnel and flame drying as described by Karrick and Edwards(1948). In the first series, using Alaskan salmon offal as the source material, three different temperatures were available, 100 degree and 145 degree air-dried meals and a commercial flame-dried meal derived from the same source. The second group, using Alaskan salmon viscera, contained two tunnel-dried meals at 100 and 145 degree temperatures. In both groups the meals were added at the 10 per cent level to the standard meat and viscera mixture. In the first series (Table 5, Diets 12, 13, and 14) no significant difference existed between the groups of fish fed the three diets. In the second evaluation (Table 5, Diets 9 and 10), in which meals of higher growth potential were fed, a significant difference in total gains was demonstrated. The salmon viscera meal dried at 100 degree temperatures was definitely superior to the 145 degree meal. The trend in the first series is consistently in favor of the lower drying temperatures at the conclusion of the 24-week period. This trend is not apparent during the first 12 weeks of the experiment. The gains which created the differences between the diets occurred in the second 12-week period indicating an acceleration in growth rate for that period in the fish fed tunnel-dried meals which was superior to that of those fed the flame-dried product. Had this experiment been conducted only during the warm-water period, it is probable that the addition of low-temperature-dried meals would have produced gains which were significantly greater than the flame-dried product.

An acetone-extracted salmon viscera meal was tested in the 1947 feeding trials. This meal was prepared from salmon viscera by a process described by Karrick and Edwards (1948) in which the temperature during dehydration did not rise above 75 degrees F. This process is not in commercial use but if it could be demonstrated that this method produced a superior meal, the development of a practical procedure might be justified. The acetone-extracted meal was incorporated with the meat and viscera mixture at the 10 per cent level and compared with a similar diet containing 10 per cent of 145 degree, tunnel-dried, salmon viscera meal. The results of the 12-week feeding trials indicated that no significant difference in growth potential existed between the two meals. Vitamin analysis, as reported by Karrick and Edwards (1948) showed that the acetone-extraction process sharply reduced the content of some of the B-complex vitamins in the salmon viscera. This reduction in the vitamin content may have had a masking effect on the temperature evaluation. Regard less of the cause, the ace-tone extracted meal did not prove superior to the tunnel-dried meal and because of its reduced vitamin content must be considered inferior.

On the basis of these experiments, it is indicated that high temperatures such as occur in flame drying may have a deleterious effect on the growth potential of fish meals. Although the differences in growth rate did not prove statistically significant, the trend indicated that high drying temperatures produced salmon offal meals of an inferior growth potential. This inference is substantiated by the significantly greater gains made by fish fed 100-degree, tunnel-dried, salmon viscera meal when compared with those fed a similar diet containing an identical meal dried at 145 degrees. The acetone extraction of salmon viscera at room temperatures did not increase the growth response of fish fed this product over that of those fed meals prepared by the tunnel-drying process.

The effect of water temperature on the utilization of meal supplements was demonstrated during the 1948 feeding trials. Prior to 1948, the diets were tested for a 12 or 14-week period at an average water temperature of approximately 54 degrees. In these feeding trials the addition of high protein meals resulted in an impetus to the growth rate and a low mortality rate. In the 1948 experiments these results were not duplicated for the entire experimental period. During the first 12-weeks of the feeding trials the water temperature averaged 44.9 degrees. In this period the growth response due to the addition of meals in the diets was not measurable and the mortality rates were greatly accelerated when compared to control diets from which meals were excluded. During the second 12 weeks the water temperature averaged 54.3 degrees. The rise in water temperature resulted in an increase in the gain in weight and a reduction in mortality in the fish fed meal diets, more comparable to the results attained in the previous feeding trials.

The effect of water temperatures on the utilization of meals is shown in Figure 2. To demonstrate the effect four diets were selected. Diet 1 was the standard beef liver control. Diet 2 contained the standard meat and viscera mixture and 10 per cent of 145-degree salmon viscera meal. This diet was chosen for comparison because it contained an identical meal to that used in the Cortland No. 6 meal mixture. Diet 4 consisted of the recommended Cortland diet and included 15 per cent beef liver, 35 per cent hog spleen and 50 per cent of the Cortland No.6 meal mixture. Diet 8 was the standard meat and viscera mixture fed at the 100 per cent level. Diet 8 served as a control on Diet 2 and measured the

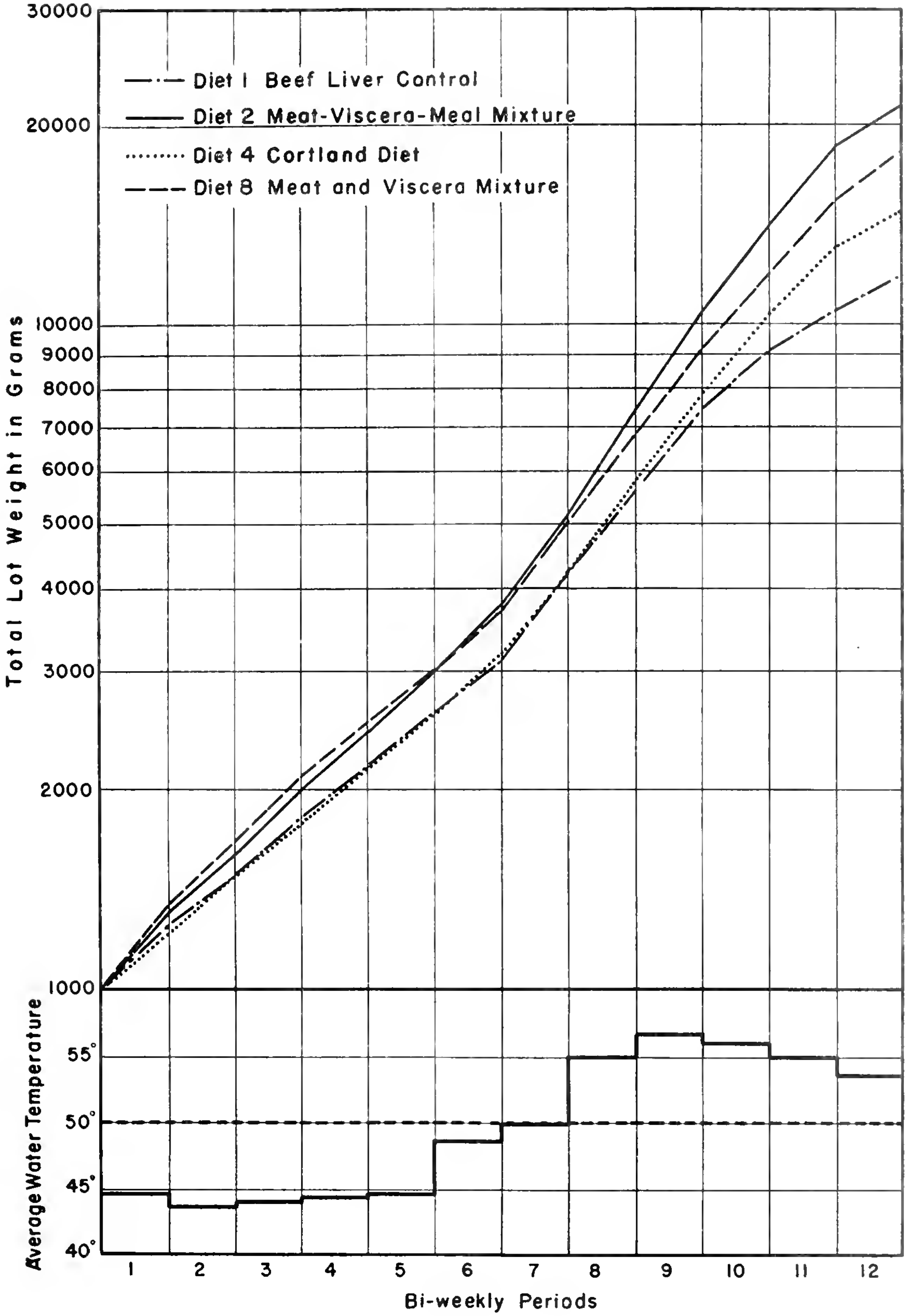

Figure 2. Effect of Water Temperature and Dry Meals on the Total Lot Weights of Blueback Salmon--1948

contribution of fish meal to the meat and viscera mixture. These diets were exact duplicates of those fed during 1947. In that year (Table 4) the Cortland diet and the meat-viscera-meal mixture produced comparable gains. Both indicated significantly higher growth rates in the fish than was made by the meat and viscera mixture which, in turn was superior to the beef liver diet. In 1947, the mortalities incurred by these diets were not significantly different.

In 1948, the total weight of the fish fed each diet, as shown in Figure 2, indicated that the addition of 10 per cent meal to the meal and viscera mixture (Diet 2) made no measurable contribution to the total weight of the fish during the first 12 weeks of the experiment. The Cortland diet (Diet 4) appeared to be definitely detrimental during the cold-water period. At the end of the first 12 weeks, the meat-viscera-meal mixture and the meat and viscera mixture were comparable in their total gains in weight. At the same time the Cortland diet and beef liver control also showed no significant differences from each other. The difference in weight that existed between the two groups, however, was significant. These results were in marked variance with the findings of the 1947 feeding trials.

At the conclusion of the 24-week experiment, the addition of meals to the diet had made a measurable contribution to the total weight of the experimental fish. In the two groupings, the addition of 10 per cent meal resulted in a significant increase in the total weight of Diet 2 over the fish in Diet 8, and the 50 per cent meal contained in the Cortland diet made a measurable contribution to the total weight when compared to the fish fed the beef liver control. Contrary to the 1947 results, the Cortland diet was no longer comparable to the meat-viscera-meal mixture but resulted in a total weight of fish produced which was inferior to the meat and viscera mixture. All four diets differed significantly from each other.

It will be noted that, with the advent of warmer water, the slope of the weight curves altered sharply. It was during this period that the acceleration in growth due to the addition of meal became apparent.

It has been the policy of this laboratory to make no compensation for mortality when evaluating practical diets on the theory that mortality is one measure of the efficiency of a diet. In this case, however, where significant differences in mortality existed and where there was a distinct possibility that the contribution of meals to the growth rate was being obscured by the mortality, it appeared desirable to plot the rate of growth for the diets in question to eliminate the effect of mortality. The rate of growth, as determined by the average weight of the fish, for the four diets in question is plotted in Figure 3. From this graph it is apparent that the water temperature did affect the efficiency with which the dry meals were utilized by the fish and, also, that the mortality was responsible for a depression in the total gain. This latter effect is particularly apparent in the case of the Cortland diet where the gain in total weight was comparable to the beef liver control but the average weight of the fish closely paralleled that of those fed the meat and viscera mixture. In this instance, however, the retardation effect of the cold water period is clearly demonstrated by the fact that the average weight of the fish on the Cortland diet did not approach that of those fed the meat-viscera-meal mixture. In the 1947 trials, at warm-water temperatures these two diets were comparable.

Unlike the mortalities which occurred in the high-viscera diets during the cold-water period, no symptoms of a vitamin deficiency could be identified upon examination of moribund fish from Diets 2 or 4. The factor responsible for these high losses has not been indentified.

The exact water temperature at which dry meals make a measurable contribution to the growth rate of blueback salmon cannot be determined accurately from either Figure 2 or 3. A comparsion of the curves in the two graphs shows that the point of divergence of the meat-viscera-meal mixture from the meat and viscera control differs. In Figure 2, the total weight of the fish on the meal diet (Diet 2) is depressed by the mortality which continued after a growth response is discernable in the average weight of the fish as shown in Figure 3. It is evident, however, that dry meals are not utilized effectively and appear to be detrimental to blueback salmon when fed at water temperatures approximating 45 degrees F.

Potential Production Diets

The ultimate aim of feeding experiments is the development of practical diets which may be used in fish-cultural operations. Several potential diets have been developed from the leavenworth feeding trials some of which have been tested in actual production operations.

As a starting diet for first-feeding fingerling, the beef liver-hog liver combination (Table 2, Diet 3) has proved superior to either product fed separately or in combination with hog spleen. This diet has the additional advantage of adaptability in that the feeding consistency may be altered to a form compatible with the size of the fish with a minimum of effort. Varying consistencies may be produced by the degree to which the diet is beaten just prior to being fed. The beef liver-hog liver ration has been used on the three hatcheries of the Grand Coulee Project since 1945 as a starting diet for blueback, chinook, and silver salmon with excellent results.

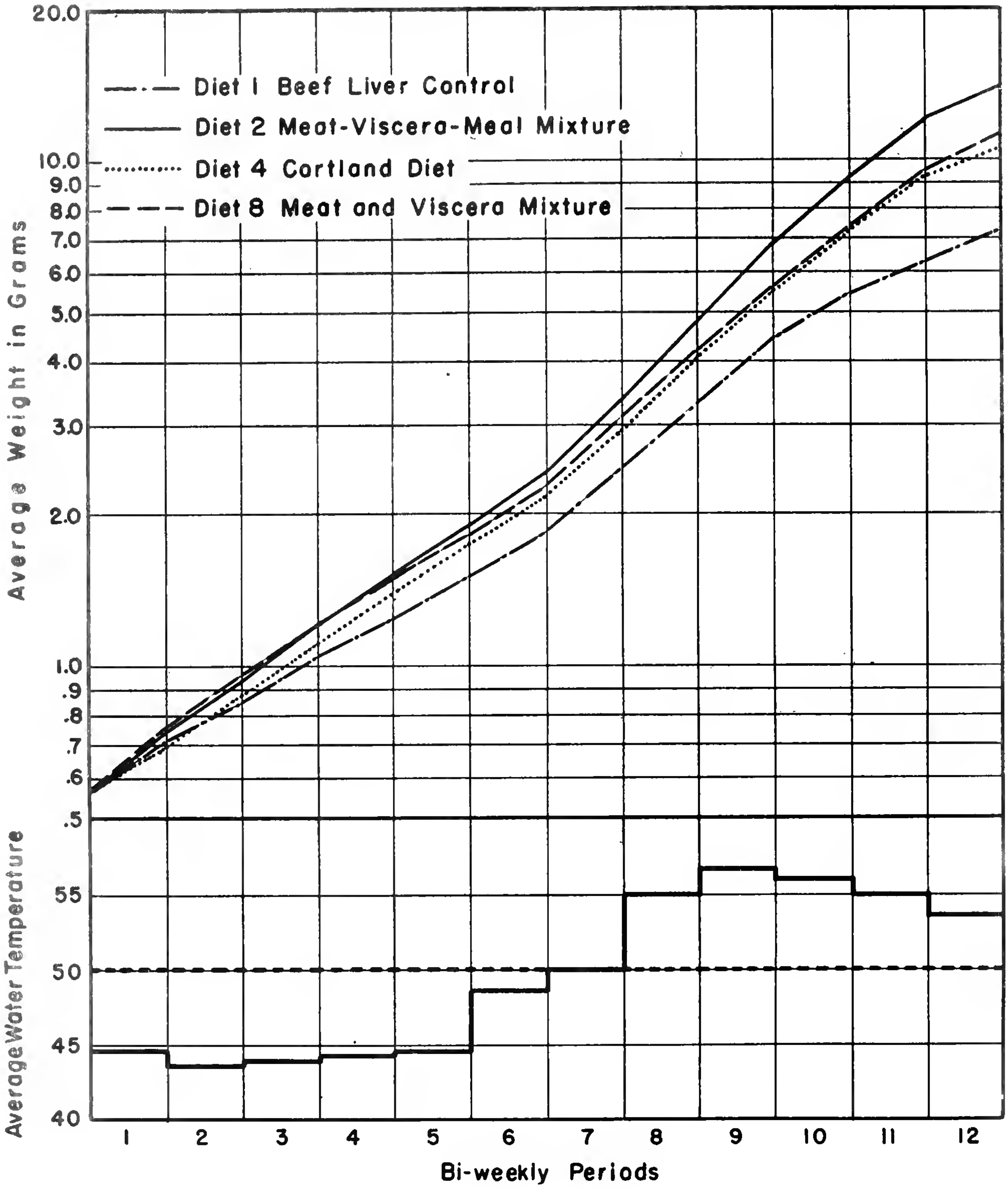

Figure 3. Effect of Water Temperature and Dry Meals on the Growth Rate of Blueback Salmon—1948

The meat and viscera mixture has proved superior to any single or combination of raw products tested on blueback salmon. This diet, which consists of 22.2 per cent, each, of beef liver, hog liver, and hog spleen, and 33.4 per cent of salmon viscera, produces excellent gains with a minimum of mortality during periods of low water temperatures--less than 50 degrees. At water temperatures above 50 degrees any of the salmon waste meals may be incorporated into the diet at the 10 per cent level to produce a significant growth response without an increase in mortality. Of the salmon waste meals tested, low temperature (100 and 145 degree) tunnel dried, salmon viscera meals exhibited the greatest growth potentials.

That hog liver in combination with salmon viscera may meet the nutritional requirements of blueback salmon, at least during periods of warm water temperatures, is indicated from these diet experiments. In the 1945 feeding trials, a combination of 30 per cent hog liver, 20 per cent hog spleen, 40 per cent salmon viscera, and 10 per cent flame-dried, salmon offal meal produced gains comparable to the standard meat-viscera-meal combination (Table 3, Diets 8 and 9). At the conclusion of the 14-week experimental period no deficiency symptoms were discernible. During the 24-week trials in 1948 an alteration of this diet, which included 40 per cent, each, of hog liver and salmon viscera plus 20 per cent of 145 degree, tunnel-dried, salmon viscera meal, was acutely anemic at the conclusion of the experiment but the total gain of the fish was comparable to those fed a meat-viscera-meal mixture (Table 5, Diets 2 and 6). The 20 per cent level of meal in Diet 6 was used to improve the feeding consistency and it may be that this high level of meal was responsible for the production of the anemic condition. Further experimentation using the hog liver-salmon viscera combination as a substitute for beef liver appears to be justified.

The recommended Cortland diets, using either 15 per cent beef liver and 35 per cent hog spleen or 50 per cent hog spleen in combination with 50 per cent of the Cortland No. 6 meal mixture, produced gains comparable to a meat-viscera-meal mixture when fed for a 12-week period at an average water temperature of 54 degrees (Table 4, Diets 2, 3, and 4). At the low water temperatures experienced during the first 12 weeks of the 1948 feeding trials, the Cortland diets were unsatisfactory for blueback salmon. Although the addition of 15 per cent beef liver resulted in a reduction in mortality and an increased growth rate when compared with the 50 per cent spleen ration, both diets showed significantly higher mortalities and lower gains than did the meat-viscera-meal mixture (Table 5, Diets 2, 4, and 5). The deleterious effects of the Cortland No. 6 meal mixture carried through into the warm water period. Although the growth rate of the fish accelerated, it was still significantly below that of the comparable meat-viscera-meal ration at the conclusion of the experiment. From these results it is indicated that the Cortland No. 6

meal mixture should not be included in the diet of blueback salmon during periods of low water temperature.

Of the numerous diets tested in the Leavenworth feeding trials only the beef liver-hog liver starting diet, the meat and viscera, and meat-viscera-meal rations have been evaluated sufficiently as production diets to recommend their adoption in actual production operations. These diets have proved practicable and are apparently nutritionally adequate as rations for blueback salmon.

The Effect of Cold Storage on Prepared Diets.

The problem of diet preparation is very real and pertinent, particularly to fish-cultural operations conducted on a small scale. Most of the diet preparation equipment available on the market is expensive and not adapted to the preparation of small quantities of food. For these reasons, such equipment is not applicable to small-scale operations. If diets could be prepared in a central plant, packaged, stored under refrigeration, and delivered to the stations as required, much of the cost of diet preparation which is contained in duplicate equipment and the inefficiency of limited operations could be eliminated.

Feeding trials were conducted during 1945, 1947, and 1948 to test prepared diets which had been held in frozen storage for a period of 60 days or more before being fed. In these experiments, the diet components, with the exception of salt, were ground and mixed while in a frozen condition and packed in small, commercial, cardboard, freezing cartons while still in a frozen state. The prepared diets were held at a refrigerative temperature of -10 degrees F. The size of the cartons varied from one-half pints to quarts. A sufficient number of cartons to meet the daily requirement of the fish were withdrawn from storage, allowed to soften slightly, broken into small pieces, and bound by mixing and the addition of salt when a binder was present in the diet.

In the 1945 experiments, three frozen prepared diets were tested. In all diets the meat and meal composition was the same and the variables, salmon viscera, salmon carcass, and tuna viscera, were introduced at the 30 per cent level (Table 3, Diets 14, 15, and 16). The diets containing tuna viscera and salmon carcass had to be discontinued before the conclusion of the 14-week experimental period due to an acute anemia in both groups of fish. The diet containing salmon viscera, on the other hand, showed no evidence of an anemia and exhibited a growth potential comparable to its freshly-prepared counterpart (Table 3, Diet 9). That both tuna viscera and salmon carcass produced an anemia is not surprising in view of the other experimental results. Phillips and Hewitt (1945) concluded that salmon carcass was deficient in the anti-anemic factor and the 1945 experiments with tuna viscera, fed freshly prepared, indicated an even greater deficiency in this product. It is apparent that the reduction in the anti-anemic factor due to storage was sufficient to deplete the salmon carcass diet below the minimal requirements of blueback salmon. A comparable diet, freshly prepared, proved adequate in the 1944 experiments.

Only one prepared frozen diet was fed in 1947. This ration, which consisted of 90 per cent salmon viscera and 10 per cent apple pomace, exhibited a lower mortality and significantly greater gains in the fish than did a duplicate diet prepared daily (Table 4, Diets 11 and 12). As the composition of the salmon viscera may have varied between lots, it cannot be concluded that storage had a beneficial effect on the diet other than the possibility that the more soluble components of the viscera were absorbed by the meal and, thus, were made available to the fish.

In 1948 the stored diets consisted of the meat and viscera mixture plus 10 per cent 145-degree, salmon viscera meal and 90 per cent salmon viscera plus 10 per cent of the same viscera meal. Duplicate freshly-prepared diets were included in the experiments (Table 5, Diets 2 and 19, 15 and 20). The results of previous years were not repeated in these experiments. The meat-viscera-meal mixture produced an anemia which was so acute as to cause a discontinuance of this lot after 16 weeks of feeding. The diet containing the high level of salmon viscera showed evidence of a pantothenic acid deficiency in the fish after 7 weeks of feeding. No gains were made, in fact the group as a whole lost weight. Losses were so severe in this lot as to force the abandonment of the experiment after 18 weeks of feeding. Surprisingly enough, no anemia was present in these fish. The results from both these diets lead to the conclusion that the loss of vitamins due to storage was sufficient to reduce the vitamin content of the diet below the minimal requirements of the fish when the food intake was reduced due to cold water temperatures.

The results of the entire group of prepared frozen diet tests indicate that prepared diets lose a significant portion of their vitamin content during the cold storage period. If the original diet contains more than the minimum vitamin requirement of the fish and the food intake is high, the fish may receive sufficient vitamins to meet their demands but when the original diet contains only a minimal vitamin content or the food intake is reduced, vitamin deficiencies may develop.

It is assumed that the primary factor responsible for vitamin reduction in prepared diets during storage is oxidation. The ground diet has infinitely greater surface exposed to the air and, therefore, is subject to greater oxidation than the unground product. Although packaged in waxed cardboard cartons, the effect of oxidation was apparent on all outer surfaces of the diet indicating that some air did penetrate the carton. The use of antioxidants to prevent oxidation within the mass of the ground product and the employment of other, more impervious, types of freezing containers offer possible solutions to the problem of vitamin destruction in prepared diets during storage.

SUMMARY

The feeding trials conducted by the Leavenworth Laboratory during the years 1944, 1945, 1947, and 1948 have evaluated the effects of feeding certain meat products, fish products, dry meal supplements, potential production diets, and prepared diets held in frozen storage, as rations for blueback salmon. The results of these evaluations may be summarized as follows:

Meat Products

1. Of the meat products tested flukey beef liver and flukey hog liver were found to produce a comparable growth response in the fish. A combination of equal parts of beef liver and hog liver demonstrated a higher growth potential than either product fed separately. Hog spleen, when combined with equal parts of either beef or hog liver, made no measurable contribution to the growth rate in excess of either of these products alone. The anti-anemic factor was present in the greatest amount in beef liver and to a lesser degree in hog liver. Both these products contained more of the anti-anemic factor than did hog spleen.

2. Beef liver, ground and canned under 25 pounds of vacuum, showed evidence of a severe thiamin depletion, sufficient to cause symptoms of a thiamin deficiency in the fish.

Fish Products

3. Salmon viscera produced an excellent growth response, superior to any meat product tested, but was a less potent source of the anti-anemic factor than was beef liver. Salmon viscera contained other vitamins, particularly pantothenic acid, in minimal amounts which caused vitamin deficiencies in the fish when the food intake was low. Salmon viscera should be fed in conjunction with other products which will supply adequate vitamin fortification, especially during periods of low water temperature.

4. Salmon offal, including the viscera, produced a reduced growth response when compared with salmon viscera. Salmon trimmings, the offal minus the viscera, exhibited an extremely low growth potential and a deficiency in the anti-anemic factor. Neither salmon offal nor salmon trimmings offer great possibilities as a source of fish food.

5. Spawned-out salmon carcass exhibited a lower growth potential than salmon viscera and was deficient in the anti-anemic factor as well as other essential vitamins. Salmon carcass should be fed with caution in the diet and only in combination with other products which will supply adequate vitamin fortification.

6. Condemned canned salmon resulted in a low growth response when included in the diet of blueback salmon at the 45 per cent level or over.

7. Tuna viscera should not be included in the diet of blueback salmon because of its low growth potential and deficiency in the anti-anemic factor.

8. Hake (Merluccius productus), although deficient in the anti-anemic factor, had an excellent growth potential. It offers possibilities as a cheap source of protein in the diet.

9. Whole rockfish and rockfish offal were deficient in the anti-anemic factor. Neither product had a growth potential sufficient to warrent its inclusion in the diet.

Dry Meal Supplements

10. Absorbent meal of mineral and vegetable origin such as apple pomace, tomato pomace, kelp meal, and diatomaceous earth made no measurable contribution to the growth rate of blueblack salmon when fed at the 10 per cent level in the diet in combination with 20 per cent, each, of beef liver, hog liver, and hog spleen, and 30 per cent salmon viscera.

11. High-protein meals of animal origin as represented by dehydrated salmon waste products made a marked contribution to the growth rate under certain enviromental conditions.

12. Evaluations of meals prepared from salmon offal and salmon viscera indicated that those derived from salmon viscera had a superior growth potential.

13. A significant difference in the growth response was demonstrated to exist between salmon viscera meals prepared from Columbia River chinook salmon and Southeastern Alaska pink salmon. The chinook

salmon viscera meal was found to be superior. Differences in the degree of maturity of the fish from the two sources may have altered the percentage composition of the visceral portions and invalidated the conclusion drawn from this experiment due to the introduction of an additional variable.

14. In the tunnel process of dehydration, 100-degree drying temperatures produced a salmon viscera meal superior to one dried at 145 degrees.

15. Salmon viscera meal, dehydrated by an acetone-extraction process at room temperatures produced a growth response comparable to that of tunnel drying at 145 degrees. Acetone extraction reduced the vitamin content of the meal particularly in certain vitamins of the B-complex. Because of the vitamin reduction, this process is considered inferior to tunnel drying.

16. Salmon waste meals made no measurable contribution to the growth and caused an increase in mortality when fed at the 10 per cent level in the diet at water temperatures approximating 45 degrees. At temperatures of 50 degrees or above the deleterious effects noted at colder temperatures were absent and a significant growth response was noted

Potential Production Diets

17. Three diets, tested and found applicable to the production hatchery have been developed from these feeding trials. A starting diet, consisting of 50 per cent, each of beef liver and hog liver proved superior to any all-meal diet tested. It was particularly adapted to a starting diet because of the variations in consistency which could be attained. A cold water diet, fed at water temperatures approximating 45 degrees and consisting of 22.2 per cent, each, of beef liver, hog liver, and hog spleen and 33.4 per cent of salmon viscera, was superior to any other diet at these water temperatures when both growth and survival were considered. The addition of salmon waste meals, at the 10 per cent level, to the meal and viscera mixture resulted in a significant contribution to the growth of the fish without an increase in mortality when fed at water temperatures above 50 degrees. At warm water temperatures this diet equaled or excelled any other diet tested as a ration for blueback salmon.

18. A hog liver-salmon viscera combination may serve as a substitute for beef liver during periods of high food intake.

19. The Cortland No.6 meal mixture, fed at the 50 per cent level in combination with either 50 per cent hog spleen or 15 per cent beef liver and 35 per cent hog spleen, was found to produce gains comparable to the meat-viscera-meal combination when fed at water temperatures

above 50 degrees. At water temperatures approximating 45 degrees, both the recommended Cortland diets had a deleterious effect on the survival rate of blueback salmon. The Cortland No. 6 meal mixture should not be included in the ration of blueback salmon during periods of low water temperatures.

The Effect of Storage on Prepared Diets

20. The experiments indicate that prepared diets, ground, mixed, packaged, and retained in frozen storage, lose a portion of their vitamin content during storage period. If the original diet contains more than a minimal vitamin content and the food intake is high the fish may receive sufficient vitamins for adequate maintenance but when the food intake is reduced vitamin deficiencies may develop.

Acknowledgments

Acknowledgment is made to the Branch of Game Fish and Hatcheries, particularly to Dr. O. Lloyd Meehean, William Hagen, Jr., and E. M. Tuttle, for use of facilities at the Leavenworth Fish-Cultural Station and the procurement of the major items of fish food used in these experiments. Appreciation is expressed to the Branch of Commercial Fisheries, Seattle Technological Laboratory, particularly M. E. Stansby, G. Ivor Jones, and Neva Karrick for the procurement and preparation of special diet ingredients and the analysis of the diet components.

LITERATURE CITED

Dassow, John A.

1948. Collection of raw material in Alaska. U. S. Dept. Com., Office Tech. Ser. Rept., "Utilization of Alaska salmon cannery waste--Part": 3-7.

Donaldson, Lauren R., and Foster, Fred J.

1937. Notes on the use of kelp meal in the diets of young salmon. Prog-Fish. Cult. 27 (Feb. 1937): 3-7.

Donaldson, Lauren R., and Foster, Richard F.

1939. Some experiments on the use of salmon viscera, seal meal, beef pancreas, and apple flour in the diet of young chinook salmon (Oncorhynchus tschawytscha). Pro. Fish-Cult. 44 (March-April 1939): 10-15.

Hewitt, George Sterling, and Burrows, Roger Eugene.

1948. Improved method for enumerating hatchery fish populations. Pro. Fish-Cult. 10-1 (Jan. 1948): 23-27.

Jones, G. Ivor: Carrigan, Edward J.; and Dassow, John A.

1948. Utilization of salmon eggs for production of cholesterol, protein and industrial fat. U. S. Dept. Com., Office Tech. Ser. Rept., "Utilization of Alaska salmon cannery waste--Part 2": 9-32.

Karrick, Neva

1948. The nutrition of fish in hatcheries -- a literature review. U. S. Dept. Int., Fish and Wild. Ser., Fish. Leaf. 325, 23 pp.

Karrick, Neva, and Edwards, Mabel A.

1948. Vitamin content of experimental fish hatchery foods. U. S. Dept. Com., Office Tech. Ser. Rept., "Utilization of Alaska salmon cannery waste -- Part 2": 33-48.

McLaren, Barbara A.: Keller, Elizabeth; O'Donnel, D. John: and Elvehjem, C.A.
1947. The nutrition of rainbow trout. I. Studies of vitamin requirements. Arch. Biochem. 15, 2, (Nov. 1947): 169-178.

Phillips, Arthur Morton, and Brockway, Donald R.

1948. Vitaminology. Pro. Fish-Cult. 10-3 (July 1948): 117-214.

Phillips, Arthur Morton; Brockway, Donald R.; Rodgers, E.O.; Sullivan, M. W.; Cook, Blendon; and Chipman, John R.

1946. The nutrition of trout. N.Y. Cons. Dept., Cortland Hatchery Rept. 15, 21 pp.

Phillips, Arthur Morton; Brockway, Donald R; Rodgers, E. O.; Robertson, R.L.; Goodell, Herbert; Thompson, John A.; and Willoughby, Harvey.

1947. The nutrition of trout. N. Y. Cons. Dept., Cortland Hatchery Rept. 16, 35 pp.

Phillips, Arthur Morton, and Hewitt, George Sterling.

1945. Evaluation of salmon flesh and salmon viscera in the diet of chinook salmon fingerlings. Trans. Am. Fish. Soc. 73, (1943): 63-69.

Phillips, Arthur Morton; Tunison, A. V.; Shaffer, H.B.; White, G.K.; Sullivan, M.W.; Vincent, Curtis; Brockway, Donald R.; and McCay, C.M.

1945. The nutrition of trout. N. Y. Cons. Dept. Cortland Hatchery Rept. 14, 31 pp.

Mitchell, C. R.

1941. The potato ricer in the fish hatchery. Prog. Fish-Cult. 55 (Nov. L941): 28-30.

Snedecor, George W.

1940. 1946. Statistical Methods. Iowa State College Press. 3 and 4 ed., 485 pp.

Tunison, A. V.; Phillips, Arthur Morton; Shaffer, H. B.; Maxwell, J.M.; Brockway, Donald R.; and McCay, C.M.

1944. The nutrition of trout. N. Y. Cons. Dept. Cortland Hatchery Rept. 13, 21 pp.

Wales, Joseph H.

1944. Fresh ocean fish as a trout diet. Cal. Fish and Game 30, 1: 43-48.

Interior--Duplicating Section--Washington, D. C. 94356