TESTS OF HATCHERY FOODS FOR BLUEBACK SALMON 1949

SPECIAL SCIENTIFIC REPORT: FISHERIES No. 60

UNITED STATES DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

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INTRODUCTION

This paper is a report of the 1949 salmon feeding trials at the Leavenworth Laboratory of the Fish and Wildlife Service. The purpose of these trials was to develop improved diets for fingerling blueback salmon (Oncorhynchus nerka) by feeding these fish various foods under actual hatchery conditions.

The 1949 studies were a continuation of previous feeding trials conducted with fingerling blueback salmon at this laboratory. In these feeding trials, the single component studies included tuna liver and the four major segments of salmon viscera. The remainder of the diets, with the exception of the beef liver control, were of the composite type. The first group of this latter type was designed to test the effect of salmon waste meals at different water temperatures. The second group evaluated the effect of various drying processes on the utilization of salmon waste meals. The third was a test of hake (Merluccius productus) as a substitute for hog spleen or hog liver. The fourth was an evaluation of various anti-anemic supplements such as crab meal, beef liver, and herring stickwater in a diet that previously had produced anemia. The fifth and last group was a comparison of crab meal and two salmon waste meals.

The presentation of this investigation is divided into three main parts. The first part explains the conditions of experiment and includes a short account of the water temperatures prevailing during the experimental period as well as a description of the experimental techniques. The second part gives a detailed account of the experimental results. The last part, which is based on the experimental results, gives two recommended diets and substitutions or supplements that may be used in these diets.

CONDITIONS OF EXPERIMENT

Before comparing the results brought about by feeding different diets, a description of the experimental techniques and of the water temperatures is given to qualify the conclusions based on the outcome of the various trials.

The techniques used in these trials are, in general, much the same as those used in previous Leavenworth feeding trials. A more complete account of the experimental design, stocking, food preparation and presentation, and of the method of statistical analysis will be found in the paper by Burrows et al. (1951).

The experimental design, statistically speaking, consisted of one replication and 20 treatments. The one replication represented two adjacent troughs, and the 20 treatments each represented a different diet or lot. The 40 troughs necessary for such a design were stocked with equal weights and comparable numbers of fish chosen at random from a homogeneous population. Each trough received exactly 500 grams of fish. By a hand count of 10 per cent of the troughs, the number of fish per trough was found to be about 2,277 with a coefficient of variation of 1.64 per cent. This number of fish weighing 500 grams represents an initial average weight per fish of .2196 grams or an initial number per pound of 2,067. After the troughs were stocked, no changes in the number of fish occurred except those unavoidable losses brought about by mortalities.

In the preparation and feeding of the diets for the 20 lots, the techniques with the exception of binding were comparable for each diet. The unbound diets were the beef liver control, and the tuna liver diet. The diets in the salmon segment group were not bound but received salmon waste meal as an absorbing agent to prevent leaching. The rest of the diets contained either hog liver or hog spleen, either of which in the presence of salt produced a very satisfactory bind. Salt was added at the rate of two grams per 100 grams of ration in the diets containing hog liver or hog spleen. The fish were fed three times a day with a modified potato ricer.

Water temperatures had an important bearing on the outcome of these feeding trials. For instance, several diets in this experiment, although suitable for use when the water temperatures were above 50° F., were definitely harmful to the fish when fed at temperatures of 45° F. Because of the importance of water temperatures, a brief description will be given of the temperature patterns and their effect on this experiment.

The water temperatures for the first 12-week period averaged 45°F. with less than a degree variation. At the end of this first period the water temperatures rose rapidly. The temperatures for the second 12-week period averaged 54°F., and, differing from the relatively constant temperatures of the first period, varied from 50° to 62° F.

The results brought about by the water temperatures were easily distinguishable. During the first half of the experiment it can be demonstrated that with a few exceptions high mortalities were the rule. The exceptions were a result of those diets without meal of any kind. In addition to the high mortalities suffered by most of the lots during this period of cold water, the growth rates were low. As soon as the temperatures started to rise, however, the growth rates increased markedly in most of the lots. Later, after the residual effects of the cold-water period had worn off, the mortality rates declined and with but a few exceptions remained low.

Since the water temperatures were definitely of two sharply defined patterns of cold water and warm water, and the differing effect of these two periods can be easily demonstrated by differences in mortality and growth rates, the splitting of the experiment into two halves serves as a most useful tool in explaining the outcome of these trials.

RESULTS OF EXPERIMENT

The results of feeding the various diets are summarized in Table 1. The most reliable of these measurements were based on the mortalities and the total weight of the fish in each of the two troughs in a lot since these two measures lend themselves readily to statistical analyses. The mean lot weights and mean mortalities, the average of the two troughs assigned to a diet or lot, are based directly on the daily mortalities and bi-weekly weights. The same basis was used for the per cent gains and the per cent mortalities which were computed by dividing the 12-week or 24-week total by the original weight or number stocked. To measure the differences in weights and mortalities produced by the various diets, analysis of variance was used in the manner prescribed by Snedecor (1946), and only the least difference at the 5 per cent confidence level was employed as a basis of comparison. In this same table will be found two other measures, the conversions and deficiency symptoms. The conversions were computed by dividing the total amount of food fed by the total weight gain. The presence of anemia was determined by checking the gill color of 90 to 150 fish per lot in each of the 20 lots.

The numerous small tables in this paper which deal only with the weights and mortalities were used to emphasize the differences achieved with diets having a common base and one variable component. These tables are all taken from Table 1; therefore any mortality or weight from one of the small tables may be compared with a corresponding figure in either another small table or in Table 1 if the figures are both in the same time period. The figures in the two periods, 12 and 24 weeks, were computed from the same original base; consequently the 24-week figure included the 12-week figure.

The discussion of the results accomplished by feeding different diets is made by giving, if necessary, a general description of the variable or variables that were tested and the justification for testing them. After this description, the results of the tests are presented in terms of deficiency symptoms, mortalities, and growth rates as they occurred in the cold-water period and the warm-water period.

Beef Liver Control

Flukey beef liver was used as the sole component of the standard control diet (Table 1, Diet 1). This diet gave results that were quite comparable to the results produced by this same diet in previous years. The feeding of flukey beef liver resulted in gains during the cold-water period that were as good or better than all the other diets except the meat-viscera mixtures (Table 1, Diets 13 and 14). During the warm-water period, however, beef liver produced gains that fell significantly below those of most other diets. The mortality rate during the entire experiment was among the lowest achieved by any diet.

Tuna Liver

Tuna liver from the yellowfin tuna (Neothunnus macropterus) was tested as the sole component of a single diet (Table 1, Diet 15). In common with the previous Leavenworth trials on tuna viscera, tuna liver did not produce good growth. At the end of the cold water period, the fish on this diet had a low mortality rate, yet a very low per cent gain. During the last half of the experiment, the mortality became excessive and the growth rate continued low in spite of the warmer water temperatures.

At 18 weeks and thereafter, pronounced lamella swelling and some clubbing of the gills were prevalent. Hemorrhagic areas occurring on the exterior portions of the body and fins were also quite noticeable during this time. No anemia was present, however, at any time.

Tuna liver obviously was not a good single component diet; but, since this liver apparently does contain the anti-anemic factors, it should be tested under experimental conditions as a substitute for all or part of the beef liver in a composite diet.

TABLE 1 —Summary of 1949 feeding trials with blueback salmon

Initial number per trough: 2,277 fish
Initial weight per trough: 500 gr

Initial average weight per fish: .2196 gr
Initial number per pound: 2,067 fish

Period: April 4 to September 21, 1949

Average water temperature: 0 to 12 weeks, 45.1° F; 12 to 24 weeks, 54.0° 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	2,248	7,023	3.6	6.0	350	1,305	88	138	4.7	None
2	Meat-viscera mixture[1]	S[2]	90	2,200	10,383	31.6	35.3	340	1,977	769	854	3.2	None
	100° C.R.[3] salmon viscera meal		10										
3	Beef liver		20	2,460	10,854	23.0	25.4	392	2,071	523	578	3.2	None
	Hog liver		20										
	Hake	S	20										
	C.R. salmon viscera		30										
	100° C.R. salmon viscera meal		10										
4	C.R. salmon viscera		40	1,929	6,214	19.6	26.2	286	1,143	448	643	4.5	None
	Hake		40										
	Crab meal		20										
5	Hog liver		40	2,302	10,192	13.1	16.2	360	1,938	298	369	3.4	None
	C.R. salmon viscera	S	40										
	Crab meal		20										
6	Hog liver		40	2,099	10,607	34.4	37.1	320	2,021	784	844	3.1	Anemic tendency at the end of the experiment.
	C.R. salmon viscera	S	40										
	145° C.R. salmon viscera meal		20										
7	Hog liver		40	2,370	10,994	27.3	30.3	374	2,099	622	689	3.2	None
	C.R. salmon viscera	S	40										
	Crab meal		10										
	145° C.R. salmon viscera meal		10										
8	Hog liver		30	1,848	7,196	41.2	47.7	270	1,339	938	1,086	3.8	Pronounced anemia at the end of the experiment.
	C.R. salmon viscera	S	30										
	Herring stickwater		20										
	145° C.R. salmon viscera meal		20										
9	Beef liver		20	2,251	11,050	32.5	34.2	340	2,230	741	778	3.0	None
	Hog liver	S	20										
	C.R. salmon viscera		40										
	145° C.R. salmon viscera meal		20										
10	Meat-viscera mixture	S	90	2,116	9,800	29.4	31.0	323	1,860	707	725	3.2	None
	Flame-dried salmon offal meal		10										
11	Meat-viscera mixture	S	90	2,262	10,880	21.9	23.7	352	2,076	498	540	3.1	None
	Flame-dried salmon offal meal		5										
	Crab meal		5										
12	Meat-viscera mixture	S	90	2,240	12,177	34.3	36.3	348	2,335	780	826	2.8	None
	Vacuum-dried C.R. salmon viscera meal		10										
13	Meat-viscera mixture	S	100	2,558	11,430	8.6	9.7	412	2,186	195	220	3.2	None
14	Meat-viscera mixture 10%, 100°-dried C.R. salmon viscera meal added during ten weeks of water temperatures above 50° F.	S	100	2,559	12,247	6.9	8.1	412	2,349	158	184	3.1	None
15	Tuna liver		100	1,270 at 12 weeks	3,303	5.9	21.0	155	561	134	474	6.5	During last 6 weeks: pronounced lamelia swelling, some clubbing, hemorrhagic areas.
16	Puget Sound salmon viscera		90	1,947	8,364	44.2	48.4	289	1,573	1,006	1,102	3.4	During cold water: clubbed gills.
	100° C.R. salmon viscera meal		10										
17	Puget Sound salmon eggs		90	1,939	13,035	48.6	51.2	288	2,507	1,106	1,166	2.3	During cold water: clubbed gills, external hemorrhagic areas.
	100° C.R. salmon viscera meal		10										
18	Puget Sound salmon G-I tract		90	1,399 at 12 weeks	4,406	57.0	65.9	180	781	1,297	1,522	4.8	During cold water: clubbed gills, external hemorrhagic areas. End of experiment: anemia
	100° C.R. salmon viscera meal		10										
19	Puget Sound salmon milt		90	980 at 12 weeks	3,299	68.2	76.8	96	560	1,554	1,748	4.8	During cold water: clubbed gills, external hemorrhagic areas.
	100° C.R. salmon viscera meal		10										
20	Puget Sound salmon livers		90	1,168 at 12 weeks	3,433	53.8	63.8	134	587	1,224	1,454	5.6	During cold water: clubbed gills, external hemorrhagic areas.
	100° C.R. salmon viscera meal		10										
	Least difference at 5% confidence level			207 gr at 12 weeks	765 gr at 24 weeks	6.5%	7.1%	41%	153%	149 fish	161 fish		

1/ Meat-viscera is a mixture of beef liver 22.2%, hog liver 22.2%, hog spleen 22.2%, and salmon viscera 33.4%.
2/ S: salt added at 2 grams per 100 grams of ration
3/ C.R.: Columbia River

Salmon Viscera Components

This group of trials was designed to compare the food value of salmon livers, salmon milts, salmon eggs, and salmon digestive tracts. The term salmon digestive tracts, as used in this paper, included the pyloric caeca, spleen, stomach, intestines, and air bladder.

The purpose of these experiments was to find a way to use some of the salmon viscera now going to waste in Alaska. At the present time, viscera is not readily available because of the storage problems at the canneries and the costs involved in shipping viscera to the United States. To solve these problems, it was thought that the logical place to start would be to find, if possible, a component of the viscera that would, by reason of its superior food value for salmon, be worth more than whole salmon viscera. If such a visceral product were found, perhaps its value might offset the shipping charges from Alaska to points in the Pacific Northwest.

The salmon viscera used in this study, unlike the Columbia River viscera used in the other diets, was obtained from Puget Sound pink salmon (O. gorbuscha). The diets in the salmon viscera component study, although classed as single component diets, contained ten per cent salmon viscera meal to prevent excessive leaching. This meal was tunnel-dried at 100° F. This addition of meal to prevent leaching may have had no small effect on the health of the fish during the cold-water period and in part may account for the serious mortalities suffered by the experimental fish in this salmon component group.

All of the lots in the visceral component study incurred high mortalities during the cold-water period of the first 12 weeks (Table 2). The mortalities of the whole salmon viscera lot were significantly lower than the salmon liver, milt, and the intestinal tract lots. There was no significant difference in mortalities between the egg lot or the whole salmon viscera lot. Because of the excessive mortalities ranging from 44 to 68 per cent, the mean weights are not too reliable in establishing differences at the end of the first 12 weeks. It may be said, however, that the salmon eggs produced as much growth as whole salmon viscera, and that the other components produced less growth than eggs or whole viscera.

During examinations of the fish in the period of cold water, it was found that as high as 25 per cent of the moribund fish in the digestive tract, milt, and liver-fed lots had external hemorrhagic areas on the fins, base of fins, isthmus, and gill opercula (Table 1, Diets 18, 19, 20). A very few fish were found to have the same trouble in the salmon egg lot (Table 1, Diet17). According to McLaren et al. (1947), these hemorrhagic areas are symptoms of a riboflavin deficiency. Also during this same period, clubbed gills, which are the usual signs of a pantothenic acid deficiency (Tunison et al.1944;McLaren et al.1947), were found in each viscera-fed lot. Examinations at the end of the

TABLE 2.—Evaluation of salmon viscera components

Diet No.	Standard component	Variable component	Per cent mortality 12 wks.	24 wks.	Mean lot weight in grams 12 wks.	24 wks.
16	10%,100° tunnel-dried salmon viscera meal	90% Salmon viscera, whole	44.2	48.4	1,947	8.364
17	10%, 100° tunnel-dried salmon viscera meal	90% Salmon eggs	48.6	51.2	1,939	13,035
18	10%, 100° tunnel-dried salmon viscera meal	90% Salmon intestinal tract	57.0	65.9	1,399	4,406
19	10%, 100° tunnel-dried salmon viscera meal	90% Salmon milt	68.2	76.8	980	3,299
20	10%, 100° tunnel-dried salmon viscera meal	90% Salmon liver	53.8	63.8	1,168	3,433
	Least difference at 5% confidence level		6.5%	7.1%	207 gr.	765 gr.

24-week period disclosed no deficiency symptoms other than a general anemia in the lot fed digestive tracts, (Table 1, Diet 18).

The mortalities were reduced during the warm-water period. The whole viscera and egg-fed lots had a 4.2 and 2.6 per cent mortality, respectively. These mortalities are comparable to that of the beef liver control, 2.4 per cent. The other diets in this group produced considerably higher mortalities, but these losses, ranging from 8.6 per cent to 10.0 per cent, were an improvement over the cold-water mortalities which varied from 53.8 per cent to 68.2 per cent.

During the last half of the experiment, the weight gains improved. The lots being fed digestive tracts, milts, and livers again showed less gain than did those lots being fed either whole salmon viscera or salmon eggs (Table 2). The final weight of the lot being fed salmon eggs, however, was not only significantly greater than the weight of the lot on whole salmon viscera but also greater than any other final lot weight in the experiment.

The overall conversion rate of 2.3 produced by the eggs was the lowest rate brought about by any diet. A partial explanation of this conversion rate and the high growth rate is probably the protein content of 27.1 per cent found in pink salmon eggs by Jones et al. (1948:23). However, the fat and vitamin content may also have played a part in this excellent conversion.

This experiment indicates that the salmon egg segment of whole viscera produces the most growth. This conclusion is in agreement with the findings of Cooke et al. (1949). The use of salmon eggs in salmon culture should await further experimentation with eggs as a part of multiple component diets, since eggs, when used as a major or sole component leach rapidly on contact with water. In addition, the use of Alaskan eggs must also depend on the solving of procurement, preservation, and storage problems. Incidentally, the problem of separating the eggs from the cannery offal, according to Cooke (1949), presents very little difficulty, and the cost of such an operation would not be excessive.

With roughly 9,000,000 pounds of salmon eggs going to waste annually in Alaska (Jones et al. 1948:12), and with the hatchery food problem being what it is, future work with salmon eggs should not be neglected.

Effect of Salmon Meals at Different Water Temperatures

In the 1948 Leavenworth trials, no advantage was found in the use of salmon waste meals during periods of cold-water. The present series of trials were designed to provide additional and confirming evidence concerning the use of meal supplements during cold-water and warm-water periods.

The 1949 experiment consisted of three diets with the same meat viscera base of beef liver, hog liver, and hog spleen at 22.2 per cent each and salmon viscera at 33.4 per cent. The hog liver and beef liver were dyed and flukey. The hog spleen was fit for human consumption and therefore not dyed. The salmon viscera was obtained from hand-butchered Columbial River chinook salmon (<u>O. tschawytscha</u>). This salmon viscera contained the gonads, livers, air bladders, and digestive tracts. To this common meat-viscera base, 100° tunnel-dried salmon viscera meal was added during the following periods in the different diets: Diet 2 contained meal throughout the experimental period of 24 weeks, Diet 13 contained no meal at any time, and Diet 14 contained meal only when the water temperatures were 50° F. or above. The temperatures were 50° F. or above for approximately 10 weeks from July 11 to September 13. Within the described periods for the different diets, the meal was added at the rate of 10 per cent with a corresponding proportional reduction in each of the original components of the meat-viscera base.

The results of this test on the effect of salmon viscera meals at different water temperatures substantiated the results achieved in the 1948 test. At the end of the cold-water period, each of the lots of fish being fed the diets without meal had a significantly greater mean lot weight than the group being fed the diet with 10 per cent salmon viscera meal. The mortalities of the lots of fish being fed the non-meal diets during this period were only 8.6 per cent and 6.9 per cent respectively (Table 3). The mortality percentages are in sharp contrast with the mortality of 31.6 per cent sustained by the fish on Diet 2 which included 10 per cent meal. These mortality percentages seem to establish, quite soundly, the validity of the contention that salmon waste meals at the rate of 10 per cent will increase the mortality of blueback salmon significantly during a period of water temperatures averaging about 45° F.

During the warm water period, the addition of salmon waste meals showed no deleterious effect on survival. The gain produced by the inclusion at this time of 10 per cent of 100° tunnel-dried salmon viscera meal in Diet 14 was responsible for the higher meal lot weight of the fish on this diet as compared with the significantly lower mean lot weight of the fish still on the meat-viscera mixture, Diet 13.

There is some question of exactly why salmon meal increased the mortalities during the cold water period. There were no signs of disease. The usual deficiency symptoms were lacking except that some small anemic fish did appear. The size of the fish in the mortality was noteworthy--invariably these fish were the smallest in the lot.

TABLE 3.—Effect of salmon meals during warm and cold-water periods

Diet No.	Standard components	Variable component cold-water	Variable component warm-water	Per cent mortality 12 wks.	Per cent mortality 24 wks.	Mean lot weight 12 wks.	Mean lot weight 24 wks.
2	20% beef liver, 20% hog liver, 20% hog spleen, 30% salmon viscera	10% S.V.M.[1/]	10% S.V.M.	31.6	35.3	2,200	10,383
13.	22.2% beef liver, 22.2% hog liver, 22.2% hog spleen, 33.4% salmon viscera	no meal	no meal	8.6	9.7	2,558	11,430
14	22.2% beef liver, 22.2% hog liver, 22.2% hog spleen, 33.4% salmon viscera	no meal		6.9		2,559	
	20% beef liver, 20% hog liver, 20% hog spleen, 30% salmon viscera		10% S.V.M.		8.1		12,247
	Least difference at the 5% confidence level			6.5%	7.1%	207 gr.	765 gr.

1/ S.V.M. represents 100° tunnel-dried salmon viscera meal

Effect of the Drying Process on the Utilization of Salmon Meal

As can be seen in the preceding experiment, salmon meal used as a supplement during warm-water periods will measurably increase the rate of growth. Some salmon meals give better results than others, however. In previous experiments the 100° tunnel-dried salmon viscera meal had produced the most gain in weight in the Leavenworth series of diet trials. The superiority of this meal over the commercially available flame-dried salmon offal meal, nevertheless, was hardly enough to warrant expensive installations on a commercial scale of the low temperature drying apparatus necessary for the manufacture of 100° tunnel-dried meal.

In the 1949 feeding trials, in addition to the previously tested 100° tunnel-dried salmon viscera meal and flame-dried salmon offal meal, a vacuum-dried salmon viscera meal was tested.

The dehydration method used to manufacture the flame-dried salmon offal meal was a wet-reduction, direct heat process. Salmon offal, in this case, consisted of the heads, collars, viscera, fins, and tails. Alaska pink salmon were the source of the flame-dried meal. The 100° tunnel-dried salmon viscera meal was also prepared by a wet-reduction process. The raw material for this meal was obtained from frozen Columbia River chinook viscera. In contrast to the method of drying the preceding two meals, the vacuum-dried meal was prepared by a dry rendering process which required no precooking to coagulate the protein. A Stokes rotary vacuum dryer operating at a 100° drying temperature was used. The vacuum-dried meal was also made from frozen Columbia River chinook viscera.

The tests included Diet 2 with 100° tunnel-dried salmon viscera meal, Diet 10 with flame-dried salmon offal meal, and Diet 12 with vacuum-dried salmon viscera meal. The different meals were added during the entire experimental period at the level of 10 per cent to the meat-viscera base.

As would be expected from the previous experiment on the effect of salmon meals at different water temperatures, the mortalities were high during the cold water period. Furthermore, all three diets produced less gain during the cold-water period than did Diets 13 and 14 which had the same meat-viscera base as Diets 2, 10, and 12, but no added meal (Table 1).

During the warm-water period, the weights sharply increased, and the mortalities decreased to low comparable levels in all three diets. The vacuum-dried salmon viscera meal exhibited a significantly greater growth potential than did the other meals (Table 4). The salmon offal meal in Diet 10 was inferior to the 100° tunnel-dried salmon viscera meal in Diet 2 but not significantly so as was the case

TABLE 4.—Comparison of different salmon meals

Diet No.	Standard components	Variable component	Per cent mortality 12 wks.	Per cent mortality 24 wks.	Mean lot weight in grams 12 wks.	Mean lot weight in grams 24 wks.
2	20% beef liver, 20% hog liver, 20% hog spleen, 20% salmon viscera.	10%, 100° tunnel-dried salmon viscera meal	31.6	35.3	2,200	10,383
10	20% beef liver, 20% hog liver, 20% hog spleen, 20% salmon viscera.	10% flame-dried salmon offal meal	29.4	31.0	2,116	9,800
12	20% beef liver, 20% hog liver, 20% hog spleen, 20% salmon viscera.	10% vacuum-dried salmon viscera meal	34.3	36.3	2,240	12,177
	Least difference at 5% confidence level		6.5%	7.1%	207 gr.	765 gr.

in previous years. This discrepancy between years is probably explained by a difference in the source of meals.

The reason for the superior growth produced by the vacuum-dried product probably was attributable to the method of preparation, since the tunnel-dried meal and the vacuum-dried meal were from the same source and were dried at comparable temperatures as was mentioned in the description of diet components. In view of the marked superiority of this vacuum-dried meal, the commercial production of vacuum-dried meals would appear to be justified on the West Coast.

Comparison of Hake with Hog Spleen or Hog Liver

Hake (Merluccius productus), disintegrated whole and then frozen, was tested as an inexpensive substitute for hog spleen in the standard meat-viscera mixture. In the two diets comprising the test, the variable was 20 per cent hog spleen in Diet 2 and 20 per cent hake in Diet 3. The common base was 20 per cent beef liver, 20 per cent hog liver, 30 per cent salmon viscera, and 10 per cent 100° tunnel-dried salmon viscera meal.

The hake variant brought about significantly less mortality and a significantly greater mean lot weight during the first 12 weeks of the experiment, but failed during the second 12 weeks of experiment to maintain or increase this weight advantage significantly over the hog spleen variant (Table 5).

From this experiment it may be said that hake offers a fair substitute for hog spleen in the Leavenworth production diet. Care must be used, however, in preparing and handling the diet, for hake does not have the binding properties possessed by hog spleen.

The other comparison, hake with hog liver, was made with Diet 4 containing 40 per cent hake, 40 per cent salmon viscera, and 20 per cent crab meal and with Diet 5 containing 40 per cent hog liver, 40 per cent salmon, and 20 per cent crab meal. Hake produced a significantly smaller mean weight and a significantly greater mean mortality (Table 1, Diets 4 and 5).

Hog Liver-Salmon Viscera with Various Supplements

During the 1948 experiments a diet of hog liver 40 per cent, salmon viscera 40 per cent and salmon viscera meal 20 per cent, displayed a very good growth rate; however, a serious anemia and resultant mortality occurred. To combat this anemia, diets were compounded using the hog liver-salmon viscera base supplemented variously with crab meal, herring stickwater, and beef liver (Table 1, Diets 5, 6, 7, 8, and 9).

TABLE 5.—Hake substituted for hog spleen

Diet No.	Standard components	Variable component	Per cent mortality 12 wks.	24 wks.	Mean lot weight in grams 12 wks.	24 wks.
2	20% beef liver, 20% hog liver, 30% salmon viscera, 10% S.V.M.1/	20% hog spleen	31.6	35.3	2,200	10,383
3	20% beef liver, 20% hog liver, 30% salmon viscera, 10% S.V.M.	20% hake	23.0	25.4	2,460	10,854
	Least difference at 5% confidence level		6.5%	7.1%	207 gr.	765 gr.

1/ S.V.M. represents 100° tunnel-dried salmon viscera meal.

The herring stickwater or press liquor used in Diet 8 contained about 25 per cent protein and 7 per cent oil, according to the manufacturer, a British Columbia fish reduction plant.

On the basis of an anemia check of over 500 fish in this group, the fish fed Diet 5 (crab meal), Diet 7 (crab meal and viscera meal), and Diet 9 (beef liver) were found to have no anemia. The lots fed Diet 6, with viscera meal only, had an anemic tendency, and the lots fed Diet 8, with herring stickwater, had a pronounced anemia.

The final weights and mortalities disclosed that the herring stickwater in Diet 8 reduced the growth rate and increased the mortality rate when compared with the control of this group, Diet 6. This particular supplementation of stickwater at the 20 per cent level in this diet was quite unsatisfactory especially since the lot went anemic toward the end of the experiment.

The beef liver supplement proved to be more promising than the stickwater supplement since, although the survivals were no better than in the group control, the final mean weight was significantly greater than that produced by either the control or the stickwater variant.

The crab meal substitution for salmon viscera meal proved decidedly beneficial. Additional comments on crab meal will be found in the next section devoted exclusively to crab meal.

Comparison of Crab Meal with Salmon Meals

On the basis of work by other investigators in fish nutrition, crab meal was included in several diets to determine its effect on anemia and growth.

The crab meal was derived from the total crab scrap of the blue crab (*Callinectes sapidus*) and reduced to a dry powder in a conventional, rotary flame-drier.

The diet number and components of the crab meal diets were: Diet 4 with crab meal at 20 per cent, hake and salmon viscera at 40 per cent each; Diet 5 with crab meal at 20 per cent, and hog liver and salmon viscera at 40 per cent each; Diet 7 with crab meal and 145° tunnel-dried salmon viscera meal at 10 per cent each, and hog liver and salmon viscera at 40 per cent each; Diet 11 with 5 per cent each of crab meal and flame-dried salmon offal meal added to a mixture of 20 per cent each of beef liver, hog liver, hog spleen, and 30 per cent of salmon viscera.

The purpose of Diet 4 was to determine if anemia would develop in this combination of hake, salmon viscera, and crab meal. In the 1948 feeding trials, a similar diet containing salmon viscera meal instead of crab meal induced an acute anemia toward the end of the experiment. No anemia was produced by including crab meal in this diet as was the case when salmon viscera meal was used.

The possibilities of crab meal were explored further in the hog liver-salmon viscera group. Here when crab meal was used in place of salmon viscera meal or in combination with this same meal, the anemic tendencies were prevented which would have developed if the control diet, Diet 6, is a reliable index (Table 1). This control diet, with 20 per cent salmon meal, caused a marked anemia in 1948 and a slight anemia in the present trials, so without too much doubt the conclusion concerning the comparison of the anti-anemic properties of crab meal and salmon viscera meal is valid.

The examination of the two diets with the meat viscera base, Diets 10 and 11, disclosed no anemic tendency. This result is to be expected since the performance of Diet 10 in previous years has shown no evidence of anemia.

In addition to its effect on anemia, crab meal contributed to higher survivals than did salmon viscera meal. In Table 6, Diet 5 with 20 per cent crab meal produced the lowest mortality rate in this group during the cold-water period. The next lowest mortality rates during the cold-water period were made with equal parts crab meal and either salmon viscera meal (Diet 7) or salmon offal meal (Diet 11). Although the results secured with Diets 5 and 7 are not strictly comparable to those secured with Diet 11 because of the different food bases used, a definite trend is present--crab meal in these diets caused less mortality than did the salmon meals. During the warm water period, neither crab meal nor salmon meal had a measurable effect on mortality.

The weight gains during the cold-water period are to a great extent obscured by the varying mortalities, but it may be said about these particular diets that crab meal, due to its effect on survival, and perhaps for other reasons, had a tendency to increase the mean lot weights. During the warm-water period, the results were obscured again because, in addition to the varied mortalities incurred during the previous cold-water period, the viscera meal or offal meal, Diets 7 and 11, had a tendency to produce more growth, although not always significant, than either crab meal, salmon viscera meal, or offal meal alone (Diets 5, 6, and 10) during either period of water temperature.

In conclusion, the experiments indicated that with these particular diets crab meal produced no anemia as did salmon viscera meal during the cold-water period. Also by the same comparison, crab meal decreased mortality and possibly contributed to growth in combination with salmon

TABLE 6.—Comparison of crab meal with salmon viscera meal and salmon offal meal

Diet No.	Standard components	Variable components	Per cent mortality 12 wks.	Per cent mortality 24 wks.	Mean lot weight in grams 12 wks.	Mean lot weight in grams 24 wks.
5	40% hog liver, 40% salmon viscera	20% crab meal	13.1	16.2	2,302	10,192
6	40% hog liver, 40% salmon viscera	20%, 145° tunnel-dried salmon viscera meal	34.4	37.1	2,099	10,607
7	40% hog liver, 40% salmon viscera	10% crab meal, 10%, 145° tunnel-dried salmon viscera meal	27.3	30.3	2,370	10,994
10	20% beef liver, 20% hog liver, 20% hog spleen, 30% salmon viscera	10% flame-dried salmon offal meal	29.4	31.0	2,116	9,800
11	20% beef liver, 20% hog liver, 20% hog spleen, 30% salmon viscera	5% crab meal, 5% flame-dried salmon offal meal	21.9	23.7	2,262	10,880
	Least difference at 5% confidence level		6.5%	7.1%	207 gr.	765 gr.

viscera meal or salmon offal meal. Further use of crab meal in experiments seem to be warranted, since these trials revealed that crab meal has several advantages not found in salmon meals when fed at temperatures averaging 45° F.

RECOMMENDED PRODUCTION DIETS FOR BLUEBACK SALMON

The requirements of a diet suitable for production purposes should be as follows: good growth, low conversion rate, low mortality, and no discernible symptoms of nutritional deficiencies. The diets in this experiment that most fully meet these requirements during periods of cold-water are Diets 13 and 14 (Table 1) which are composed of a meat-viscera mixture of 22.2 per cent each of beef liver, hog liver, hog spleen , and 33.4 per cent salmon viscera. When warm-water prevailed, Diet 14 proved superior to Diet 13 (Table 3). Diet 14 during the warm-water period, consisted of the preceding meal-viscera mixture at the rate of 90 per cent and salmon viscera meals at the rate of 10 per cent. Although the meal used with Diet 14 was a 100° tunnel-dried salmon viscera meal, other salmon waste meals could have been used with satisfactory results. The best results from a meal probably would be obtained with vacuum-dried salmon viscera meal (Table 4).

If the hog spleen in this production diet is unavailable or too expensive, hake, which is much less costly, may be substituted (Table 5).

The hog liver-salmon viscera combination, although not showing up as well as the recommended diet in this experiment, nevertheless has possibilities of being a satisfactory diet for blueback during warm-water periods (Table 1, Diets 5, 6, and 7). If a meal is used with this combination, crab meal or a combination of crab meal and salmon meal should be used and not one of the salmon meals alone. Beef liver could be added to supplement this diet, if necessary (Table 1, Diet 9).

For other possible diets or substitutions in the recommended diets, see Burrows et al. (1951).

SUMMARY

With these particular diets and using blueback salmon as the test animal, the summary of results is as follows:

1. Tuna liver as the sole component of a diet produced a low growth rate, a high mortality rate, numerous dieficiency symptoms, but no anemia.

2. Of the various segments of salmon viscera, salmon eggs produced

by far the greatest amount of growth.

3. When either salmon viscera meal or salmon offal meal was included in certain diets and fed while the water temperatures were about 45° F., the survivals and weight gains of the lots were significantly lower than those lots being fed the same diets without meal. During the warm-water period, the salmon waste meals increased the growth rate of the lots and had no measurable effect on the survivals.

4. Vacuum-dried salmon viscera meal produced significantly more growth than either 100° tunnel-dried salmon viscera meal or flame-dried salmon offal meal.

5. Hake proved to be a satisfactory substitute for hog spleen in meat-viscera mixture.

6. The combination of hog liver and salmon viscera produced more growth than a combination of hake and salmon viscera. The combination of beef liver, hog liver and salmon viscera produced more growth than hog liver alone with salmon viscera. Both of the above comparisons were made with diets containing high levels of salmon meal.

7. Of the anti-anemic supplements, beef liver proved satisfactory and herring stickwater did not. The use of crab meal instead of salmon viscera meal with hog liver and salmon viscera prevented anemia also.

8. When crab meal or a mixture of crab meal and salmon viscera meal or salmon offal meal was substituted for one of the salmon waste meals in these diets, the mortality rate was significantly lowered furing the 12-week period when the water temperatures averaged 45° F. With a combination of crab meal and salmon viscera meal in the diet, the final mean weight was significantly greater than produced by a comparable diet supplemented only with crab meal. With a combination of crab meal and salmon offal meal in the diet, the final mean weight was significantly greater than produced by a comparable diet supplemented only with crab meal. With a combination of crab meal and salmon offal meal in the diet, the final mean weight was significantly greater than producdd by a comparable diet supplemented only with salmon offal meal.

9. The meat-viscera mixture without meal was recommended for cold-water feeding. During warm-water periods, the same meat-viscera mixture plus 10 per cent salmon waste meal was recommended. Hake was substituted for hog spleen in this meat-viscera combination with crab meal and a salmon waste meal also could be used as a production diet, but only during warm-water periods.

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