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FOOD OF THE SQUAWFISH *Ptychocheilus oregonensis* (Richardson) OF THE LOWER COLUMBIA RIVER

BY RICHARD B. THOMPSON

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ABSTRACT

A study is presented of 3,546 stomachs of the squawfish, *Ptychocheilus oregonensis* (Richardson), collected from April 1955 to April 1956 in the lower Columbia River. The basic food table of the squawfish, based on a modified point system with emphasis on salmon predation is presented. Sixty-three percent of the stomachs examined were empty. Size of squawfish, season of the year, and geographical distribution within the river affect the occurrence and importance of the food items.

Major food items were fishes, crayfish, and insects, and, in much lesser amounts, plant materials, mollusks, and miscellaneous items. Squawfish from 3 to 8 inches long subsisted on a diet of insects; above that length fishes and crayfishes attained importance. At 11 inches, fishes and crayfishes were dominant and insects were only 5 percent of the stomach content.

All occurrences of juvenile salmon in squawfish stomachs were related to releases of young salmon from hatcheries. The role of the squawfish as a predator on salmon was limited to time and place where juvenile salmon concentrations were high following release.

FOOD OF THE SQUAWFISH, *Ptychocheilus oregonensis* (Richardson) of the Columbia River

By RICHARD B. THOMPSON, *Fishery Research Biologist*, BUREAU OF COMMERCIAL FISHERIES

An average of 56 million young salmon has been released annually into the Lower Columbia River [1] during the past 5 years from Federal and State fish-cultural stations and hatcheries. These young salmon varied from unfed fry of about 1½ inches long to fingerlings of 5½ inches. At the time of their release into the river, the young and relatively defenseless salmon are in dense concentration and therefore easy prey for predatory fishes. Before the dispersal of the salmon into the turbid water of the main Columbia River, they are particularly vulnerable to predators.

Numerous observations of predatory fish actions on the small salmon immediately after their release have been made by hatchery personnel. Some control measures on the predator populations have been attempted with gill nets and dynamite. The most abundant predator collected was the Columbia River squawfish, *Ptychocheilus oregonensis* (Richardson).[2]

As a result of the indications of predation cited, a program of study was initiated by the Columbia River Fishery Development Program which had as one of its activities an investigation of the role of the squawfish as a predator on young salmon in the Lower Columbia River.

The first phase of the study was to examine the distribution of the species in the Lower Columbia River and its tributaries, particularly with respect to the location of present and planned salmon hatcheries and fish-cultural stations. Included in this phase was the examination and analysis of the basic foods of the squawfish. The present food study is based on the examination of the stomachs of squawfish taken in the distributional-study collections. The fish were collected from the mouth of the Columbia River at Astoria (Oreg.) to McNary Dam, 180 miles east of Portland (Oreg.) and some 240 river-miles from the mouth. These sampling operations were conducted from April 1955 to April 1956, inclusive.

The second phase of the planned operation was to conduct a more detailed study of the life history of the squawfish in a smaller area. This was done by employees of the Columbia River Fishery Development Program and will be reported on at a later date.

The purpose of the present food analysis is to determine the basic foods of the species within the study area. In addition, if losses of salmon to squawfish were found to occur in appreciable numbers, it was desired to determine where and at what times these losses were the highest. The collection of squawfish stomachs was not designed for a detailed study of diet, but to determine the basic foods of the species. A time-consuming attempt at detailed accuracy in the stomach analysis was not advisable, hence the more rapid, but admittedly less accurate point system of stomach-content evaluation was selected for use.

REVIEW OF LITERATURE

Little information is available on the life history and food habits of the squawfish in the Columbia River. Very few food studies have been made on the species. Most of the recorded information has been obtained from collections made in British Columbia, Canada.

Clemens and Munro (1934), in a food study of the squawfish from central British Columbia, examined stomachs from 119 squawfish that ranged in size from 1½ inches to 12 inches. They determined that the smaller squawfish up to 4 inches in length fed entirely on aquatic insects and other

[1] Progress Report, Fiscal Year 1956. Fishery Development Program of the Columbia River. U.S. Fish and Wildlife Service, Portland, Oreg. 66 pp.

[2] Observations on hatchery releases and squawfish predation in little White Salmon River in the spring of 1953, by Paul D. Zimmer. Issued by U.S. Fish and Wildlife Service Regional Office, Portland, Oreg. August 1953 (mimeographed).

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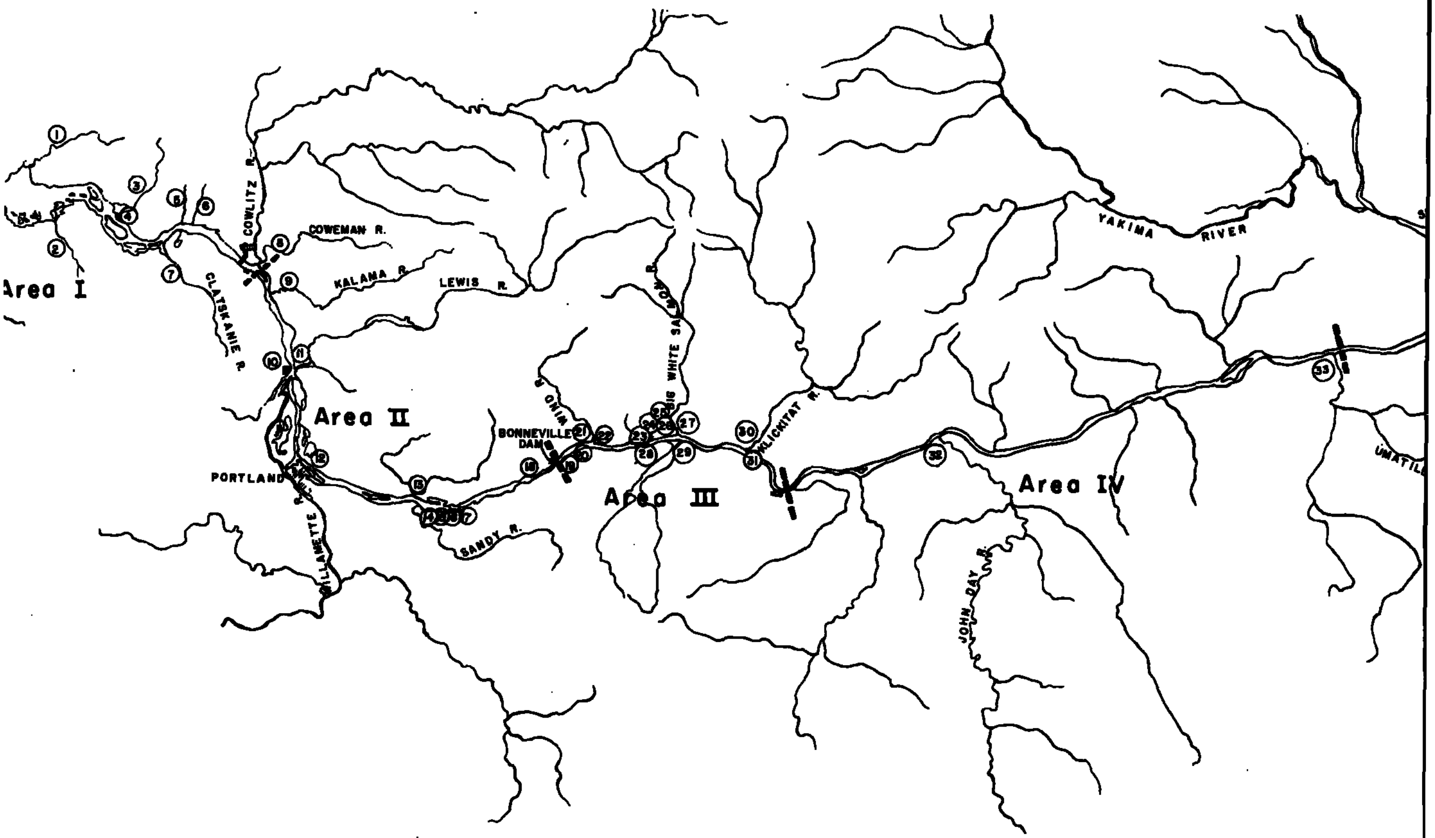

Sampling stations where no squawfish captured indicated by blocks; area boundary defined with dashes.

1 Grays River
2 Big Creek
3 Elokomin Creek
4 Cathlamet
5 Abernathy Creek
6 Germany Creek
7 Clatskanie River
8 Coweman River
9 Kalama River
10 St. Helens
11 Lewis River
12 Portland
13 Washougal River
14 Sandy River
15 Corbett
16 Vista Slough
17 Oneonta Creek
18 Beacon Rock
19 Eagle Creek
20 Herman Creek
21 Upper Wind River
22 Wind River (mouth)
23 Dog Creek
24 Drano Lake
25 "Drinking Fountain"
26 Spring Creek
27 Big White Salmon River
28 Broughton Drift Area
29 Hood River—Wells Island
30 Klickitat River
31 Lyle Drift Area
32 John Day River
33 Umatilla River

FIGURE 1.—Columbia River and tributaries showing location of gill-net sampling stations and subarea boundaries.

invertebrates. A few individuals as small as 4½ inches fed on fishes, but squawfish of all sizes contained insects at certain times of the year. Of the 119 squawfish, 67 had eaten fish and 27 of these had eaten young salmonoids (salmon, trout, and kokanee).

Chapman and Quistorff (1938) examined 95 squawfish stomachs collected in the north-central Columbia River in the State of Washington. All but 37 of these were empty; 9 contained fish remains, none of which were identifiable as salmonoids. The remainder of the food items were principally aquatic insect life. The diet of the squawfish was not unlike that of the rainbow trout taken in the same area.

Ricker (1941), as a result of long-term studies on Cultus Lake, tributary to the Fraser River in British Columbia, determined that the squawfish, because of its abundance and predatory habits in that lake, exacted the greatest toll of all predators on the sockeye salmon (*Oncorhynchus nerka*) fry and fingerlings residing in the lake prior to their departure for the sea. During the winter the young salmon formed the main food of squawfish larger than 4½ inches. During the summer the squawfish fed on other fishes (small cyprinids and sculpins) presumably because of the absence of young salmon in the waters frequented by the squawfish. The number of salmon consumed per squawfish was low, commonly 0.2 to 0.4 per stomach, but the abundance of squawfish made them the foremost predator in the lake. A systematic removal program was initiated principally against the squawfish and charr (*Salvelinus malma*) and by 1938 it succeeded in reducing the number of squawfish to one-tenth of their 1935 level. As a result of the removal of predators, the authors reported sockeye survival to the migrant stage increased threefold (Foerster and Ricker, 1941).

The squawfish have been considered a significant agent affecting the abundance of sockeye salmon of Lakelse lake, British Columbia (Brett and McConnel, 1950). Six hundred and twenty-three squawfish were collected with gill nets and the stomachs examined. Sockeye salmon contributed 31 percent, by volume, to the squawfish stomach contents during the summer months. The calculated losses of salmon within the lake, from fry to migrant size, were accounted for by an estimated consumption of 140 salmon per predator per year, a figure which was accepted as reasonable.

Studies on the closely related Sacramento River squawfish (*Ptychocheilus grandis*) by Taft and Murphy (1950) suggested that the squawfish prey on young trout and compete with trout of all sizes for food.

MATERIALS AND METHODS

Squawfish stomachs examined in this study were obtained by field crews of the Columbia River Fishery Development Program during the period April 1955 to April 1956. The fish were taken preponderantly by gill nets set at 36 sampling stations established along the Columbia River from Astoria, at the mouth, to the vicinity of McNary Dam, and in the lower reaches of selected tributary streams.

Observations recorded by the U.S. Corps of Engineers at Bonneville Dam indicate that during the period of squawfish sampling river conditions, compared with the conditions of other years, were normal. (Corps of Engineers, 1955.)

Mesh sizes of the gill nets ranged from 1½ inches to 4 inches, stretched measure. The nets differed slightly in type and usage; most were set nets, which were anchored in place with the lead line on the bottom of the river. Fishing in certain areas was conducted with nets that drifted with the current; minor squawfish catches were made with these drift-type nets.

The set nets were set during the day, left to fish overnight, and examined the following day. Sampling in this manner was conducted throughout the study period, with minor exceptions for the repair of nets and gear. The sampling crews moved from one set of adjacent stations to the next upstream sites; continuing until the upper sampling stations were completed, then starting again at the downstream stations. A complete survey of all stations was completed approximately each month.

The stomachs of 3,546 squawfish were collected and examined in this study.

Figure 2 shows the length-frequency distribution of the 3,546 squawfish examined in the food study. The immature and unknown category includes the small fish that could not be sexed by visual inspection and also mature fish, the sex of which was unreported. The consideration of the percentage occurrence and percentage composition of foods by each length class reduces the bias of the results caused by variations in sample length composition. The sampling covered a wide enough range of seasons, water conditions, habitats, and fish sizes to provide reliable data on the basic food and feeding activity of the squawfish in the Lower Columbia River during the time of sampling.

A solution of 70 percent alcohol was injected into the stomach of each fish as soon as it was removed from the net. The amount of alcohol inserted depended on the size of the fish, but was

Immature and unknown, 1,043; males, 1,307; females, 1,196; total, 3,546.

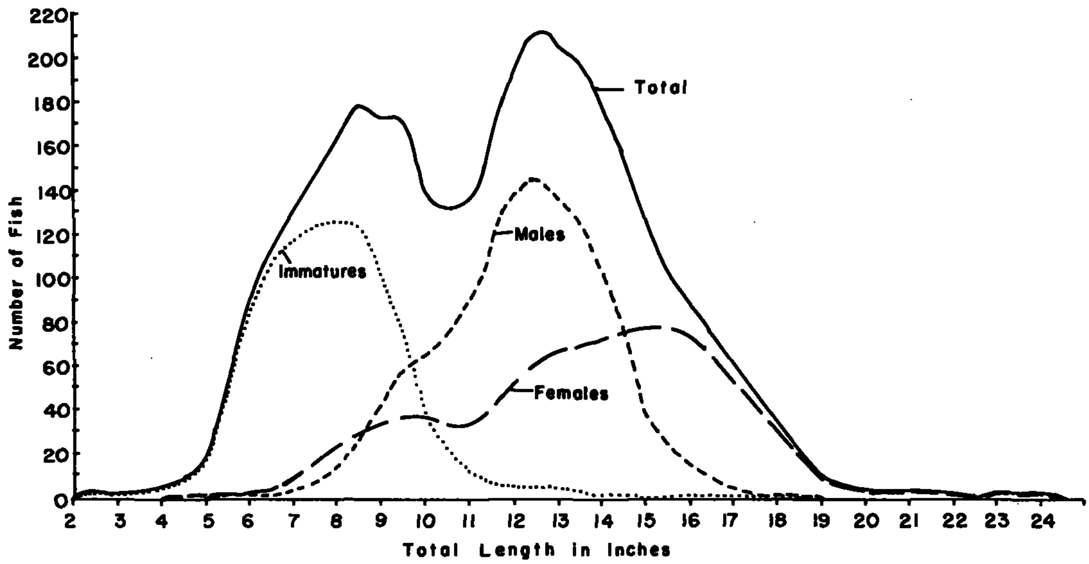

FIGURE 2.—Length-frequency distribution of squawfish in food analysis, by sexes and total. Grouped to ½-inch-length classes and smoothed by a moving average of three.

seldom more than 10 milliliters. The preservative was necessary to stop digestive action on the stomach contents, for digestion was found to proceed at a rapid rate after the fish had been removed from the water, especially in warm weather. A few untreated stomachs collected early in the study were discarded because the contents had been digested.

The fish were measured on a measuring board to the nearest one-tenth of an inch and weighed to the nearest one-hundredth of a pound. Following this, they were sexed and the degree of maturity noted and recorded. The stomachs were then removed and preserved for later examination.

The procedure followed in examining the stomachs was as follows: first, the stomach food volume was estimated and points allotted; second, the contents of the stomach were placed in a petri dish for identification and evaluation of the individual food items. Each food item was identified as specifically as possible, although no extensive taxonomic classification was attempted on insects, plant materials, and miscellaneous items.

EVALUATING FOOD ITEMS

The three generally accepted methods of assessing the stomach contents of fishes are by number, by occurrence, and by some measure of the comparative or actual volumes of the food items. The use of only one of these three methods provides only partial information of feeding habits. Some combination of the three must be used to determine accurately the food and feeding habits of the species.

The numerical system is the most simple. It is a direct count of the various food items found in the stomachs. This, however, tends to place undue emphasis on small items and perhaps those foods that are most resistant to digestion. The small items with numerical dominance may make up only a small portion of the bulk of the foods. The time involved in making the counts and the errors involved in attempting enumeration of broken and partially digested items made the use of such a system inadvisable for the purposes of this study.

The frequency of occurrence of a food item is the number or percentage of fish in the sample which contained a given food item. The statistic may be a measure of the feeding selectivity and food availability to the feeding fishes. These two factors are considered together in this report.

The volumetric system is based on the bulk of food items found in the stomachs. Conditions affecting the size of items after ingestion, such as the rate of digestion and elapsed time, may distort the results, placing emphasis on the recently eaten and more durable items. However, a large series of samples over a period of time should show with reasonable accuracy the average volume of food items eaten. The volumetric determination of the diet of a species of fish does not indicate the nourishment received from the various food items. Until dietetic values of the items are determined for each consuming species, volume seems to ofter the best criterion.

Numerous variations of the basic volumetric analysis have been developed for food investigations with different specific purposes. The point method was first used by Swynnerton and Worthington (1940), who listed the individual food items in each fish stomach as "common," "frequent." They used rough counts and judgment of volume by eye to determine each item's importance in the stomach. Each food category was allotted a number of points based on its importance in the stomach and these points were summed and reduced to percentages. This gave the percentage composition of the various foods in all the fish examined. The technique was basically volumetric, the rough counts of organisms being adjusted as to their size to make one large organism count as much as a great number of small items.

Hynes (1950), in a study of the food of sticklebacks of the British Isles, developed a method of food assessment based on volumetric estimation. Hynes considered a full stomach to be valued at 20 points, but allotted values of only 1, 2, 4, 8, and 16 points. No intermediate values were used, since he felt that the technique was only approximate and no additional flexibility was necessary. The author recognized the difficulty that when a full stomach containing only one kind of food was found it received only 16 points, rather than the 20 points a full stomach should have received. However, few of the large number of sticklebacks examined in his study contained only one food item and he found that the results of the technique corresponded closely with results obtained by other methods of assessment. Hynes recommended that ". . . in future work it would be better to allot the points to the stomach in the first instance, and then to subdivide the number allotted to the various food items present."

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Hynes lists the favorable factors of this type of evaluation: ". . . it is rapid and comparatively easy, it requires no special apparatus for measurement, it is not influenced by frequent occurrences of small organisms in small numbers, nor of heavy bodies, and does not involve trying to count large numbers of small and broken organisms." He further stated that it does not give the spurious impression of detailed accuracy which is given by some other methods.

The author cited as the technique's major shortcomings the subjectiveness of the investigator and the influence of prejudice in the allotment of points. However, he continued, ". . . where large numbers are analyzed over a period of months this difficulty is to some extent overcome." In examining a large series of stomachs, the investigator becomes experienced in estimating their fullness. However, the identification of the food items does not become any less important and the investigator must continue the careful identification of remains of organisms as specifically as possible. These criticisms apply equally well to other methods of food assessment.

The present assessment of the stomach contents of the squawfish of the Lower Columbia River is based on Hynes' technique, with slight modification.

Immediately after being opened, each squawfish stomach was evaluated according to its degree of fullness and allotted a certain number of "stomach points." A full stomach was valued at 20 points. No food values of less than one point were given; an empty stomach received zero points. No consideration of the comparative sizes of the stomachs was made, it being assumed that a full stomach was just as important to a small fish as was a full stomach to a large fish. However, since stomach size could have an effect on the extent of predation, the numbers of salmon and all other fishes found in the stomachs were counted. Thus the distorting influence of predator-size on predator-capability was to some extent overcome. These counts of the salmon remains supplemented the use of the points system in establishing the predatory role of the squawfish.

After the points were allotted to each stomach for its degree of fullness, the points were distributed among the individual food items present.

Each food category present was allocated points according to its relative volume in the whole of the stomach contents. In this manner, volume became the foremost consideration in evaluating the contents of the stomachs. The allotment of the stomach points prior to the evaluation and identification of the food items prevented the possibility that large, relatively undigested items, such as fish and crayfish, might lead the investigator to overestimate their volumetric importance. No attempt was made to evaluate partially digested remains on the basis of their volume when first eaten. Items were scored only by their volume when the stomach was examined.

During the early course of the investigation it became apparent that the point and percentage values were weighted too heavily for the rather small volume of food found in the stomachs. The technique of assessment did not take into proper consideration the lack of food in the entirely empty stomachs nor in those stomachs only partially filled with food.

In order to give the food items a point value corresponding accurately with their actual relation to the potential stomach volume, a modification of the basic point system was devised. An estimate of the maximum possible total of points attainable by the fish in a sample was calculated by multiplying the number of fish examined by 20, the food value of a stomach when full. An estimate of the "empty" volume was determined by subtracting the points gained by all the food items from this maximum possible total. The volume percentages were then determined for each food category, including "empty," from this maximum possible total and not the food point total. An example of the point system of food assessment for a four-fish sample is illustrated in table 1.

This estimation of the potential volume of a fish's stomach is a rough estimate of capacity. It is a necessary consideration, however, when the basic diet and the feeding activities of predatory fishes are under investigation and the results from the sample are applied to the general population. At the time of examination of the stomach, only the points gained by the food present were estimated. No direct estimate of "emptiness" was made for an individual stomach. When the stomachs for any given samples were grouped, the potential capacity was then calculated to arrive at an estimate of the "empty" volume in the sample.

TABLE 1.—*Example of the point system of food assessment for a 4-fish sample*

Fish No. and stomach volume	Food points allotted	Stomach contents	Food item points	Percentage composition
1. Full	20	2 sculpins	20	25.00
2. Two-thirds full	13	1 lamprey larvae	8	10.00
		10 Caddis larvae	5	6.25
3. One-half full	10	1 rainbow trout	6	7.50
		2 crayfish, small	4	5.00
4. Empty	0			
Total	43			(53.75)
Maximum possible	(4)×(20)=80			
Empty	80−43=37	Empty		46.25
				100.00

Stomach volume can be increased greatly by stretching the stomach walls from a rather thick, folded state when the stomach is empty to a thin membrane when full. The maximum extension of the walls and the capacity of the stomach can only be estimated. The allotment of points to the volume of food items present was based on experience gained through the examination of hundreds of stomachs with a variety of volumes and foods.

The roughness of the capacity estimate detracts little from its value as used in this study. Here its basic use is to obtain an estimate of feeding activity by the populations of squawfish. Without it, application of the results of sample stomach analysis to the general population is impossible.

The problems of stomach contents analysis and methods of presentation are difficult ones and should be approached anew with each species and purpose of study. As Reintjes and King (1953) stated, "Regardless of the method of analysis used, there are many uncontrollable variables inherent in food studies which detract from the precision of the results. One may safely conclude, however, that those food items that rank large in number, large in volume, and high in frequency of occurrence are important foods . . . at the time and in the area sampled."

RESULTS

The detailed results of the study of the food of squawfish from the Lower Columbia River are shown in table 2. Numbers of items were obtained only for the fishes occurring in squawfish stomachs. No attempt was made to obtain counts

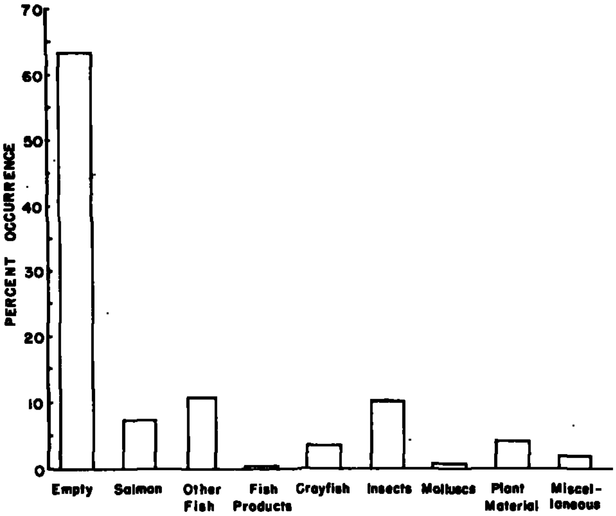

FIGURE 3.—Percentage occurrence of food items in 3,546 squawfish stomachs from the lower Columbia River.

of individual items of other foods. The main purpose of the study was to determine the basic food table of squawfish populations and an understanding of the role played by the squawfish as salmon predators. The counts of consumed fishes aid in determining this. Counts of small, nonfish items would have been time consuming, inaccurate, and would have offered only supplemental information to the main purpose of this study.

Of the 1,272 countable fishes found in the stomachs examined, 1,102, or 87 percent, were salmon. Sculpins comprised 6 percent, lamprey larvae 2.5 percent, and other species, mostly cyprinids, made up the remaining 4.5 percent.

Figure 3 shows that 63 percent of all the squawfish stomachs examined were totally empty. A measure of the emptiness of the stomachs only partially filled with food is not possible with this method of assessment.

The percentage composition is the evaluation of the importance of the food items as based on the modification of Hynes' (ibid.) "points" method. These point totals were grouped into the major food categories, and expressed as percentages of the total possible number of points, which included "empty" values. The inclusion of the points for emptiness illustrates not only what food was found and in what comparative volume but also the extent of overall feeding activity and food availability to the squawfish. Figure 4 illustrates the percentage composition of the foods

TABLE 2.—*Results of the stomach analyses of 3,546 squawfish,* Ptychocheilus oregonensis, *from the Lower Columbia River*

Food item	Number of items	Stomachs in which item occurred		Food "point" total	
		Number	Percent	Number	Percent
FISH					
Salmon and salmon remains	1,102	265	7.47	2,548	3.6
Sculpin, *Cottus* spp.	80	65	1.83		
Lamprey	30	21	.59		
Trout, *Salmo* spp.	16	11	.31		
Sucker, *Catostomus* spp.	8	7	.20		
Chiselmouth, *Acrocheilus alutaceus*	20	9	.26		
3-spined stickleback, *Gasterosteus aculeatus*	8	5	.14		
Chub, *Mylocheilus caurinus*	3	3	.08		
Squawfish, *Ptychocheilus oregonensis*	1	1	.03		
Shiner, *Richardsonius balteatus*	4	4	.11		
Adult salmon carcass remains		23	.65		
Unidentifiable fish remains		234	6.60	[1]2,870	[1]4.0
Sum	1,272	648	18.27	5,418	7.6
FISH PRODUCTS					
Salmon viscera		1	.03		
Salmon ova (eyed)		4	.11		
Salmon eggs (bait)		5	.14		
Fish refuse		4	.11		
Sum		14	.39	193	.3
CRUSTACEA					
Crayfish		128	3.61	1,027	1.5
INSECTS					
Plecoptera		38	1.07		
Odonata		14	.39		
Trichoptera		46	1.30		
Diptera		7	.20		
Hymenoptera		11	.31		
Coleoptera		10	.28		
Unidentifiable insect remains		235	6.63		
Sum		361	10.18	1,557	2.2
MOLLUSKS					
Snails		13	.37		
Clams		19	.54		
Sum		32	.91	139	.2
PLANT MATERIALS					
Algae		79	2.23		
Wheat kernels		27	.76		
Unidentifiable plant remains		48	1.35		
Sum		154	4.34	701	1.0
MISCELLANEOUS					
Annelids		5	.14		
Stones and pebbles		3	.08		
Mud and detritus		43	1.21		
Feathers		1	.03		
Rodents (fur and remains)		6	.17		
Salamanders		2	.06		
Sum		60	1.69	298	.4
Empty		2,243	63.25	61,587	86.8
Grand total				70,920	100.0

[1] Totals for all nonsalmon fishes.

of the squawfish stomachs examined. From it and from table 2 it is evident that the squawfish are omnivorous; probably they are opportunistic omnivores, willing to eat anything available that is palatable. However, fishes were the most important food item in both occurrence and composition.

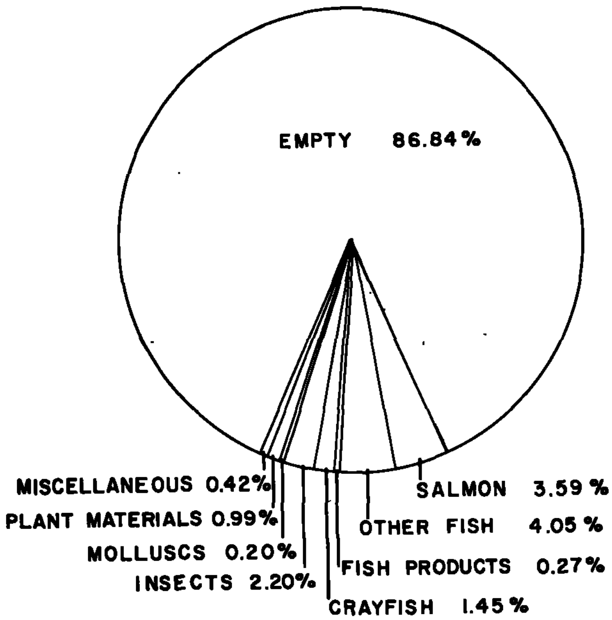

FIGURE 4.—Composition of contents from 3,546 squawfish from the Lower Columbia River.

Salmon were by far the most important genus of fish found in the entire sample. Insects, crayfish, and plant materials, in that order of importance, were the only other important categories of food. An interesting point from figure 4 and table 2 is that 87 percent of the estimated potential volume of the squawfish stomachs was empty.

Size of organisms eaten

The squawfish stomachs examined indicated that the fish are largely nonselective as to the sizes of organisms eaten. Smaller fish, of course, are limited to the smaller food organisms; however, larger squawfish showed evidence of feeding on small organisms also.

Algae, wheat kernels, and small insect larvae were found in the stomachs of some large fish, objects of small size in relation to the size of the fish and to other items of food.

The smallest items found in the stomachs were bits of green algae. These were usually found in conjunction with other items of food and may have been taken incidentally, but some stomachs contained only algae. The largest food items were fish. One squawfish, 18 inches in total length, had an 8-inch Columbia River chub, *Mylocheilus caurinus*, in its stomach and gullet.

Occurrence of gorging

Very few squawfish were found with stomachs distended with food. The few taken in this condition were full of young salmon and were captured in close proximity to and within a few days following a release of artificially reared salmon. There were indications that the squawfish, under these conditions, were capable of "pumping" the undigested remains of salmon through the alimentary tract. Salmon remains were ejected from the anus when some of the sqawfish were first handled. These remains even in the lower part of the intestinal tract showed little of the effect of digestion; the fins were whole and the integument intact.

Diurnal fluctuations in feeding

The sampling for data on diurnal fluctuations in the feeding activities of squawfish was inadequate. The majority of the catches were made at night, when gill-net fishing was most efficient, and the nets were usually lifted the following morning. The results from drift-net fishing, where the fish were captured during a relatively short period of time, were too meager to provide information on diurnal feeding.

Variation in feeding habits

Variations in the percentage occurrence of foods eaten by different-sized squawfish are shown in figure 5. In this illustration, the fish were grouped into 1-inch length classes and the percentage occurrences of the food items and empty stomachs were calculated and graphed. Due to duplication of food items in some stomachs, the summed percentages were, in most length classes, slightly more than 100 percent. However, since only 3 percent of the fish containing food contained more than one kind of food item, the highest total of summed percentages was only 105 percent. For clarity and simplicity in figures 5 and 9 none of these totals was plotted at more than 100 percent, so the area in the figures denoting the empty stomachs should be a bit more extensive. This slight loss of area in the empty category reduces only slightly the validity of the figure in presenting the relation between size and the occurrence of food items.

The most obvious change in food occurrences as the squawfish increase in size is the decrease in the occurrence of insect foods and the increase in

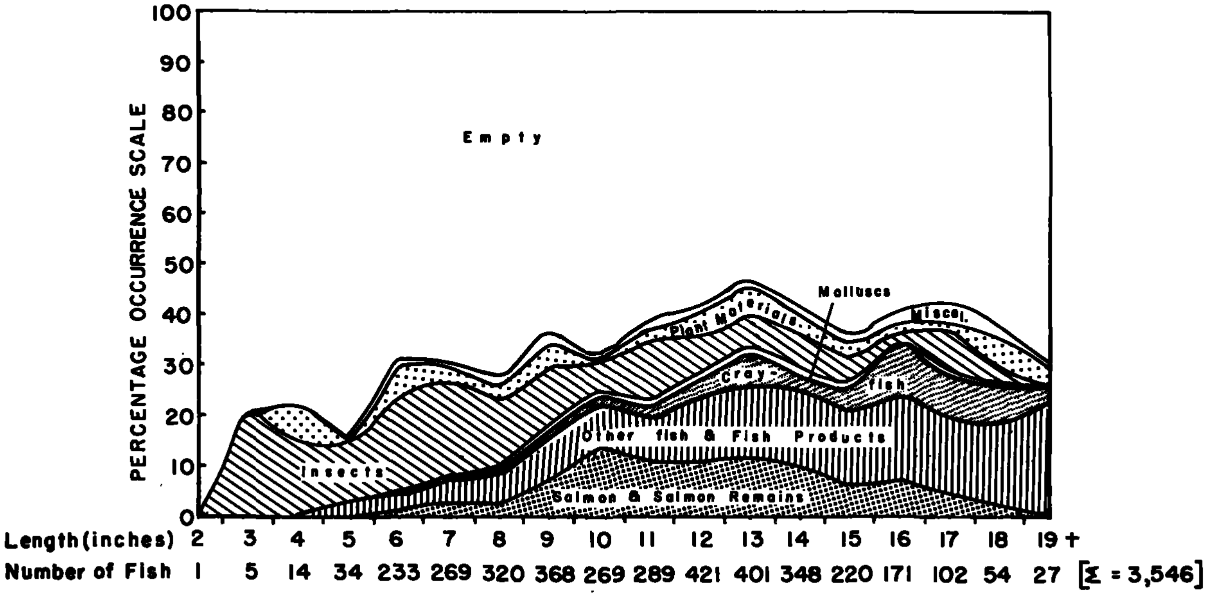

FIGURE 5.—Percentage occurrence of food items and empty stomachs by 1-inch length groups; sexes grouped.

occurrence of fish and crayfish. Other food items—mollusks, plant materials, and miscellaneous items—did not occur in great enough frequency to illustrate any trends. Plant materials were eaten equally often by all sizes of squawfish. Hynes (ibid.) observed similar changes in the size of food items in the diet of sticklebacks with a change in fish size and stated that the change ". . . is an expression of increase in maximum size of the organisms eaten." Smaller fish are unable to swallow the larger organisms available to the larger squawfish, and as the fish grow larger it becomes less worth while to spend time catching the smaller food organisms.

The smallest squawfish found to have consumed salmon were 6 inches in total length (figs. 5 and 6). The length frequency of salmon-eating squawfish approximates the distribution of the total squawfish sample (fig. 6). The largest squawfish containing salmon was 18 inches in total length. Fish, including salmon, do not reach dominant occurrence in the stomachs until the squawfish are about 10 inches in total length (fig. 5). The percentage occurrence of fish then remains at approximately the 20-percent level. Insects decrease in occurrence markedly in squawfish of 9 inches total length, but are found in 2 to 10 percent of all larger fish. This evidence indicates that the most common food of the squawfish changes from insects to fishes at a total length of 9 to 10 inches. (Preliminary age-length determinations indicate squawfish of this size to be approximately 4 years old.)

Ricker (1946) states that the larger fish have empty stomachs more often than do smaller ones, with few exceptions. Hynes' (ibid) stickleback data agree closely with Ricker's statement, and Hynes states, "It will be noted that as the fish grow the percent with empty stomachs increases steadily." He interpreted this as indicating the sticklebacks eat more sporadically as they grow larger. Figures 5 and 7 indicate that for Lower Columbia River squawfish, the opposite situation is the general rule. Very few fish below 5 inches' total length were sampled, but a definite decrease is shown in the percentage occurrence of empty stomachs as the squawfish increase in size.

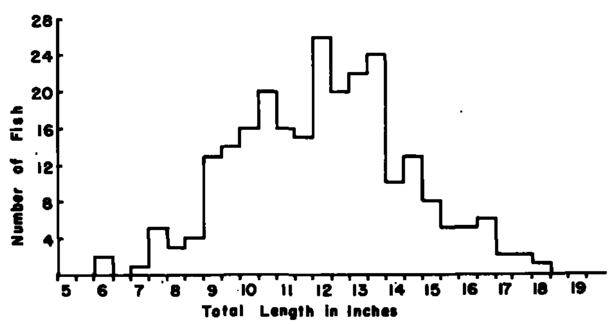

FIGURE 6.—Length-frequency distribution of salmon-eating squawfish.

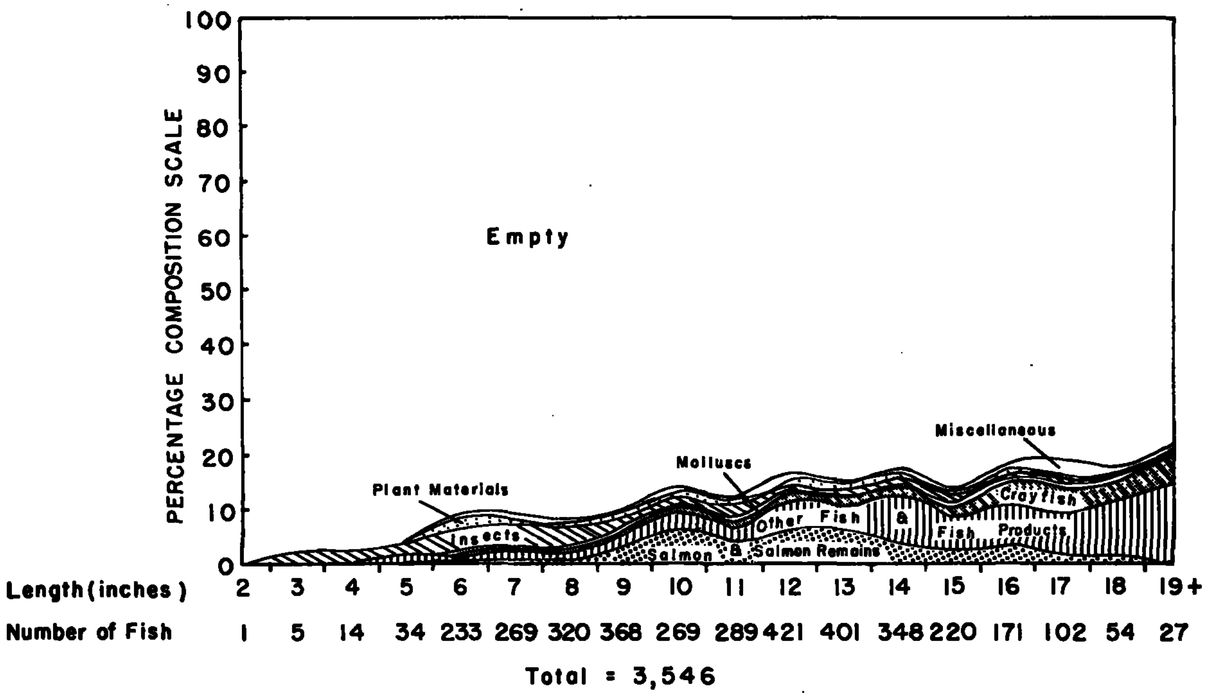

FIGURE 7.—Percentage composition of stomach contents of squawfish by 1-inch length classes.

The percentage composition of food items in relation to squawfish size (fig. 7) follows a pattern not unlike that of the percentage occurrence. Insects decrease in importance as the fish get larger and fishes and crayfish attain dominant importance in large fish. The point of transition in the importance of these categories also is at the 9- to 10-inch total length size. The lesser food items occur at about the same level of importance throughout the range of sizes, rarely comprising more than 2 percent of the stomach composition.

In comparing the frequency of occurrence (fig. 5) with percentage composition (fig. 7), two points of difference are readily apparent. The first is the increase in "emptiness" in the percentage composition. This is due to the occurrence of partially empty stomachs which were not included in the "empty" category of figure 5, but contributed points to that category when emptiness was considered as part of the composition of the stomachs. The second point is the decrease in comparative importance of the food items that are usually small, such as insects and plant materials. Salmon, other fishes and fish products, and crayfishes all seem to decrease in importance from figure 5 to figure 7, but the decrease in the smaller food items is proportionately much greater.

Variation by sex

Figure 8 shows the percentage composition of the stomach contents for the total sample for the categories of male, female, and the immature-unknown group. Slight differences are seen to occur in the diet of males and females, and, of

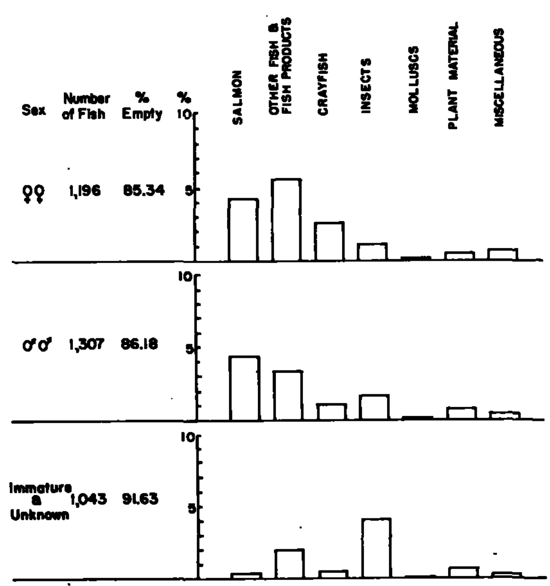

FIGURE 8.—Percentage composition of stomach contents for females, males, and the immature-unknown group.

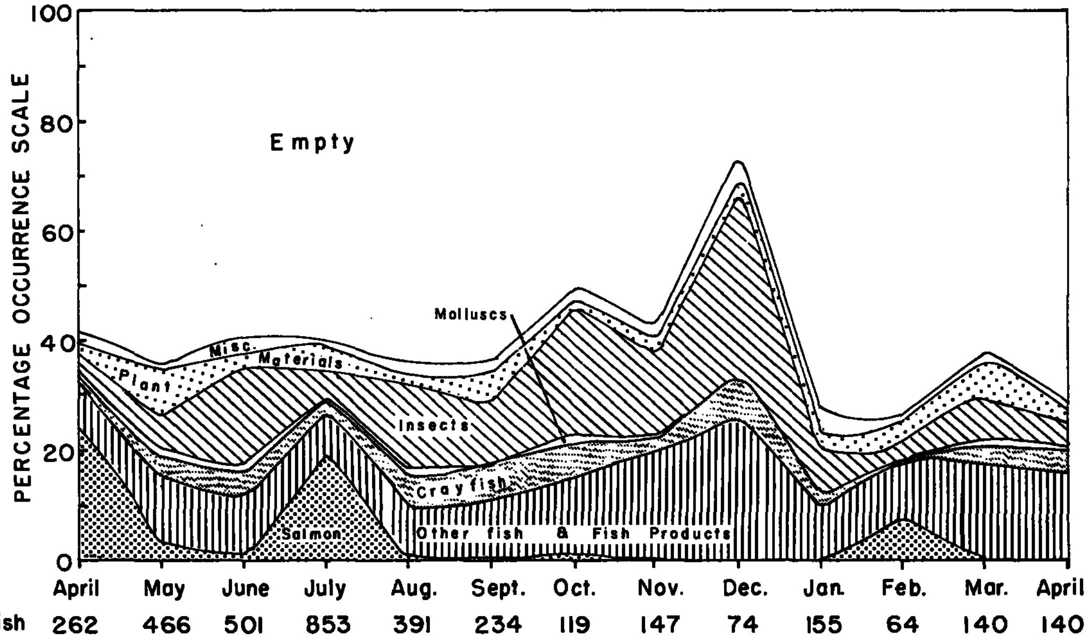

Figure 9.—Percentage occurrence of squawfish food items and empty stomachs, by months.

course, the diet of the immature fish is different due to their smaller size. However, the differences shown in figure 8 are within the limitations of the sampling and food evaluation techniques, neither of which were designed for detailed purposes. For this study, then, it is assumed that no differences exist in the feeding habits of male and female squawfish.

Variation by season

As would be expected in the feeding activity of coldblooded animals, there were distinct variations in the seasonal feeding activities and diet composition of the squawfish. The percentage of squawfish containing food held at a fairly constant level from April to November. A rise in food occurrence appeared in December, following which the percentage occurrence of stomachs containing food dropped to its lowest point in January (fig. 9). The percentage composition of the stomach contents (fig. 10) shows a similar pattern of seasonal variation.

The components of the diet also showed seasonal variations in quantity. Salmon were found to occur in significant amounts only following releases of young salmon from hatcheries where sampling occurred during and following releases in April, July, and February. Since it was not possible to sample for squawfish at every release of salmon from all hatcheries in the Lower River, predation following releases during other months was missed. The occurrence of salmon in the squawfish diet appears to be dependent on hatchery releases, and is not associated with natural seasonal phenomena as are the other food items.

The other foods were found in usual occurrences and quantities except during the month of December, when the mean value of food points per stomach was unusually high (fig. 11). Closer examination of the December data indicates that the majority of the points were allotted to foods found in squawfish from Eagle Creek, Herman Creek, and the Wind River sites in the Bonneville Pool, and from Umatilla River, the uppermost tributary in which sampling occurred. The Bonneville Pool samples contained mostly nonsalmonoid fishes and a few insects. The Umatilla River December sample of 21 squawfish, none of which was empty, received 68 points for fish and 134 points for insects, the majority of the insects being stone-fly nymphs. The apparent increase in feeding activity in December is due, then, to results obtained from 74 stomachs, which were 2 percent of the total sample. These stomachs gained 507 food points for an average of 6.8 points per stomach, by far the highest average during any month.

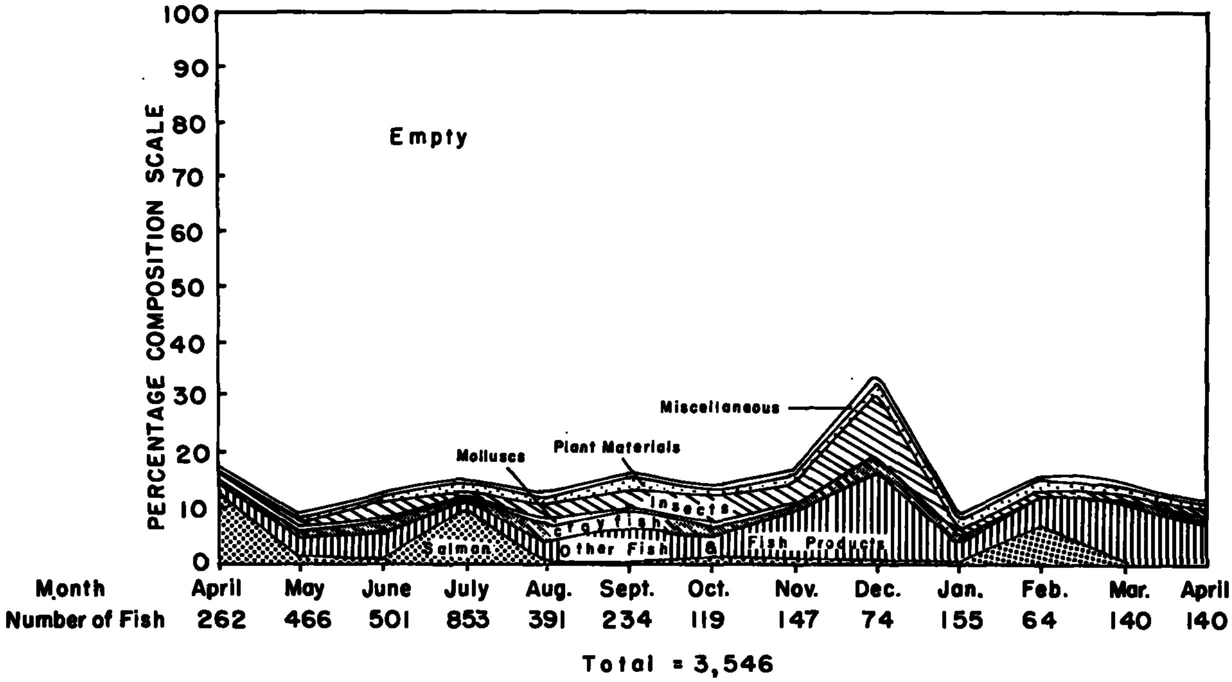

FIGURE 10.—Percentage composition of squawfish stomach contents, by months.

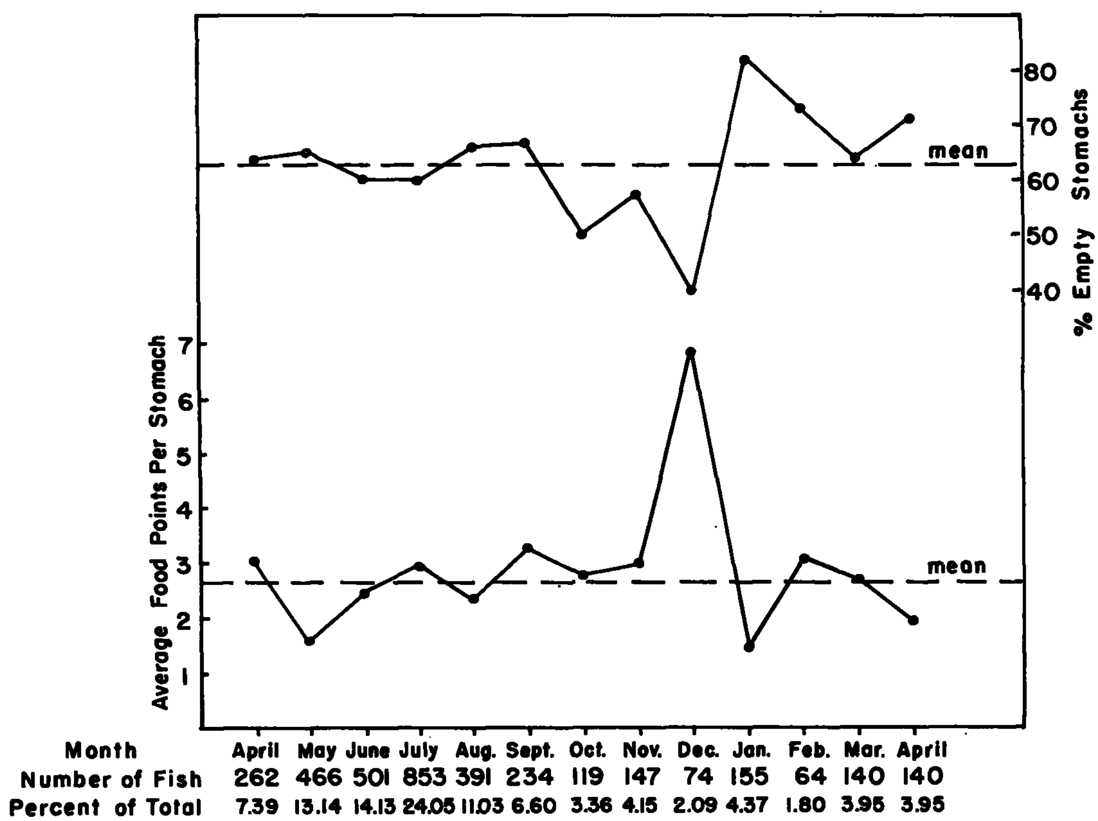

FIGURE 11.—Mean monthly food points and monthly percentages of squawfish with empty stomachs.

The mean monthly food points per stomach are shown in figure 11. The great variation between the annual mean and the December value of food points per stomach is readily apparent. Empty stomachs were at minimum percentages during the fall months, the minimum being December, concurrent with the peak in mean food points per stomach.

An explanation of the variation shown by the December samples is not readily available. The foods found do not differ in kind from those found during the remainder of the year, but the quantities do differ, not only from the adjacent months but from the whole year's sample.

Perhaps this is further evidence of the "opportunistic omnivorous" habits of the squawfish. They seem to feed to the gorging stage when desirable food items are available, but do not appear to hunt actively for food at all times. They are, it appears, a sluggish fish not willing to exert themselves in searching for food, but when an opportunity occurs, they are stimulated to feed voraciously and will do so until a point determined by capacity and availability is reached.

Variation by subarea

To determine whether or not the diet of the squawfish differed between subareas within the entire sampling area, the main area from Astoria to McNary Dam was divided into four smaller areas. The locations of these subareas and their boundaries are shown in figure 1 and described as follows:

Area I. Mouth of Columbia River to the mouth of the Cowlitz River, including the Cowlitz and its tributaries.

Area II. Mouth of the Cowlitz River to Bonneville Dam.

Area III. Bonneville Pool area; from the dam upstream to the site of The Dalles Dam.

Area IV. The Dalles Dam to McNary Dam. Collections for this study made only in the John Day and Umatilla Rivers in this subarea.

The percentage composition of foods for each area is shown in figure 12. Although the differences in foods between areas seem to be minor, chi-square tests indicated that differences for all food categories were significant. The variation in salmon occurrence and importance from one area to another is understandable in the light of the artificial factors contributing to salmon concentrations and abundances. The variations in composition of other foods cannot easily be explained.

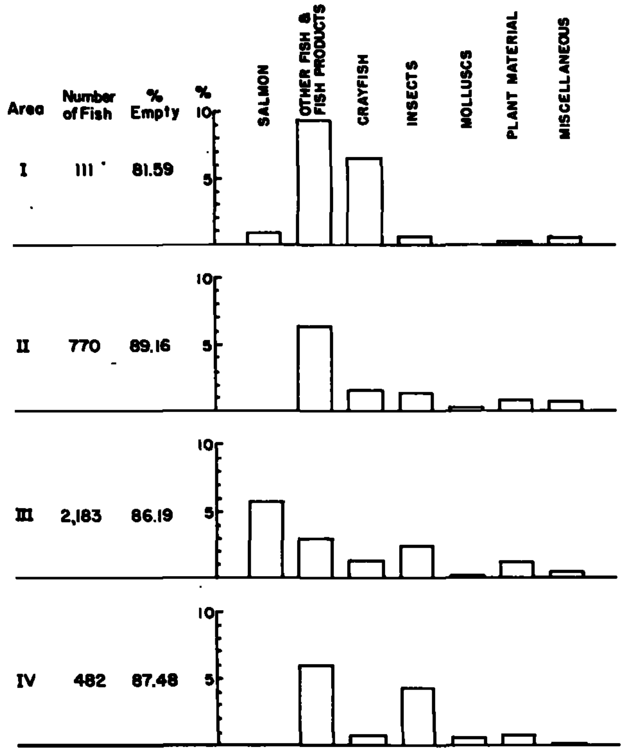

FIGURE 12.—Percentage composition of squawfish stomach contents from four subareas.

Since differences in food habits were found to be due in some measure to differences in size of squawfish, the length frequencies of the squawfish captured in each area were compared (fig. 13). The differences in size of squawfish between the subareas are difficult to compare because of differences in sample sizes. Inspection by eye indicates that the range of sizes was approximately the same in each area. The size composition of the samples from the different subareas, then, does not readily illustrate a reason for the food variations between areas. (Those fish smaller than 5 inches in area IV were taken with an electrical fish-shocking device.)

No faunistic sampling was made for the items of food found in the stomachs. Therefore, an estimate of the abundance of these food items in the subareas of the river cannot be made. An explanation of the area food differences may actually lie in differences in the abundance in food items and their availability to the squawfish.

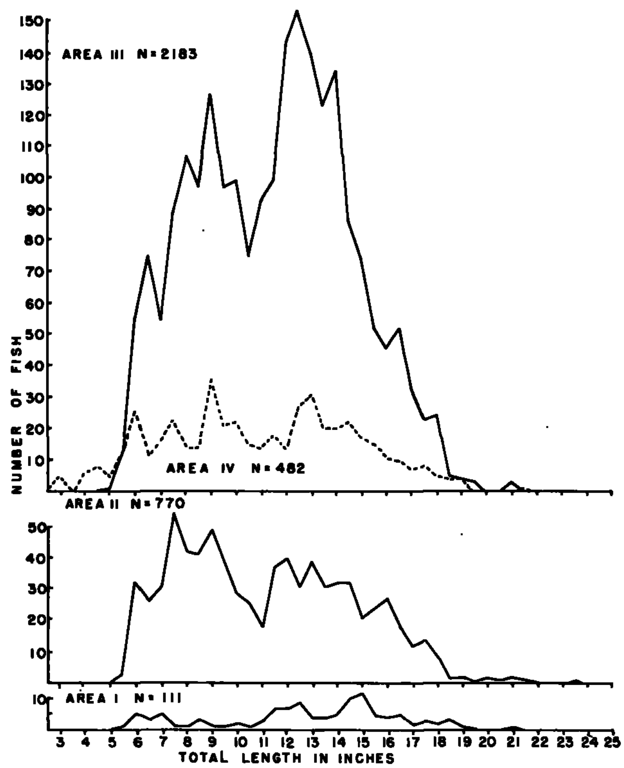

FIGURE 13.—Length-frequency distribution of squawfish by four subareas.

Further study on food item abundances and squawfish foods is necessary to attain an understanding of these area differences in squawfish foods.

A fact of importance emerging from the squawfish stomach analyses was the high occurrence of empty stomachs, particularly during the months of January, February, and March. Eighty-two percent of the January sample of 155 squawfish was completely empty. Another point of interest is that only 3 percent of the squawfish containing food contained more than one kind of food item.

Predation on juvenile salmon from hatcheries

From figure 14 it is readily apparent that every occurrence of salmon in squawfish stomachs was preceded by a recent and nearby release of artificially reared juvenile salmon. The predation noted in Germany Creek is the only exception. Most occurrences of salmon in stomachs were within a day or two following a release. Squawfish sampling was not continuous or intense enough within a sampling area to show a decrease in the availability of salmon. The delays at the Wind River sites in the occurrence of salmon in squawfish stomachs following releases can be explained by the fact that the point of release at the Carson Hatchery is some 12 river-miles upstream from the sampling sites. There is a lagoon in the lower reaches of Wind River before it empties into the main Columbia River. The river distance would cause some straggling to occur in the salmon migration. A residual delay in the lagoon would also be a factor in the duration of availability of the young migrant salmon to the squawfish. The stream characteristics of Herman Creek could also allow some prolongation of availability of salmon to squawfish. The hatchery is located about one-half mile upstream, and there is also a small lagoon at the mouth of the creek.

Table 3 lists the gill-net sampling sites where squawfish were found which contained salmon fingerlings and also the nearest point of artificially reared salmon releases.

TABLE 3.—*Sampling sites where salmon were found in squawfish, and nearest source of hatchery-released salmon*

Site	Nearest hatchery and location
Germany Creek	None close by.
Herman Creek	Ox Bow Hatchery (Oregon Fish Commission) approximately ½ mile of stream and ¼ mile of "estuary" above net site.
Wind River Mouth and Upper Wind River.	Carson Hatchery (U.S. Fish and Wildlife Service), about 14 miles above mouth of river and about 12 miles above Upper Wind River site.
Drano Lake	Little White Salmon Fish Cultural Station (U.S. FWS), at mouth of Little White Salmon River where it enters Drano Lake.
	Willard Hatchery (U.S. FWS), about 6 miles upstream from mouth of Little White Salmon River.
Drinking Fountain	Spring Creek Fish Cultural Station (U.S. FWS) about 1½ miles upstream from gill net site.
Spring Creek	Spring Creek Fish Cultural Station (U.S. FWS). One net site was in front of hatchery and another one about 150 yards downstream.

SUMMARY AND CONCLUSIONS

(1) This study is based on the examination and evaluation of the stomach contents of 3,546 squawfish collected during the 13-month period of sampling from April 1955 to April 1956, from the lower 240 miles of the Columbia River and its major tributaries within this area.

(2) The evaluation of the foods is presented numerically for the identifiable fishes, and by percentage occurrence and percentage composition for all foods. The percentage composition is based on a modification of a "point" system of food assessment.

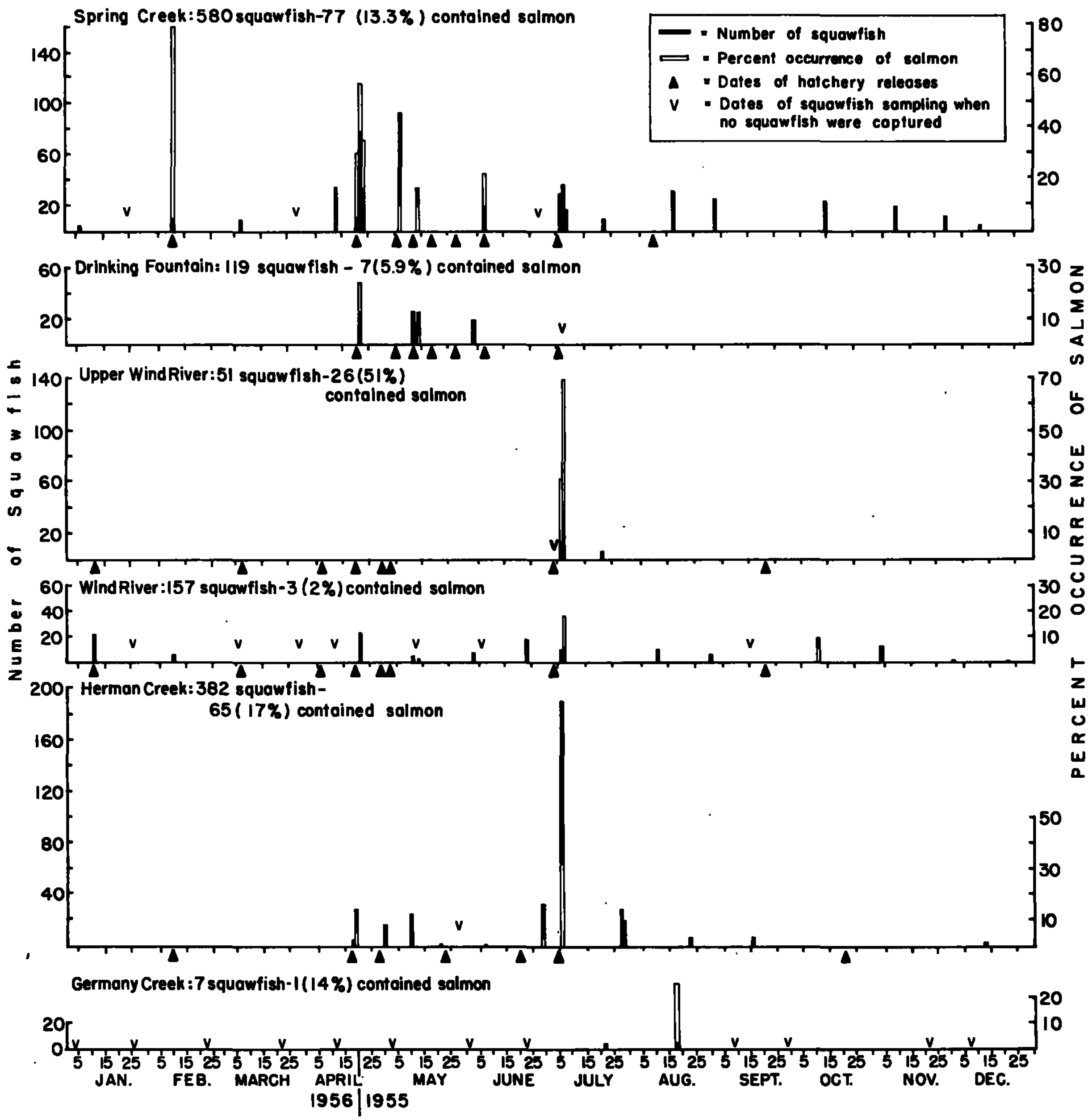

FIGURE 14.—Relation between hatchery releases and the number of squawfish captured and percentage occurrence of salmon in squawfish stomachs.

(3) Sixty-three percent of the stomachs of the squawfish examined were completely empty, and 87 percent of the calculated potential volume of the stomachs was empty.

(4) A total of 1,102 juvenile salmon was found in 7.5 percent of the squawfish and comprised 3.6 percent of the stomach composition. Other species of fishes, insects, and crayfish were the other important items of foods found.

(5) From the results of this study it appears that squawfish are omnivorous in habit, taking the opportunity to feed on foods that are available.

(6) Squawfish less than 8 inches in total length had fed preponderantly on insects; squawfish 8 to 11 inches in length on insects and fishes. Squawfish more than 11 inches had fed mostly on fishes and crayfish.

(7) Slight differences were found to occur in the diets of male and female squawfish. However, these differences were not considered significant enough to warrant the separation of the sexes in the food study, and the results of analysis of stomach contents of males and females were grouped.

(8) Some variations in diet due to seasons of the year were noted, but could not be explained completely. Most food items were found during all seasons. Fishes, other than salmon, and crayfish had no definite period of scarcity or abundance in the squawfish diet. Insects were at their minimum in the stomachs during the first calendar quarter. The period of maximum insect occurrence was from August to December.

(9) Some differences in diet between subareas of the main sampling area were evident. Complete understanding of the reasons for this must await further study aimed at this particular problem. The food item showing the greatest variation from one area to another was salmon, the area distribution of which was considered the result of artificial propagation and release.

(10) The most striking and obvious result of this study was the detection of the localization of predation on hatchery-released salmon to the immediate vicinity of the release points. It is recommended that future studies be conducted to measure the absolute effect of such predation; that is, to determine the total losses of released salmon to predators within a given distance of the point of release. Such a program of study would be far from simple, but should be initiated soon in consideration of the large financial expenditures necessary to produce these young salmon, justified at present only by the expectation that they survive to provide a significant contribution to the commercial fishery.

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