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FOREWORD

These short reports are intended to inform the public, industry, and other interested parties of the current studies of the Commission's staff and of the basis for conservation measures. Reports will be published from time to time when studies are sufficiently complete to provide reliable biological evidence for conclusions upon which regulations are based. Research Briefs are free and may be obtained upon request from the Fish Commission office.

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A STUDY OF THE BAIT SEINE FISHERIES OF OREGON

Introduction

The albacore fishery in the Pacific Northwest began off the Oregon Coast in 1937 and rapidly developed into a major industry throughout the area. In the early years most of the catches were made by boats trolling with feather jigs, but as the fishery developed, the vessels equipped to use live bait began landing a greater proportion of the catch.

The albacore fishermen soon found that anchovies (*Engraulis mordax*) were the most successful live bait. In most cases the anchovies are caught by the albacore vessels, but occasionally the bait is supplied by commercial bait fishermen.

Because the bait is most often caught in or just outside bays or estuaries, there has been considerable speculation as to the numbers of salmon and trout taken incidentally with the bait. Other bait and food fisheries have been developed in Yaquina Bay and Coos Bay which also might conceivably capture immature salmon and trout. This report is being written to present the data gathered by the Oregon Fish Commission on these fisheries during the past five years.

Lampara Net Fishery

Bait for the tuna boats is caught with a lampara net, about 900 feet in length, which is an impounding net with a bag in the center. The wings are especially made of eight-inch stretched mesh, and there is a gradation toward smaller mesh in the center of the net where the bag is of one-half-inch mesh.

When the tuna boat is seeking bait, the net with a buoy attached to one end is placed on the deck at the stern of the boat. When the captain locates what he thinks is a suitable school of anchovies, he orders the buoy to be thrown over the side into the water. The net pays off the stern of the vessel while the boat makes a complete circle, surrounding the fish. Finally the buoy to which the net is attached is picked up again so that both ends are aboard the boat. The wings of the net are then pulled on board until the catch is concentrated in the bag. The fish are removed from the bag and placed in the bait tanks with a dip net.

In August, 1947, a biologist from the Oregon Fish Commission observed the operation of a lampara net while aboard the albacore boat "Western Sun". During the voyage three sets of the lampara net were made, two inside the Columbia River bar near the North Jetty and one off North Head. The first set was made at 5:45 a.m. on August 13, approximately one-half mile inside the base of the North Jetty and about 400 yards offshore.

The catch when viewed in the bag of the net appeared to be almost 100 percent anchovies. About 130 scoops of fish were placed in each of the two bait tanks. A "scoop" is one dip with the dip-net and contains approximately 175–200 anchovies. Each scoop was examined as it was placed in the tank. What appeared to be a three or four pound salmon was seen in the bag but the fish was thrown into the river before it could be examined. Two small starry flounders (*Platichthys stellatus*) and three or four tomcod (*Microgadus proximus*) were also seen. One set of the net was enough to fill both tanks.

A random bucket of about 300 fish was examined, all of which were anchovies except one tomcod and two long-finned smelt (*Spirinchus dilatus*).

The fish in the bait tanks were watched closely to see what species were present. After a short time a few herring came to the surface and died. One chinook salmon about seven inches long was seen.

At 10:45 p.m. August 14 the bait was dumped at sea because of the rough weather, and the boat returned to the mouth of the Columbia River for shelter. It was estimated that the bait in this first set consisted of 95 percent anchovies. The other five percent were mostly herring, with some smelt, tomcod, one chinook salmon fingerling, and one three or four pound trout or salmon. Only two salmonoids were seen among the approximately 45,000 bait fish, although a few others may have been present without being observed.

At 8 a.m. August 15 another set was made off the North Jetty at approximately the same location as the first set. Only about 45 scoops were obtained. Two shad of about three-quarters of a pound each and several smelt were seen. No salmonoids were observed. No more bait could be located inside the river, so in the afternoon the boat crossed the bar and headed north, keeping within a mile or so of the beach.

At 3:30 p.m. the net was set about three-quarters of a mile northwest of the North Head Lighthouse. This set was more successful and 155 scoops were obtained, making a total of 100 scoops in each bait tank. In addition to the anchovies, one fingerling chinook salmon and one smelt were seen. A random small scoop of bait was counted and found to contain 170 anchovies and no other species.

A close watch was kept on the bait tanks and the next day a few smelt came to the surface and died. During the following six days at sea the tanks were observed at frequent intervals. The tanks were cleaned every evening by siphoning the debris from the bottom and all dead fish were examined. The bait was observed as closely as possible during fishing operations. At the end of the trip the remaining fish were examined carefully to identify the different species. This close scrutiny disclosed a total of six chinook salmon fingerlings and no other salmonoids among the approximately 35,000 bait fish.

The following species were preserved and identified.

1. Long-finned smelt (*Spirinchus dilatus*)
2. Surf or silver smelt (*Hypomesus pretiosus*)
3. Pacific tomcod (*Microgadus proximus*)
4. Pacific herring (*Clupea pallasii*)
5. 3-spined stickleback (*Gasterosteus aculeatus*)
6. Perch, shiner (*Cymatogaster aggregatus*)
7. Chinook salmon (*Oncorhynchus tshawytscha*)
8. Anchovy (*Engraulis mordax*)
9. Shad (*Alosa sapidissima*)
10. Starry flounder (*Platichthys stellatus*)

This list is not in order of importance. The anchovies were of course by far the most numerous. The two species of smelt and the herring were quite abundant. Several tomcod, three or four starry flounders, two shad, one stickleback, and six salmon fingerlings were also observed.

The observations made on this trip indicate that the tuna bait fishery operating in and close to the mouth of the Columbia River depends almost entirely on species of little or no importance as food or game fish.

There is another fishery for albacore bait in Yaquina Bay, 150 miles south of Astoria. Herring and pilchard which are used as bait in the crab and longline fisheries, and shiners (*Cymatogaster aggregatus*) which are used as bait in the sport fishery are also caught in Yaquina Bay.

During the summer of 1948, a biologist with the Oregon Fish Commission made notes on the Yaquina Bay tuna bait fishery. In that season there was a steady fishery for anchovies to be used for tuna bait. One of the bait seiners experimented with holding the anchovies in large floats anchored in the bay. The sides of the cribs were slatted with strips of wood between which were narrow spaces to allow a continuous circulation. Fish held in this manner were fed daily with cereal meals. The fish were transferred with a long-handled dip net from the cribs into the bait tanks. The bait was sold by the scoop to the tuna boats, each scoop weighing from five to seven pounds according to the bait seiners. Casual observations disclosed only four or five salmonoids during the entire season.

In 1949 there were so few bait boats in Yaquina Bay that the fishery for anchovies was negligible. One of the bait seiners supplied only one boat all summer. Two other tuna boats obtained bait for themselves. Albacore fishing with bait was poor in 1949 in all Oregon waters and in 1950 practically no tuna were taken with live bait off the Oregon Coast.

Before World War II, observations were made by Fish Commission biologists on the operation of a lampara net on two different occasions. The first of these took place in June, 1939 inside Coos Bay just below Empire. During the course of obtaining a supply of bait for albacore fishing a number of hauls were made by the boat "Five Brothers". No salmon, trout, or any other food or game fish of any commercial importance were taken. The catch consisted almost entirely of sand lances (*Ammodytes tobianus personatus*). There were also a few scattered herring in the catch, but the amount of fish other than sand lances did not constitute above one percent of the total.

A further opportunity for observing a lampara net in action presented itself to a Fish Commission biologist who was on board the pilchard seiner "Western Queen" in the course of carrying out a pilchard tagging program. On August 15, 1940, the pilchard fleet was anchored at Cape Falcon during the afternoon. The captain ordered the Japanese crew to use the bait net to get small fishes that the crew could use as food. The net was several hundred feet in length with a one-half inch stretched mesh bag.

The net was set just outside the surf in the cove south of Cape Falcon. Several hundred pounds of fish were taken. No salmonoids or other food or game fish were observed. An estimate of the percentage of the various species in the catch is as follows:

Pilchard (*Sardinops caerulea*)	10%
Anchovy (*Engraulis mordax*)	5%
Pacific herring (*Clupea pallasii*)	4%
Night surf smelt (*Spirinchus starksi*)	50%
Whitebait (*Allosmerus attenuatus*)	30%
Tomcod (*Microgadus proximus*)	1%

In addition to taking bait for albacore fishing, lampara nets are occasionally used in Yaquina Bay for capturing pilchard to be used for crab and long line bait. In July and August, 1949 several successful sets were made, one of which yielded a catch on August 30 of 6,000 pounds of pilchards.

These fish were frozen in 50-pound blocks, 35 of which were examined by a biologist and found to contain only pilchards.

Further notes on the Yaquina Bay pilchard fishery were obtained on September 2, 1949, when a Fish Commission biologist accompanied a commercial boat on one of its trips. Three sets of the lampara net were made. No pilchards were located but about 400 pounds of other fish were taken, 98 percent of which were small herring. The other 2 percent consisted of English sole (*Parophrys vetulus*), smelt, one skate, tomcod, walleyed perch (*Hyperprosopon argenteum*), two chinook jack salmon, one adult silver salmon, and three or four fingerling salmon. A 2½-gallon bucket was filled with a random sample of fish all of which were identified. The bucket contained 465 herring, 5 surf smelt, 3 tomcod and 1 sand dab.

The scattered observations made on the lampara net bait fishery indicate that no harm is being done to any important food or game fish at the present time. It is of course possible that young salmonoids might be taken at other times and places when biologists are not present to record the fact. Continuing observations are needed to determine whether bait fishing should be prohibited at any particular time or place.

Beach Seine Fishery

During the summer of 1949, one of the Yaquina Bay boats operated a beach seine for capturing the larger perch which were sold to the fresh market. Such a beach seining trip was observed by two Fish Commission biologists July 12, 1949. Three different hauls were made and no salmonoids were seen in the approximately 160 pounds of fish taken. The following table shows the composition of the catch.

1. Perch, shiner (*Cymatogaster aggregatus*)	90%
2. English sole (*Parophrys vetulus*)	5%
3. Bullhead (*Leptocottus armatus*)	
4. Perch (*Damalichthys vacca*)	
5. Perch (*Hyperprosopon argenteum*)	5% (items 3–7)
6. Shad (one only) (*Alosa sapidissima*)	
7. Starry flounder (*Platichthys stellatus*)	

Observations on the beach seine fishery in Yaquina Bay were made again in the summer of 1950. On June 19 a trip was made to the upper part of Yaquina Bay. The seining grounds were reached just before the low water slack tide. Two hauls were made and the catch consisted of about 200 pounds striped and walleyed perch. In addition to the food fish a great many shiners were taken but discarded. The miscellaneous catch consisted of about 10 small crabs (*Cancer magister*), a small skate, two small shad about eight inches long, and three herring. A number of small starry flounders and sand dabs were also taken. No salmonoids were observed.

Another set was made in a different area which resulted in a large catch of shiners all of which were released.

The following day (June 20) another trip was made for shiners to be used as bait by the sport fishermen. One haul of the seine at low tide yielded enough shiners for bait, but the water pump on the boat failed and most of the fish died. Another haul was made and about 1,000 live fish were captured and returned to the docks successfully. In addition to the shiners, about 20 pounds of food perch were kept. Also taken were about 75 crabs, which were released, a good many small starry flounders, three herring, two small shad, and a large number of speckled sand dabs (*Citharichthys stigmaeus*). No salmonoids were seen.

Coos Bay also supports a small beach seine fishery for herring. In the winter of 1949-50 a Fish Commission biologist stationed at Charleston reported that an occasional silver salmon was taken in South Slough by the beach seiners. None were reported from operations in the lower bay. This biologist estimated that possibly 20 salmon were taken during the season, most of which were reported to have been released. Two male silver salmon about 17 inches long were brought into the laboratory by the herring seiners.

Summary

In some years, considerable quantities of anchovies to be used for albacore bait have been taken in and just outside the bays and estuaries of Oregon.

Examination of the bait catches by lampara nets along the Oregon Coast indicates that an insignificant number of salmon fingerlings are taken incidental to the anchovy catch.

The lampara nets used to capture pilchards in Yaquina Bay for crab and longline bait take very few immature and adult salmon. These can be released in good condition.

Very few salmon or trout are taken by the beach seines which are used to catch perch in Yaquina Bay.

A few immature salmon are taken by the herring beach seines operated in Coos Bay. Again these fish can be released in good condition.

Conclusions

There were only small numbers of salmonoids caught by the various bait and beach seine fisheries investigated from 1939 to 1950. However, the observations should be continued since the possibility still remains that in certain areas and at certain times greater numbers of salmonoids might be taken.

Acknowledgments

Several Fish Commission biologists have collected data at various times which have been included in this report. Vernon Brock and Edwin Niska, formerly biologists with the Oregon Fish Commission, made the observations in Coos Bay and off Cape Falcon during 1939-40 respectively. Robert Livingstone and Clarence Bevington gathered most of the Newport data while stationed there as temporary seasonal biologists. Alfred R. Morgan, Fish Commission biologist with headquarters at Charleston, contributed to the study by making notes on the herring beach seine fishery in Coos Bay.

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Aquatic Biologist

MIGRATION OF WHITE STURGEON (*Acipenser transmontanus*) IN THE COLUMBIA RIVER

Introduction

Although the commercial utilization of sturgeon in the Pacific States was started more than 60 years ago, and approximately one hundred millions of pounds of this valuable fish have been taken from the Columbia River alone, nobody until now has had any real information concerning the migratory habits of this species. All that was known was that there are two different species of sturgeon, the green (*Acipenser medirostris*) and white (*A. transmontanus*), and that the former occurs in salt and brackish water while the latter is confined to the rivers. There is also a strong possibility that these two species have not been always properly separated in the past statistics and that the earlier records of catches of white sturgeon in the sea were perhaps not correct.

An exact knowledge and understanding of sturgeon migrations in the Columbia River is necessary for the scientific management of sturgeon resources. It must be pointed out that in their paper on the History and Development of the Fisheries of the Columbia River, Craig and Hacker (1940) consider green and white sturgeon as anadromous species. No doubt this consideration is based on Jordan and Evermann (1904) who state that "it is doubtless true that the white sturgeon, like most other sturgeons, is anadromous in its habits, living ordinarily either in salt water or in the river-mouths except at spawning time, when it ascends the larger rivers for considerable distances, but it is also true that some individuals remain in fresh water throughout the year. They have been taken in Snake River in Idaho at least from March to October inclusive". Evidence indicating that the white sturgeon is not an anadromous form in that it does not ordinarily go to sea is that it has never been taken in any quantity in the commercial fish traps at the mouth of the Columbia River. Furthermore they are very rarely taken any distance at sea. (Bajkov, 1949.)

The white sturgeon, being a fresh-water fish, does not migrate like salmon to the sea, but nevertheless its movements up and down the river during certain seasons are quite considerable and therefore must not be neglected. Furthermore, the sturgeon is a bottom fish, more sluggish than the salmon, and its ability to jump over waterfalls and other barriers is limited. Its long range movements, therefore, must be greatly influenced by artificial barriers such as high dams, which even for fast-swimming salmon often represent an impassable obstacle. On the other hand we know that the sturgeon is widely distributed all over the Columbia River from the estuary to the headwaters and that a considerable population of sturgeon, including possibly a portion of the breeding stock, still exists in the Snake River, an upper tributary to the Columbia.

The questions arise: Do or can the white sturgeon freely migrate during any period of their life from the Snake River to the mouth of the Columbia and vice versa? Where are the principal spawning grounds of sturgeon located and do the breeding fish remain in that vicinity all year round? Is there only one, well-mixed population of sturgeon all over the Columbia River, or are there several independent populations, geographically isolated with their own spawning and feeding grounds? What is the present size of the sturgeon population in the Columbia River? We must know the answer to each of these questions before the management and conservation of the sturgeon in the Columbia River System can be accomplished.

In order to obtain reliable information regarding the migration and at the same time to check the rates of growth of white sturgeon, an extensive tagging project was undertaken by the Oregon Fish Commission. Some fish were tagged in 1947 and 1948, but the major tagging started in November, 1949 and has been continued until the present time. The total number of sturgeon tagged is approximately 4,000, and it is proposed to tag several thousand more during the coming months and in many different localities. The bulk of the sturgeon were tagged during the autumn of 1949 and during the entire year of 1950 (Table 1).

TABLE 1.
STURGEON TAGGED IN THE COLUMBIA RIVER FROM 1947 THROUGH 1950

Time of Tagging	*Location*	*Number Tagged*	*Number Recovered to the End of 1950*
Summer, 1947	Various places in the Columbia River	147	12
Summer, 1948	Various places in the Columbia River	159	1
Summer, 1949	Cook, Washington, and other places	151	18
November, 1949	Near the mouth of Sandy River	622	108
March, 1950	Beacon Rock, Washington	145	11
April, 1950	Beacon Rock, Washington	221	21
May, 1950	Beacon Rock, Washington	491	39
June, 1950	Beacon Rock, Washington	231	8
July, 1950	Beacon Rock, Washington	216	5
August, 1950	Beacon Rock, Washington	2	0
	Bonneville Dam	68	1
	Willamette Series	261	5
September, 1950	Bonneville Dam	411	0
	Beacon Rock	5	0
	Willamette Series	156	0
	Clatskanie, Oregon	2	0
October, 1950	Beacon Rock	110	0
	Bonneville Dam	380	4
November, 1950	Mayger, Oregon	14	1
December, 1950	Prescott, Oregon	86	7
Also in 1950	Various places in the Columbia River	79	0
	Snake River	2	0
	Total	3,959	241

Some tagging was done under the joint Columbia River program of the Washington Department of Fisheries and the Oregon Fish Commission and by Mr. Ivan Donaldson, a biologist for the U. S. Corps of Engineers at Bonneville Dam, cooperating with the above-mentioned state agencies.

A considerable number of tagged fish were recaptured all along the Columbia River from Bonneville Dam to Astoria by commercial fishermen and sportsmen. Many tags as well as good information regarding the recaptures were returned to this office where the data have been analyzed and recorded. A number of recovered fish were also released for a second time, and full information about their recapture was obtained. All these recaptures gave definite and invaluable data about the sturgeon migrations. It is hoped that much more shall be learned about the migration of the Columbia River sturgeon in the near future as more recoveries are made.

Thousands of undersized sturgeon are caught and released annually by the commercial fishermen and sportsmen. These immature fish often constitute a real nuisance to the gillnetters whose major consideration is the salmon fishery. It is quite possible that an individual young sturgeon may be taken several times before it is large enough to be kept by commercial fishermen. Even the sportsmen may repeatedly recapture the same fish. There are at least two instances when the same tagged sturgeon has been recaptured four times by sportsmen within a period of a few months.

Technique

The fish for tagging were obtained by all reasonable means. A number of commercial and sport fishermen have cooperated in the tagging program, supplying undersized fish at no expense to the Fish Commission. The main bulk of sturgeon, however, were obtained by set lines operated by biologists at the Lee Motley camp near Beacon Rock, approximately four and one-half miles below Bonneville Dam on the Washington side of the river. In addition several hundred sturgeon were removed from the Bonneville Dam fish elevator and tagged.

The tags used for sturgeon (Fig. 1) were of the conventional Peterson type, consisting of two circular colored plastic discs, $5/8$ inch in diameter, one numbered and the other blank, attached by means of a rust-proof nickel pin inserted through the skin of the fish. After the pin with tag is inserted and the blank put on, the sharp end is cut to the proper length and bent into a loop with a pair of pliers. In addition to the Peterson tags a limited number of streamer-type tags consisting of a small stainless steel tab attached to the fish by means of nylon line was also used. It has been

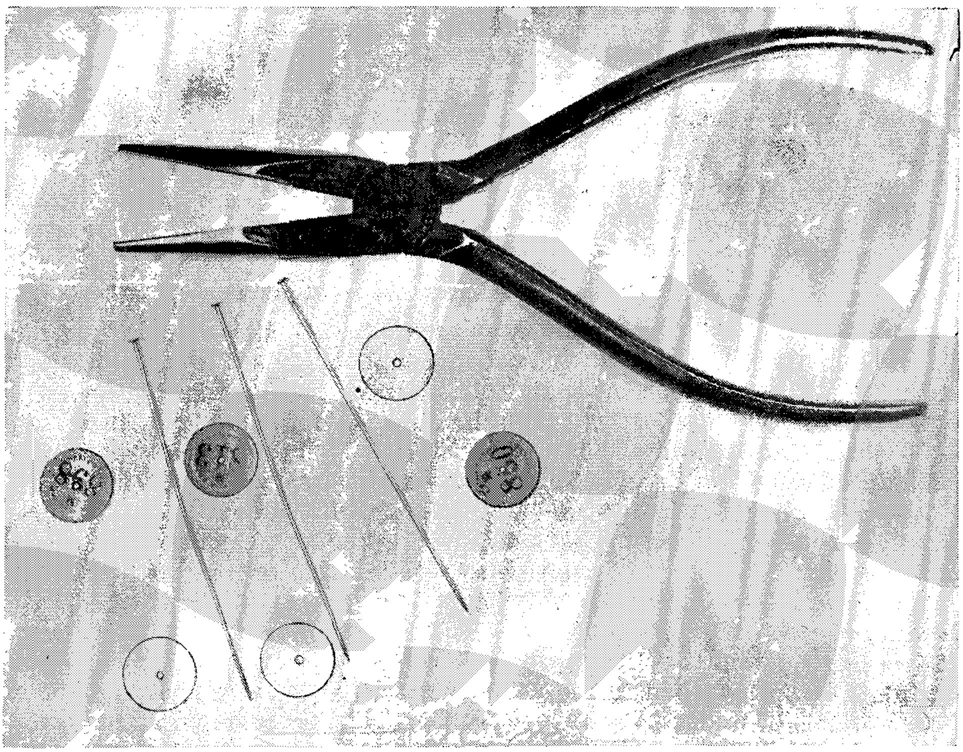

Figure 1. TAGGING EQUIPMENT USED FOR STURGEON TAGGING ON COLUMBIA RIVER. (Note celluloid discs, nickel pins, and pliers used for handling pins.)

found experimentally that if the tagging is done carefully it does not harm the fish. Before the heavy tagging in the Columbia River was begun the tags were placed on several dozen sturgeon at the Bonneville hatchery pond where they have been found generally satisfactory for a period of more than three years.

At first the tags were attached just below the dorsal fin, until it was discovered that some of them became covered by the skin as the fish grew larger. Therefore, in the spring of 1950, the method of tagging was modified and the tags were attached at the base of the upper lobe of the caudal fin (Fig. 2). Information available at present indicates that the tags hold better in the hard cartilaginous tissue of the caudal fin and are not so easily covered by the skin. Care had to be taken, of course, to avoid injuring the posterior end of the notochord which in small fish is only from one-third inch to one-half inch below the inserted pin. It must be always remembered that the sturgeon is a long-lived species, which does not die after spawning like the Pacific salmon. Therefore, the sturgeon tagging must be done with extreme care, avoiding as much as possible the direct contact of the pin with the muscle of the fish. The discs must not be too loose and the pin should be bent in such a manner that it is not readily tangled in the gill nets. It must be mentioned, however, that in spite of all precaution the tags are sometimes caught in gill nets and the fish after some struggle become free and swim away leaving only the entangled tags in the nets. In these cases, the tags were usually returned by the fishermen stating the date and locality, and the record was kept as a "recapture". In other words, the tagged fish after completing the mission was still alive in the river.

All tagged fish have been measured by means of a measuring board from the tip of the snout to the fork of the tail. The length was taken to the nearest one-fourth inch, and the weight to the nearest one-eighth of a pound. Usually during the tagging, a sample of the first ray of the pectoral fin, either from the right or left side, was removed by means of sharp clippers and preserved for the study of age and growth. Examination of the recaptured specimens reveals that they can withstand such removal of the fin ray without any apparent damage and that the fins do regenerate.

Release and Recovery of Tagged Sturgeon

The first extensive tagging of Columbia River sturgeon started on November 1, 1949. This tagging venture involved small immature specimens from 16 to 33 inches which had been caught in two commercial fish traps belonging to the Broughton brothers located a short distance below the mouth of the Sandy River, i.e. one-half mile below the mouth of the Sandy and on Government Island.

The tagging was performed every second day until November 26. Despite the fact that the fish run was nearly over and the weather was bad, 622 sturgeon under commercial size were tagged and released (Table 1).

The second extensive tagging was undertaken between March and October, 1950, near Beacon Rock on the Washington side of the Columbia River approximately four and one-half miles below Bonneville Dam. About 2,000 fish were tagged, the bulk of which was obtained by set lines. In general, fish caught at Beacon Rock were larger than those taken in the

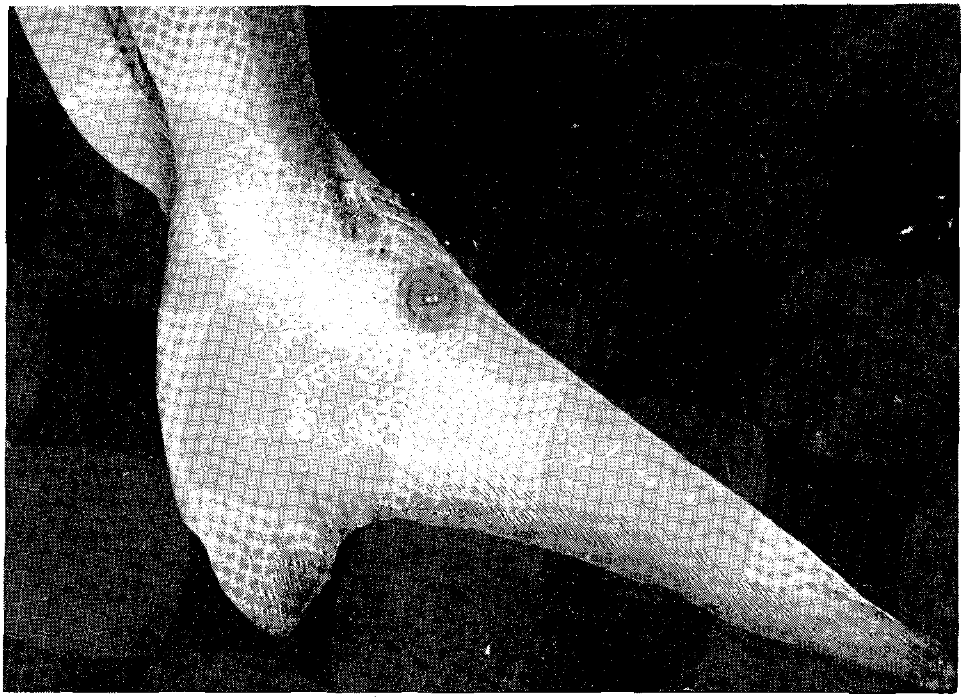

Figure 2. PHOTOGRAPH OF CAUDAL FIN (TAIL) OF STURGEON SHOWING THE PETERSON TYPE TAG IN PLACE.

commercial traps, and among them were some individuals weighing 100 pounds.

Three hundred eighty immature sturgeon, ranging from 16 to 44 inches, were tagged during October, 1950, in the Bonneville Dam elevator and released in the forebay just above the dam. At that time they occurred in abundance at the foot of the dam.

Another lot of small sturgeon totaling 417 in number, was obtained in August and September, 1950, from the same elevator at the foot of Bonneville Dam and was tagged for the Game Commission of Oregon before transplanting into the upper Willamette River. In addition 65 untagged sturgeon were transplanted into the Willamette River at the same time.

In addition to these, several hundred sturgeon were tagged at various points above and below Bonneville Dam. Most of these were tagged in the lower Columbia River, between Mayger and Prescott, Oregon, during the late fall and winter of 1950-1951. The two last localities are situated approximately half way between Bonneville Dam and Astoria and have a rather strategic importance for the observation of up and downstream migrations of sturgeon during various seasons.

Excluding the Bonneville elevator (see later) and Willamette series, the total number of tagged fish recovered up to the end of December, 1950, was 231, which constitutes about nine percent of all tagged fish released.

Analysis of Tagged Sturgeon Recaptures

The analysis of the returns from the tagging is somewhat complicated and difficult. Because of the probable cyclic nature of the migrations it might be entirely wrong to conclude, for example, that a sturgeon recaptured two miles above the tagging place and twelve months after tagging moved only two miles upstream during that time. The fish in question might have gone a hundred or more miles downstream into brackish water and returned to the same place in the course of its regular seasonal migration. Another confusing factor in the analysis is the unequal fishing pressure in different localities which could give misleading data as far as the recaptures are concerned. For example, if from a point of tagging 10 per cent of the fish moved upstream into a heavily fished area and 90 percent moved downstream into a lightly fished area the recaptures could indicate wrongly an upstream migration. Every effort has been made to take these factors into consideration. Finally, the selectivity of the fishing gear itself cannot be neglected. Naturally, the traps and possibly even drift nets adapted especially for catching salmon migrating upstream would be less effective in catching downstream migrants.

As previously mentioned, 622 sturgeon were tagged at two traps in the vicinity of the mouth of the Sandy River in November, 1949. The two traps were approximately two and a half miles apart. The number of fish tagged from each trap was approximately equal. No fish tagged from the upper trap were recaptured in the lower trap, while 18 (about six percent) of those tagged from the lower trap were recaptured in the upper trap. (These had traveled at the rate of from one to two miles per day.) When such movement coincides with a concentration of fish in great numbers below Bonneville Dam, where the fish do not occur in abundance at other times, it seems likely that an upstream migration is taking place.

If there is an upstream migration of sturgeon, the upper location of two traps would be expected to catch fish tagged in the lower trap; on the other hand, if the sturgeon are migrating downstream, it would be practically impossible to capture the tagged individuals at either trap. Indeed, if the fish were scattering all over the area there would be a good chance of catching some of the upper trap individuals also in the lower trap. There were, of course, a few specimens recaptured within a few days at the same trap in which they were initially caught and tagged. Further evidence of an upstream migration at this time of the year lies in the capture of large numbers of untagged sturgeon in trap gear which was constructed for catching salmon going upstream and not adapted for catching downstream migrants.

Ivan Donaldson, biologist at Bonneville Dam, has operated the fish locks, which are the only facilities capable of passing the sturgeon over the dam, during all months of the year and has found that sturgeon attempt to pass the dam in greatest numbers in the autumn.

The sudden appearance of immature sturgeon in greater than usual numbers at the foot of Bonneville Dam from the beginning of September through October and November in 1950 gives added evidence of their upstream fall migration. At the same time a scarcity and in many instances even complete absence of small sturgeon from the drift net catches in the lower part of the Columbia River during the late fall as reported by fishermen suggests that the main bulk of them do undertake the upstream movement. Unfortunately we have no data about the migration of the larger sturgeon at that time of the year, because the few adult individuals caught

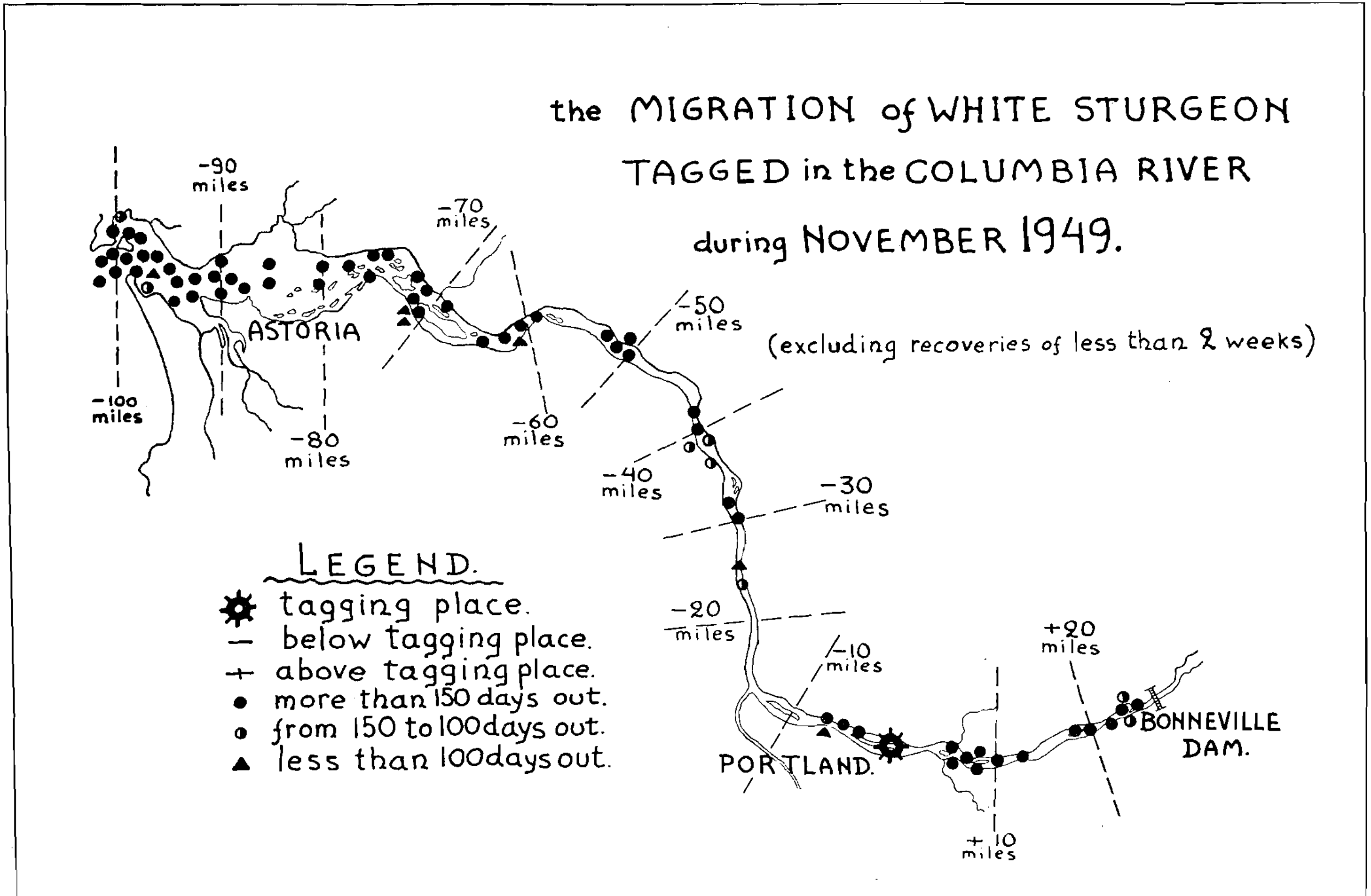

Figure 3. TAGGING AND RECOVERY OF WHITE STURGEON IN THE COLUMBIA RIVER, NOVEMBER, 1949.

in the commercial traps were not tagged. Very likely their migratory habits are more or less similar to those of the immature fish.

Apparently the bulk of the Columbia River sturgeon start a downstream migration shortly after November. Such a statement is based on the number of recaptures of November tagged fish recovered all the way from St. Helens to Astoria during the winter, spring and summer of 1950 (Table 2). Of 622 tagged sturgeon, 108 were recaptured within a year with 94 being taken below and 14 above the point of tagging.

TABLE 2.
THE AVERAGE DISTANCE TRAVELED BY DOWNSTREAM MIGRATING STURGEON TAGGED NEAR THE MOUTH OF THE SANDY RIVER IN NOVEMBER, 1949

(622 sturgeon were tagged; 94 were recaptured below and 14 above the point of tagging.)

Months of Recapture	*Number of Fish*	*Average Distance of Downstream Migration*
November	28	2.6 miles
December through March	10	46 miles
April through July	44	50 miles
August through September	10	71 miles
October	2	69 miles

Figure 3 illustrates very well the downstream movement of the fish tagged near the mouth of Sandy River in November, 1949. The average speed of this migration, based on 50 recoveries, was approximately one-half mile per day. It appears that the fish travel faster at the beginning of the run, for the average speeds for December, January, and February were 4, 0.84, and 0.65 miles per day, respectively. However, some irregularities in sturgeon movements must be mentioned. For example 14 individuals (or about 14 percent of the recoveries) were caught from 6 to 28 miles above the tagging place and between 140 and 268 days after they were released. It is impossible to tell at the present time if these individuals moved directly upstream after being tagged and remained there or if they migrated first downstream, spent the winter near the mouth of the river, and came up again during the following summer. Taking into consideration the above-mentioned periods of time, it seems that the second supposition is more probable. There is one record showing the upstream migration of a 42-inch white sturgeon, tagged in April, 1949 near Astoria, which was recaptured 50 miles upstream in May of the same year.

Fortunately some tagged sturgeon recaptured in the lower portion of the Columbia River between St. Helens and Astoria were released again by the fishermen with the tags intact, their serial numbers, exact time and localities, as well as the length and weight being recorded. The further recapture of the same fish, especially around November, when they were originally tagged, would give invaluable data as far as the study of migration is concerned.

Some of the second recaptures of sturgeon tagged near the Sandy River in November, 1949, are very significant and therefore must be mentioned. One 25-inch sturgeon was caught and again released near Astoria on June 28, 1950. It had migrated 101 miles downstream in 236 days. On July 1, i.e., three days later, it was recaptured and released again approximately one mile farther downstream. Apparently at that time it was still continuing its downstream migration. Another sturgeon, 23 inches in length, was recaptured and released on February 26, 1950, near Goble, Oregon. It had gone 40 miles downstream in 109 days and was still migrating downstream when recovered again on May 15, 1950, ten miles below the place of its first recapture. Still another sturgeon, measuring only 17 inches, was caught on O. K. drift near St. Helens on February 16, 1950. It had traveled 25.2 miles in 83 days. Its second recapture was made in brackish water at Tongue Point, near Astoria, approximately 95 miles below the tagging place, on July 1, 1950, 218 days after tagging.

It is very interesting that on one occasion two small sturgeon which were tagged at the same time at the trap near Sandy River were recaptured together on May 12, 1950, in a net above Tongue Point. They had migrated approximately 95 miles downstream in 191 days.

The largest percentage of recoveries from the lot tagged in November, 1949 was made near the mouth of the Columbia River. Some of these recoveries very likely were made in brackish water. It is well known that all species of sturgeon can survive in both fresh and salt water, regardless of whether they are anadromous or purely fresh-water species. Besides that, many anadromous species of fish and sturgeons are not exceptions to this rule, (*Acipenser guldenstadtii* in Europe, *A. baeri* in Asia, etc.) have fresh-water forms which never enter the sea and which are at present indistinguishable from the sea-run forms (Berg, 1932).

There have been authentic records of occasional catches of American lake sturgeon (*Acipenser fulvescens*) in brackish water of Hudson Bay as well as the Eurasian fresh-water *Acipenser ruthenus* in Caspian and Polar Seas. It has been proven by several recaptures of the tagged anadromous Caspian Sea sturgeon (*Acipenser stellatus*) that it travels from one river to another often separated by several hundred miles of sea (Berg, 1932).

As already stated, for a number of years the general opinion has been that the white sturgeon is an anadromous fish to the extent that it migrates to and from the ocean. Evidently this is not true because many large sturgeon stay in the upper Columbia and Snake Rivers during their entire life and never go to sea. As a matter of fact at the present time they cannot pass Bonneville Dam except for the few passing upstream by means of the fish locks.

It is very common to find white sturgeon in brackish water, and in this connection we must mention a very interesting and rather unusual recapture of one of the tagged sturgeon. A five-pound white sturgeon with tag No. R-3847 was released from a commercial fish trap in the Columbia River, approximately 110 miles above Astoria, and was recaptured in the Naselle River in the state of Washington. The recovery was reported by Mr. Anthony G. Lewis of South Bend, Washington. That particular fish migrated first to the ocean, then apparently turned north and entered Willapa Bay and the Naselle River, traveling at least 200 miles in 343 days. As far as is known, this is a record for white sturgeon migration and also the first recapture of a Columbia River sturgeon in another river system. The specimen gained one and one-half pounds in weight from November 1, 1949, to October 9, 1950. Figure 4 shows the direction and extent of this unusual migration.

From the lot tagged at Beacon Rock during the spring and summer of 1950, there were 84 recaptures (including five second recaptures). Recov-

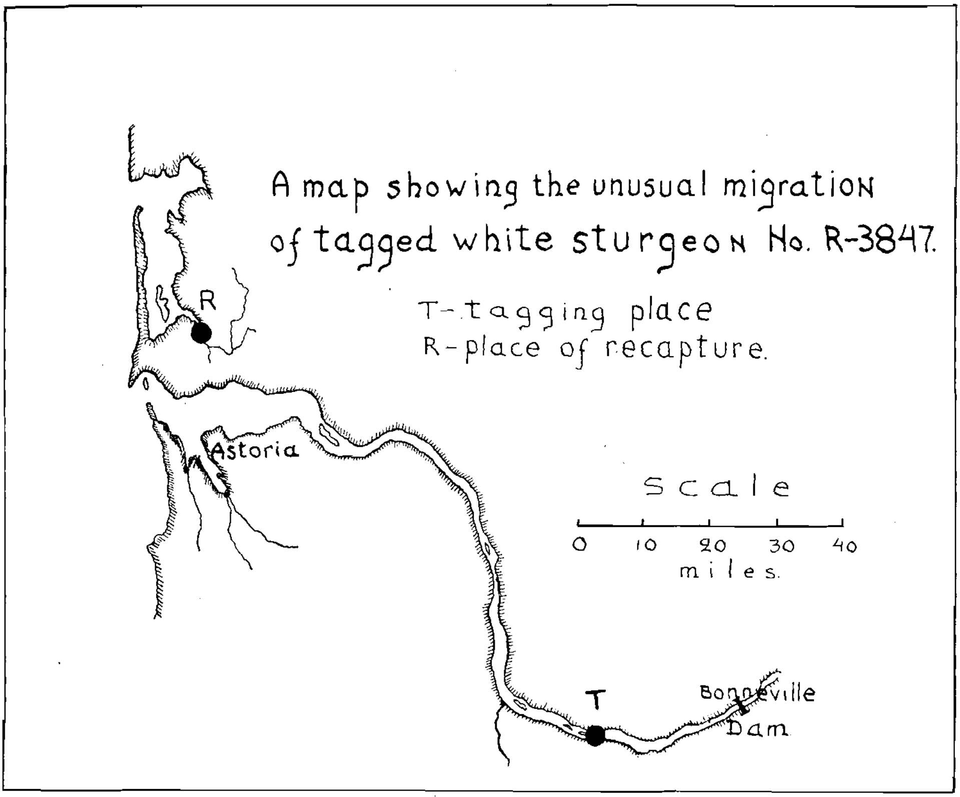

Figure 4. THE MIGRATION OF A WHITE STURGEON FROM THE COLUMBIA RIVER TO WILLAPA BAY.

eries indicate that out of these fish, nine moved upstream toward Bonneville Dam which is about five miles from Beacon Rock with none recaptured above the dam. The size of these fish was from 22¼ to 45¼ inches, and most of them reached the vicinity of Bonneville Dam late in summer or early fall.

Twenty-two recoveries from the same lot were made from 7 to 120 miles below Beacon Rock; the size of these specimens was between 16¾ and 44 inches and the time of migration from 28 to 254 days. The average speed of these downstream migrants was approximately 0.65 miles per day, which agrees very well with that of downstream migrants tagged near the mouth of the Sandy River. Among this group there was one of the most interesting second recaptures. Namely, a 16¾-inch sturgeon tagged on April 17, was recaptured again at Beacon Rock on May 21. It did not move from the tagging locality for 35 days. It was released again and after another 10 days was caught for the third time 60 miles downstream. The rest of the recaptured Beacon Rock sturgeon, 53 in number, ranging between 15 and 54 inches and including several of the largest recaptured specimens showed no migration at all during the summer months. The longest time which those fish apparently remained in the same locality was 97 days. It is interesting to note that most of these "non-migrants" were recovered during the months of May and June, and that none of them were seen after July 27.

It was noticed that in June and July much larger sturgeon were taken by the set lines and by the sportsmen at Beacon Rock. It appeared that small sturgeon were possibly absent from the area. They again became more plentiful in the vicinity of Beacon Rock and Bonneville Dam from the middle of August through October and November. There is, therefore, a strong possibility that a general upstream migration of sturgeon was underway in the late summer and fall. Simultaneously the absence of stugeon had been noticed immediately above Bonneville Dam, when an experimental set line of 60 hooks failed to catch a single sturgeon during 12 consecutive days. This unusual experience strongly indicates the possibility that the entire sturgeon population moved upstream from the Bonneville lake forebay area into the upper part of the river. This theory seems to be logical because the absence of fish immediately above the dam coincided with the tremendous concentration of small sturgeon just below the dam. At that time as many as 117 small sturgeon were taken in a single lift of the Bonneville Dam elevator. Taking into consideration that the size of the elevator is only 20x20 feet and that it probably takes only a small portion of sturgeon present, one must conclude that at that time a great many immature sturgeon were congregated at the foot of the dam. It seems, therefore, that Bonneville Dam represents a nearly impassable barrier to sturgeon. Only a negligible number of individuals have been observed migrating through the fish ladder from time to time.

Figure 5 and Table 3 summarize the recoveries of white sturgeon tagged at Beacon Rock in 1950.

TABLE 3.

SUMMARY OF DATA RELATIVE TO EXPERIMENTAL TAGGING OF THE COLUMBIA RIVER STURGEON AT BEACON ROCK, WASHINGTON, DURING THE SPRING AND SUMMER OF 1950

	Downstream Migrants	*Non-migrants*	*Upstream Migrants*
Average number of days out	92.3	33.0	75.0
Average distance in miles	64.0	0.0	3.5
Number of fish	21	55	9
(percentage)	(24.7%)	(64.7%)	(10.6%)

Of 859 sturgeon tagged at Bonneville Dam and released above the dam, from August through October 1950, there have been practically no recoveries as yet, except four specimens caught near the tagging place shortly afterwards. The absence of recoveries from that portion of the river can be explained by the fact that there was no commercial fishing in the months since that time and that the sport fishing pressure was light. It is expected that some recoveries of these tagged fish will be made during the next season. However, one very significant recovery, the first recapture of sturgeon released at Bonneville above the dam, has been reported by a sportsman. The fish in question was 39 inches in length and had been tagged at Bonneville elevator on October 12, 1950. It was recaptured 76 days later near the mouth of Hood River, approximately 18 miles above Bonneville Dam. Another sturgeon tagged at the same place was recovered 140 days after tagging 17 miles above the dam. Possibly the fish exhibited some sort of fall upstream migration, similar to that indicated below Bonneville Dam. When the present paper was submitted to press it was reported by the com-

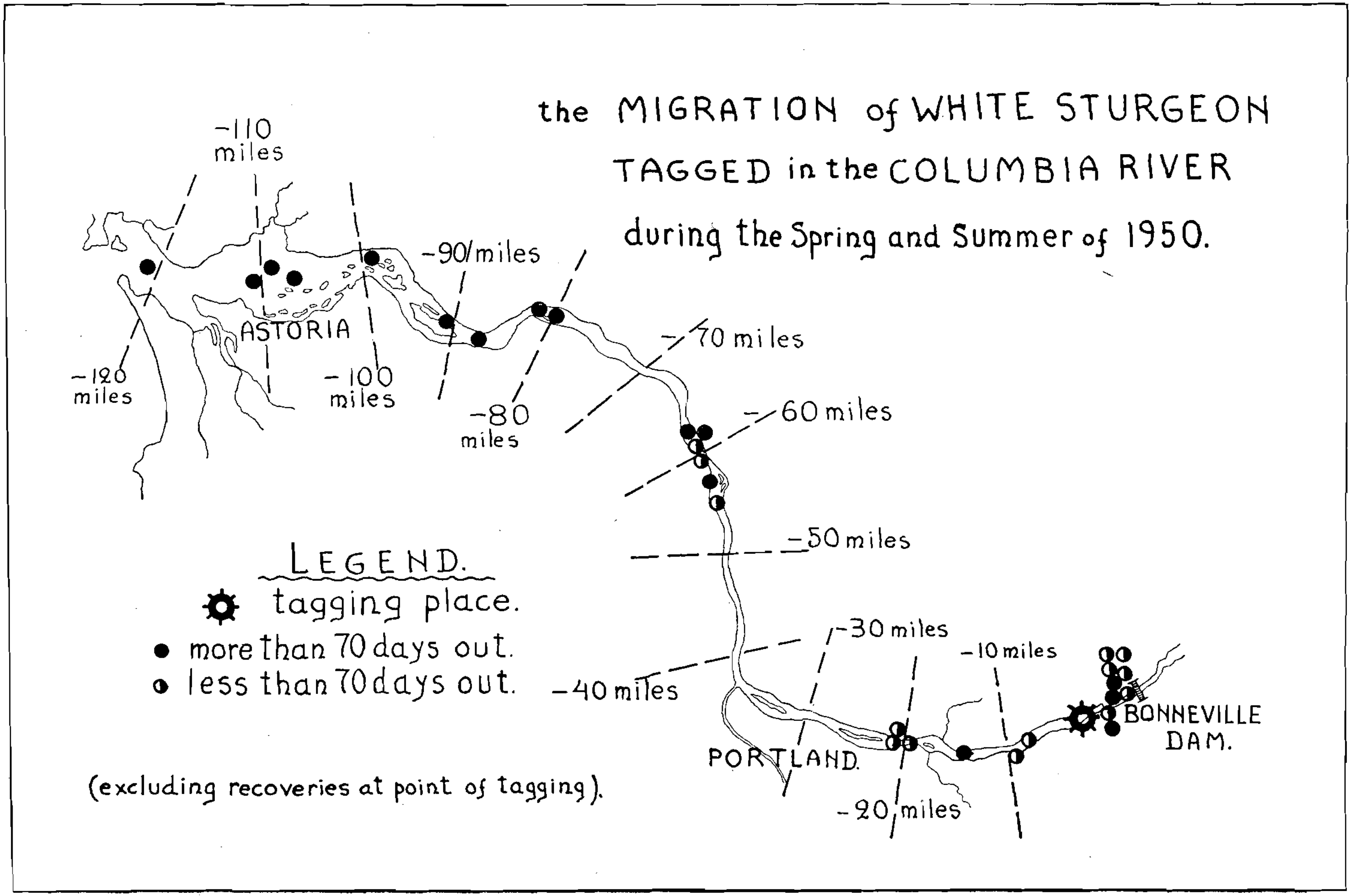

Figure. 5. THE RECOVERY OF BEACON ROCK TAGGED WHITE STURGEON IN THE COLUMBIA RIVER, 1950.

mercial fishermen that a number of tagged sturgeon were recovered at Cook, Washington, about 20 miles above Bonneville Dam in November, 1950.

The latest tagging, which is still in process during the writing of this report, started in December, 1950 at Prescott and Mayger, Oregon, approximately halfway between Astoria and Portland. These sturgeon were tagged at the deep pool near Prescott, where they seem to be congregating in winter.

Summary and Conclusions

Summing all available data regarding the movement of white sturgeon in the lower portion of the Columbia River between Bonneville Dam and Astoria, the recoveries of tagged sturgeon seem to indicate that:

1. Small immature sturgeon as well as medium sized individuals appear to migrate upstream during the fall of the year and in the beginning of winter. Then they change the course of migration and begin to move downstream during the second part of winter and spring.

That these movements are feeding migrations appears highly possible. Smelt are abundant in the lower river in late winter and early spring after which the salmon and lamprey enter and ascend to their spawning grounds. Since the sturgeon feed on all of these forms their downstream migration may be to feed on smelt and their upstream migration to feed on salmon and lamprey carcasses.

2. The range of the sturgeon downstream migration can extend well into the brackish water at the mouth of the Columbia River, and occasional specimens may travel even farther into the ocean and enter the neighboring rivers.

3. No tagged sturgeon released below Bonneville Dam have been recaptured above the dam as yet, or vice versa. Therefore, as far as can be judged now, Bonneville Dam seems to represent an impassable (or nearly impassable) barrier which separates two populations of the Columbia River sturgeon and prevents them from intermixing.

4. The up and downstream migrations of sturgeon, though having a definite seasonal character, are not as sharply marked as for example salmon migrations. That is to say that they are more variable both in time and in the number of individuals. In other words some individuals start their migration much earlier than others and travel much longer distances. Probably there are even some cases, when due to the abundance of food or other favorable conditions, certain individuals remain most of the time in one locality or make only very limited seasonal migrations. For instance there is no significant migration of sturgeon during the summer months in the vicinity of Beacon Rock.

5. The average speed of migrating sturgeon, usually being approximately only half a mile per day, is about 16 times slower than in the fall chinook salmon. An exception to this was a 16½-inch sturgeon that was tagged in the beginning of November and traveled 72 miles in 14 days for an average speed of five miles per day. It is not clear yet how much the movements of sturgeon are influenced by the raising of water level, speed of current, turbidity, temperature of water, and by tagging itself.

6. Besides the above-mentioned movements of sturgeon along the river course, there are other movements which are also well pronounced and should be considered as regular migrations. Namely, these are vertical

migrations from deeper to shallower water at certain times of the year. Sturgeon usually congregate in deep holes during the cold winter months and come into more shallow water at the approaching of the biological spring.

7. The present study represents the results of only slightly more than one year's work and naturally cannot be regarded as complete. The sturgeon is a long-lived and slowly maturing species which requires a much longer period of investigation. Many more details are yet to be learned about the spawning migrations of adult fish, the possible migration of fingerlings, as well as about the migratory habits of sturgeon in the upper parts of the Columbia and Snake Rivers. The extensive tagging program is being continued, and it is planned to tag greater numbers of all sizes of sturgeon through more extensive areas in the near future in order to learn more about the migratory habits and the rate of growth of that fish. Such a study is of paramount importance from the viewpoint of maintaining and rebuilding the sturgeon fishery in the Columbia River where this fish is again gaining great popularity among the commercial fishermen and the sportsmen alike.

Acknowledgments

The author wishes to express his sincere thanks to all persons who returned the recovered tags and information. Their names are too numerous to be mentioned in this brief paper. Mr. Lee Motley, the owner of a sport moorage at Beacon Rock, Washington, amateur naturalist and experienced sturgeon fisherman, has contributed a considerable share to the study. Mr. Clarence E. Graham, also the owner of a sport fishing moorage at Prescott, Oregon, and Mr. W. Talus, the manager of the Union Fishermen's Cooperative Packing Company at Mayger, Oregon, did the same in a strategic midway point between Bonneville Dam and the mouth of the Columbia River.

Mr. Ivan Donaldson, fishery biologist, U. S. Army Engineers at Bonneville Dam, gave invaluable assistance in obtaining several hundred immature sturgeon for tagging and liberating above the dam.

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SPRING CHINOOK SALMON DIET EXPERIMENTS AT THE BONNEVILLE HATCHERY

Objectives

The objectives of this feeding experiment were: (1) to compare under Tanner Creek and Columbia River water conditions standard diets for spring chinook salmon as currently used by two agencies; (2) to start preliminary work in selecting a suitable, economical food for young salmon; and (3) to investigate the adequacy of various diets during the cold water periods of the winter. The experimental feeding period ran from September 15, 1949, to March 15, 1950, a total of 180 days.

Selection of Fish

The fish used were spring chinook salmon of the 1948 brood year. On August 1, 1949, 15,000 fish averaging 150 to the pound were transferred from the Oakridge, Middle-Willamette salmon hatchery to the Bonneville Hatchery located at Bonneville Dam on the Columbia River. These fish were fed twice daily on a diet of 100 percent fluky beef liver until September 15, when the experimental feeding program started.

The feeding troughs, six in number, were located in the hatchery building. They were wooden troughs standardized to a length of 11 feet ½ inch by 18 inches wide with a water depth of 11½ inches. The inlet of each trough was regulated so as to give 15 gallons per minute inflow of water. The water used was almost entirely from Tanner Creek, but some Columbia River water was used when needed.

A sample of the fish was weighed and counted to calculate the average weight of the individual fish. A net haul was then made through the pond. The fish which were captured were placed in a tub of water and carried to the hatchery, and six buckets of water were placed in a circle around the tub of fish. With a dip net, the fish were transferred one at a time to each bucket in rotation. One man dipped the fish while the other counted with a hand talley. At intervals, each of the six buckets were randomly placed in one of the six troughs. Each trough was stocked with 3,500 grams of these fish.

The remaining fish after the experimental lots had been removed were held in the concrete pond for replacements. The daily mortality in the troughs was replaced with fish from the pond until the feeding experiment began. After this time no replacements were made. The fish were held in the troughs for 14 days prior to experimental feeding in order that they might become accustomed to the trough and trough feeding. After allowing the fish to become acclimated to the trough space, the experimental feeding program started on September 15, 1949.

Diet Composition and Feeding Procedure

Listed in Table 1 are the various diets used in the experiment.

All lots were fed twice daily except during January. The first feeding was in the morning as soon as the troughs could be cleaned and the food prepared. The second feeding took place in the mid-afternoon. For the month of January the fish were fed three times daily. In this manner it was hoped that better consumption and utilization of food would be obtained

TABLE 1.
COMPARISON OF THE EXPERIMENTAL DIETS

Lot Number	*Composition*	*Percentage Composition*
1.	Fluky beef liver control	100.0
2.	Fluky beef liver	96.0
	① Supplemental salts	4.0
② 3.	Fluky beef liver	14.7
	Salmon viscera	81.3
	Brewers yeast	2.0
	Salt (NaCl)	2.0
③ 4.	Fluky beef liver	22.06
	Hog liver	22.06
	Hog spleen	22.06
	Salmon viscera	31.86
	Salt (NaCl)	1.96
④ 5.	Meals	60.0
	Fluky beef liver (blower diet)	40.0
⑤ 6.	Dextrin	18.0
	Casein (vitamin free)	52.0
	Crab meal	8.0
	① Supplemental salts	6.0
	Calcium carbonate	1.0
	Corn oil containing Vitamins A, D and E	15.0
	Water soluble vitamins	
	(1 part gelatin added to 10 parts of above mixture)	

① The composition of the supplemental salts used in diets No. 2 and 6 was as follows:

$NaCl$	335 grams	KI	1.6 grams
$K_2HPO_4 \cdot 3H_2O$	845 grams	$MnSO_4 \cdot 4H_2O$	0.7 grams
$Ca_2H_2(PO_4)_2 \cdot 4H_2O$	190 grams	$ZnCl_2$	0.5 grams
$MgSO_4 \cdot 7H_2O$	204 grams	$CuSO_4 \cdot 5H_2O$	0.6 grams
$CaCO_3$	600 grams	NaF @ 0.2% of complete ration total (wet weight) or	4.46 grams
$Fe(C_6H_5O_7)_2 \cdot 6H_2O$	55 grams		

② This is one of the experimental diets used by the Washington State Department of Fisheries.
③ This is one of the production diets used by the U. S. Fish and Wildlife Service at their Leavenworth, Washington, station.
④ This is one of the experimental diets used by Dr. L. R. Donaldson at the University of Washington School of Fisheries. The composition of the meals used in diet No. 5 was:

Tomato pulp	10%	Commercial flame dried fish meal	30%
Alfalfa meal	10%	Air dried salmon meal	10%
Wheat germ	5%	Crab meal	10%
Brewers yeast	10%	Kelp meal	5%
Salmon egg meal	10%		

⑤ Wisconsin purified diet (McLaren, et al. 1946, 1947).

while feeding through the abnormally cold water conditions. On three separate days muddy water forced suspension of feeding operations.

All food fed with the exception of the dry diet (No. 5) was fed through a hand ricer. The dry diet was sprinkled across the surface of the trough at the upper end. Three minutes were spent at each trough placing the food slowly therein. All diets were prepared daily, and fed the same day as prepared. The food was taken in a frozen to semi-frozen condition from the freezer storage at the hatchery and while still frozen was ground through the 3/16-inch plate and then through the ⅛-inch plate of an Enterprise No. 10 hand-operated food chopper. The ground ingredients were mixed together as necessary and then bound by the addition of salt. The diets were returned to the hatchery cooler after the morning feeding, and were taken out for the afternoon feeding. The temperature of the cooler room was 32° F. The mixing of the foods and the binding with salt made all of the diets float except diets Nos. 1 and 5.

The lots were weighed every two weeks. At this time the new weight of the food to be fed for the coming two-week period was calculated. The dry weight of the food given daily to the experimental fish was fixed at 1.03 percent of the weight of the group of fish to be fed. On the basis of wet food weight this ration equals about 3.00 percent of the weight of the fish. The dry weight of the diets was computed from the analysis during the experiments of five samples of food by the Astoria Seafoods Laboratory. Consequently, as the experiment proceeded, the amount of food presented to each group of fish varied somewhat, and the faster-growing lots received proportionately more food.

Disease and Prophylaxis Treatments

It was noted in early October that some of the smaller fish in all lots showed heavy fungus infections of the tail area. On October 16 and 20 a two percent salt bath was given all lots with some evidence of success. On October 29 a treatment prophylaxis of pyridylmercuric-acetate 1/500,000 was given. The fish withstood the treatment well.

On October 30 first evidences of a kidney ailment were noted in mortalities in lot No. 4. This disease is characterized by the presence of white lesions along the kidney surface and is more pronounced in the posterior portion of the kidney. The kidney is much enlarged giving the fish a fat appearance; the lesions are full of a yellowish-white semifluid material in which are found countless numbers of rod-shaped gram positive bacteria and disintegrating kidney tissue. It is not known whether the bacteria are the primary or secondary invaders. Treatments for the kidney disease were started on October 31 and were continued until November 20. Sulfamerazine, veterinary grade, was mixed in the food of all lots in the ratio of three grams of sulfa powder to one pound of food. The disease after being found in lot No. 4 was later found in the mortalities of all lots. Subsequent findings show that the sulfa drug was not too effective in the control of the kidney trouble.

Beginning on December 11 and continuing through December 31, sulfamerazine medication was again given. This was at the rate heretofore discussed. Little if any beneficial effect could be noted. On January 1, 1950, sulfaquinoxaline (20 percent in wheat short base) was fed to all lots at the rate of six grams per pound of food fed. This represents about double the quantity of sulfa previously fed per day. However, this material was only 20 percent active ingredient whereas the sulfamerazine was 100 percent active ingredient. The treatment with the sulfaquinoxaline was given for four days. No beneficial results were noted.

Because of a frayed condition of fins and some evidences of a fin-rot condition, on December 22 a 1/20,000 solution of phemerol was used for a 30-second dip as recommended by McLaren et al. (1949) for treatment of fin rot in salmonoid fishes. An undue loss was encountered immediately following this treatment. The mortalities examined had, for the most part, badly swollen and pustuled kidneys. Only lots 2, 3, and 4 were treated. Treatment on lots 1, 5, and 6 was suspended when the results became known. It is believed however that the phemerol dip was not entirely the cause of the mortalities because of the presence of the kidney disease which had debilitated the fish previously.

Efficiency of Diets

In order to determine the conversion factor, i.e. the pounds of food necessary to rear one pound of fish, as well as the cost of the foods involved, Table 2 was set up. The weight increases, the amount of food, the kind of food fed, conversion factor, and the cost per pound to rear the fish were determined where possible.

Figure 1 shows the weight gains of each lot for the 180 day period and water temperatures, while Figure 2 shows the cumulative mortality by two week periods with water temperatures throughout the feeding period.

TABLE 2.
SUMMARY OF A SPRING CHINOOK DIET EXPERIMENT CONDUCTED AT BONNEVILLE HATCHERY, SEPTEMBER 15, 1949 THROUGH MARCH 15, 1950

Lot Number	*Weight Increase in Grams*	*Percent Increase*	*Diet*	*Amount Food Fed in Grams*	*Food Price Per Pound*	*Food Cost*	*Cost to Rear One Pound Fish*	*Pounds of Food Per Pound of Fish*
1	325	9.2	Beef liver 100% (Control)	24,185	.15	$7.99	$11.39	74.1
2	1,060	30.2	Beef liver 96%	22,749	.15	7.51		
			Supplemental salts 4%	908	.50	1.00		
						8.51	3.66	21.4
3	249	7.1	Beef liver 14.7%	3,328	.15	1.10		
			Salmon viscera 81.4%	18,435	.02	.81		
			Brewers yeast 2.0%	454	.15	.15		
			Table salt 2.0%	454	.06	.06		
						2.12	3.92	91.0
4	769	21.9	Beef liver 22.06%	5,859	.15	1.93		
			Hog liver 22.06%	5,859	.10	1.29		
			Hog spleen 22.06%	5,859	.10	1.29		
			Salmon viscera 31.86%	8,457	.02	.37		
			Table salt 1.96%	516	.06	.07		
						4.95	2.93	34.5
5	—450	—12.8	Beef liver 40%, Dry meals 60%	9/15 to 11/23/49				
			Beef liver 86%, Supplemental salts 4%, Corn oil 10%	11/23/49 to 3/15/50		Not determined, since diet proved inadequate		
6	—1,592	—45.4	Wisconsin purified diet	6,385		Not determined, since diet proved inadequate		

Gill Color Checks

On October 26 and again on March 15, gill color examinations were made on a sample of 100 fish from each lot. A criterion was set up as follows:

Gill color bright red .... No. 1
Gill color red .... No. 2
Gill color pink .... No. 3
Gill color pale pink to white .... No. 4

One person made the observations while another recorded them. A sample of fish was netted up and each fish examined singly. A blunt probe was used to lift the opercle and expose the gills.

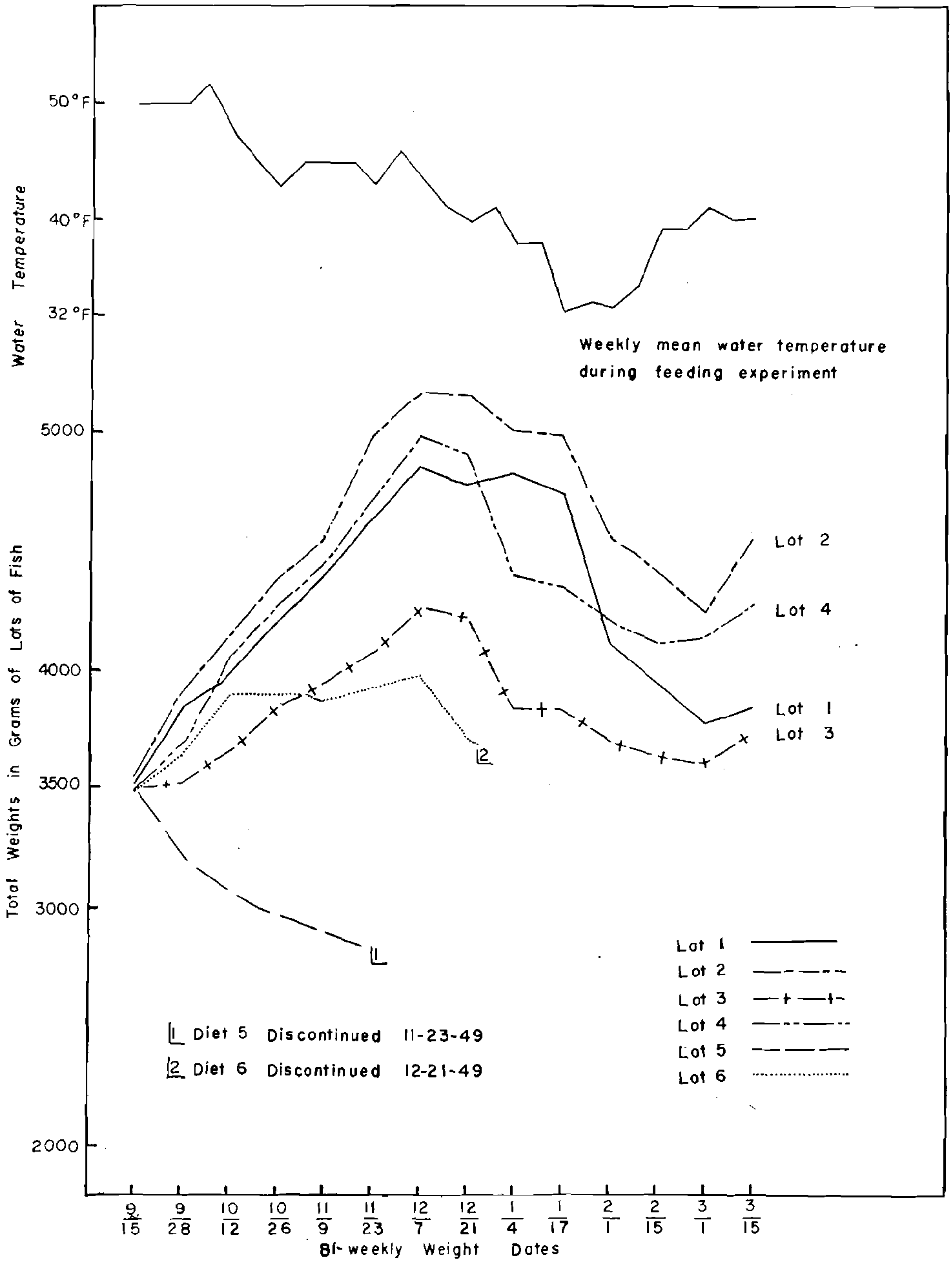

Figure 1. WEIGHT CHART OF LOTS FOR THE TWENTY-EIGHT WEEKS FEEDING PERIOD.

There appeared to be a definite relationship between gill color and mortality. For example, lot No. 6 which showed the highest mortality also showed the greatest number of white-gilled fish, and conversely those lots with the gill color classified as bright red showed the least mortalities. The gill color is one means of checking fish for anemia.

TABLE 3.

GILL COLOR CHECKS

	Gill Color				
Lot Number	*No. 1*	*No. 2*	*No. 3*	*No. 4*	*Total*
October 26, 1949 check:					
1	58	24	11	7	100
2	78	14	4	4	100
3	68	19	8	5	100
4	45	40	10	5	100
5	11	44	31	14	100
6	23	43	21	13	100
March 15, 1950 check:					
1	45	29	13	13	100
2	73	19	5	5	100
3	84	11	3	2	100
4	84	14	0	2	100
5*	49	34	10	7	100
6	18	26	26	30	100

* Lot No. 5 was placed on a diet similar in composition to No. 2 on November 23, 1949.

Discussion

The fish in lot No. 5 lost weight from the first weigh day on until the lot was discontinued on November 23. It was apparent shortly after starting the dry diet in No. 5 that the fish would not eat the food; shortly thereafter the fish became emaciated and the losses rose sharply.

Lot No. 6 started out quite well on the purified diet but soon started losing weight and continued to lose until discontinuance on December 21. In lot No. 6 the fish ate the food quite well during the time they were on the experimental purified diet, but they became dark and emaciated and all showed symptoms of anemia. The gill color was predominantly pale pink to white in color indicating an anemic condition.

A close relationship between the cold water and increased mortality of the lots is shown in Figure 2. The average weight per fish as plotted in Figure 3 is calculated by dividing the weight of the lot by the number of live fish at the biweekly weighings. This figure shows that growth was present but limited during the month of January, when the water temperatures were near the freezing point.

It will be noted in Table 2 that the conversion factor for the pounds of food required to produce one pound of fish was very high. This can be attributed in part to the poor quality of beef liver used. The beef livers were denatured livers purchased in the frozen condition. The livers were in most cases cooked in the dye solution and as a result, the product was inferior. It is also believed that the conversion factor is not indicative in this feeding experiment because the fish were fed the alloted amount of food daily whether the food was eaten or not. When the water temperatures were at or near 32° during the month of January, the fish refused to eat almost entirely and appeared to be in an almost dormant condition.

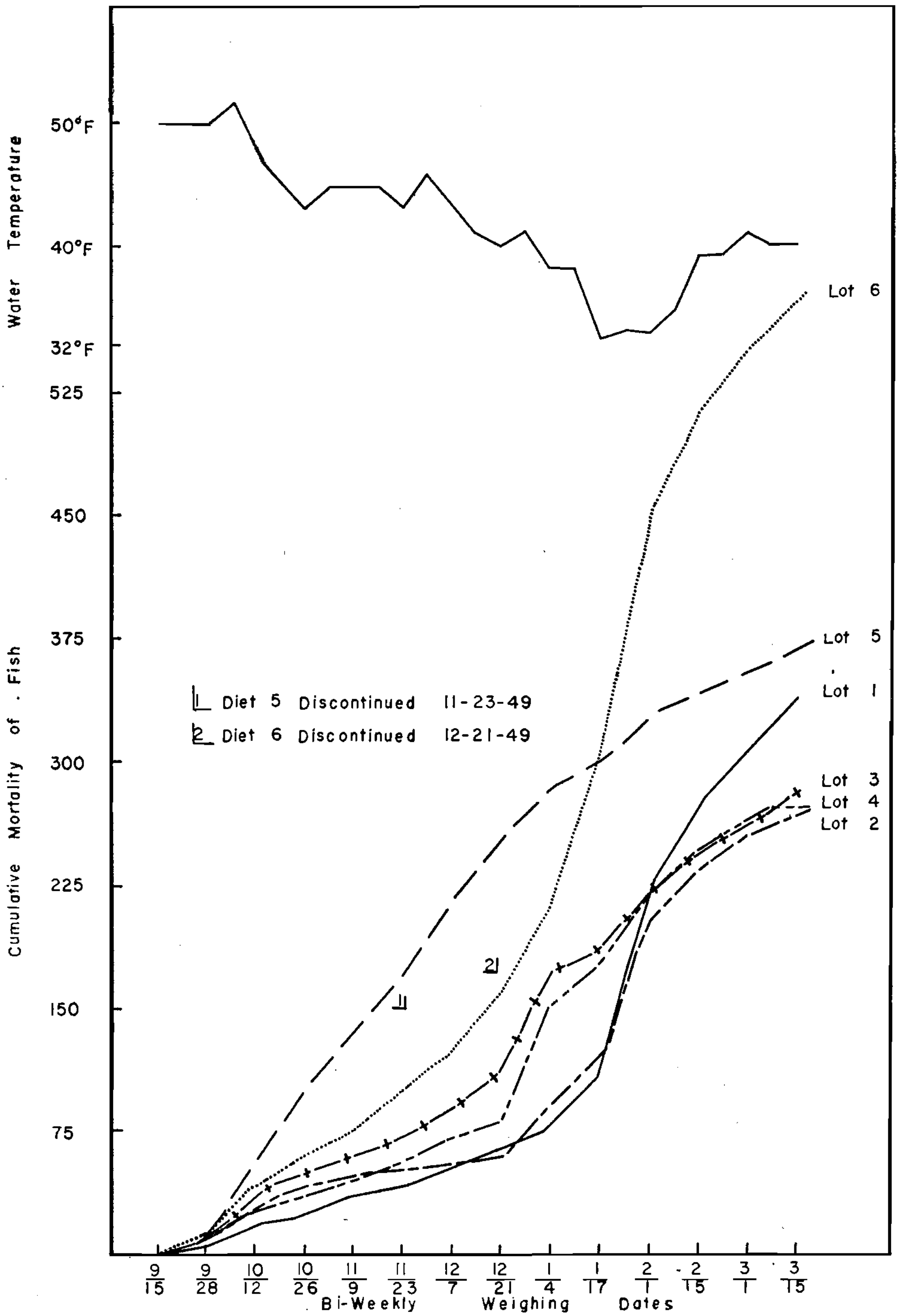

Figure 2. CUMULATIVE MORTALITY CHART OF LOTS FOR THE TWENTY-EIGHT WEEKS FEEDING PERIOD.

An analysis of variance as outlined by Snedecor, 4th Edition, pp. 253–259, was made for (1) weight variation among biweekly periods for lots 1, 2, 3, and 4 combined and (2) between lots 1, 2, 3, and 4 individually and for the experiment as a whole.

The analyses indicated that the differences in growth observed between the various diets were highly significant except for diets 1 and 4. Here, highly significant is used to mean a likelihood of less than one percent of the observed difference arising by chance.

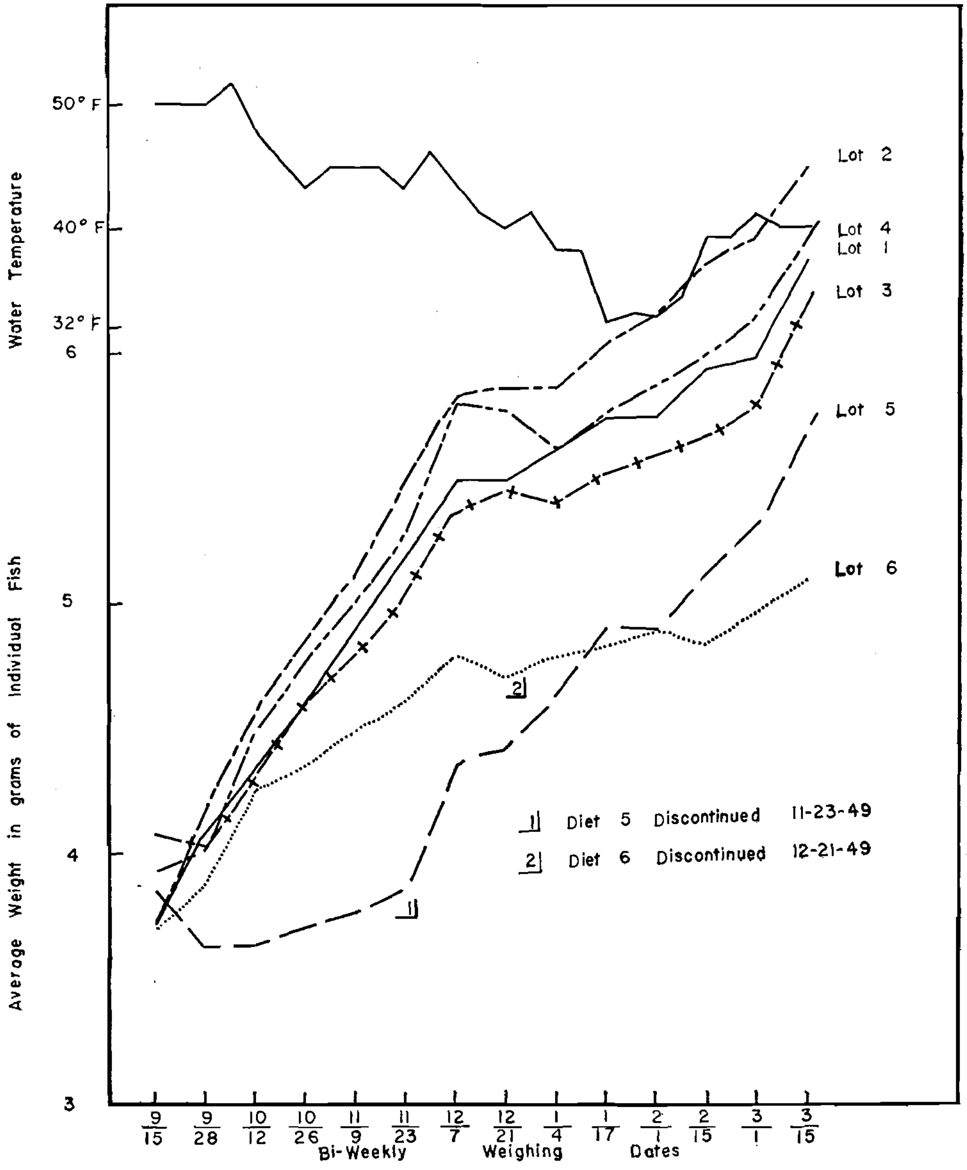

Figure 3. AVERAGE WEIGHTS: INDIVIDUAL FISH: FEEDING EXPERIMENT SEPTEMBER 15, 1949—MARCH 15, 1950.

Diet 2 composed of 96 percent beef liver and 4 percent supplemental salts was found to be the superior diet and better than the other diets. Both diets 1 (composed of 100 percent beef liver) and 4 (composed of 22.06 percent beef liver, 22.06 percent hog liver, 22.06 percent hog spleen, 31.86 percent salmon viscera and 2 percent salt) were found to be better than diet 3 (composed of 14 percent beef liver, 81 percent salmon viscera, 2 percent brewers yeast and 2 percent salt). However, no significant difference was found between diets 1 and 4.

Conclusions

1. Diet No. 2 (beef liver plus four percent biological salts) was found to be the best diet used in this experiment. The biological salts when added to the beef liver binds the liver and as a result less leaching occurs. Chemical analysis of beef livers of the coastal area shows them to be low in minerals. The added salt supplement in diet No. 2 was probably sufficient enough in amount to be utilized by the fish, resulting in superior growth.

2. Diet No. 3 (one of the experimental diets used by the Washington State Dept. of Fisheries) was found to be an inferior diet when fed under the conditions which existed at Bonneville during the feeding program. The fish ate the diet quite well, but resultant growth and heavy mortalities indicated that this diet was not a particularly good one.

3. Diet No. 4, a production diet of the U. S. Fish and Wildlife Service Leavenworth Fisheries Station, was found to be a superior diet when fed under existing conditions at Bonneville.

4. The dry "blower" diet, No. 5, an experimental diet successfully used at the University of Washington School of Fisheries, was found to be inadequate here. The fish refused to eat the food from the first day's feeding and never did become accustomed to the diet. Thus, it is not known whether this diet is nutritionally adequate or not for spring chinook salmon, since the fish for some unaccounted for reason would not ingest the food.

5. The purified diet, No. 6, also proved inadequate in maintenance of growth and vigor of the fish. The fish ate the food quite well but developed characteristics of anemia shortly after the feeding experiment began.

6. It was noted that mortalities increased with a sharp decrease in water temperatures.

Acknowledgments

The vitamin supplements for diet No. 6 were kindly furnished through the courtesy of the Merck Company, Inc., Rahway, New Jersey, and by Hoffman-LaRoche, Inc., Nutley, New Jersey. The Union Fishermen's Cooperative Association and the Columbia River Packers Association of Astoria supplied the salmon viscera for the experiment.

Acknowledgment is also made to Mr. Richard Harrison of the Oregon Fish Commission for his help in the feeding project.

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FOOD OF THE CHINOOK AND SILVER SALMON TAKEN OFF THE OREGON COAST

Introduction

During the last three troll seasons, 1948–1950, enough stomach samples from troll-caught chinook and silver salmon have been collected and analyzed to justify the incorporation of the resulting data in a preliminary report. Unfortunately, the samples taken to date do not represent a complete coverage of all areas of the Oregon Coast throughout the entire troll season. However, there are enough data to give a fairly good picture of the food habits of these two species in certain areas and during certain parts of the season. It was hoped that the stomach sample data, when used in connection with tagging data and with catch per unit of effort data taken from the fishermen's log books, might also help to explain the feeding migration of these two species and their tendency to concentrate in certain localities along the coast at certain times. Additional data are necessary before the influence of food on salmon migrations at sea can be clearly understood.

Methods of Collecting Data

Part of the samples were obtained on salmon tagging trips, using fish which were not tagged. These included fish that were so insecurely hooked that they would have been lost unless taken aboard with a gaff hook, small fish that were hooked unnoticed in rough weather and were dead by the time they were brought aboard, and other fish the fishermen desired to keep.

These salmon were the source of the stomach samples taken in 1948 and 1949, and part of those taken in 1950. It is recognized that this means of obtaining stomach samples has certain definite drawbacks; the samples obtained are not necessarily representative of the fish that are available on the particular day they are taken, and the conditions under which they are taken are largely dictated by the more immediate task of tagging. However, for a large part of the coast, it has been the best means available for getting salmon stomach samples.

During the 1950 season, a large number of stomach samples were obtained from the ocean sport troll fishery off Newport. Most of these samples were obtained during August, and the overwhelming majority were from silver salmon. However, a few chinooks were taken, and these were well enough distributed through the month to allow a fairly accurate comparison with the silvers.

The stomachs were collected at sea as the fish were being dressed and were, for the most part, preserved in formalin and brought in to the Astoria laboratory for examination. Here the various food organisms present in each stomach were listed and weighed to the nearest 0.1 gram. However, in some instances, the stomachs were examined at sea, and the contents were not weighed.

All intact fish found in the stomachs were listed by species. In some cases it was possible to identify partly digested fish by species but in others only by general groups. Fish remains in a more advanced state of digestion sometimes had enough fins left intact to determine whether they had come from soft or spiny rayed fish, but in many cases these remains could not be identified.

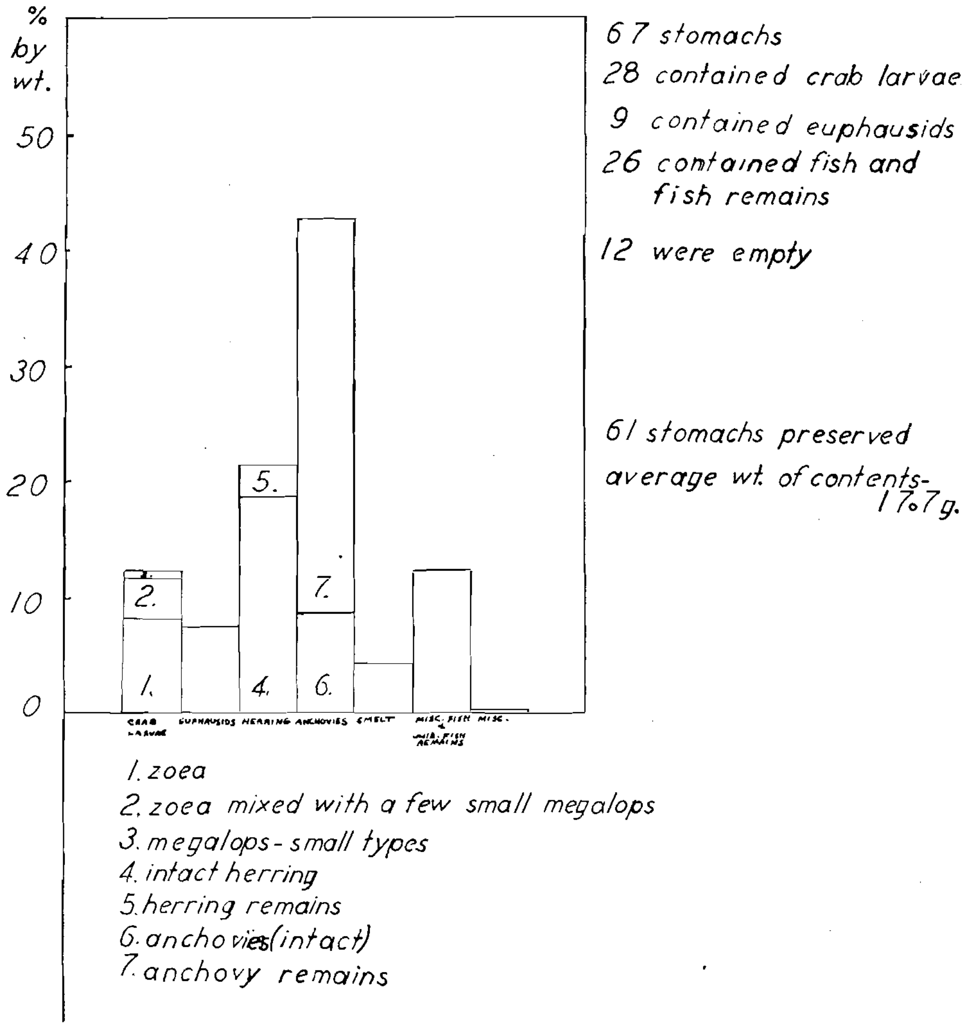

Figure 1. SILVER SALMON STOMACHS TAKEN DURING JUNE AND JULY, 1948-50.

Fish remains identified only as "clupeid" were probably mostly herring and anchovies; considerable numbers of both were found and there were no intact specimens of pilchard or shad in the stomachs examined in the laboratory. However, two pilchard were reported from a chinook stomach examined at sea.

The megalops stage of the edible crab, *Cancer magister,* could at all times be distinguished from other megalops larvae by larger size and characteristic appearance. Usually they were found separate from the smaller crab larvae in the stomachs and could be weighed and listed separately. Occasionally they were mixed in an inseparable mass with other megalops larvae. When this situation occurred, the larvae were listed as "crab megalops—mixed". Several stomachs contained zoea larvae. A high proportion of these were the zoea of *Cancer magister*. However, there were often other species present with them, and it would have been very difficult to separate them. Several stomachs examined at sea were listed as containing "crab larvae", with no further identification given.

The Food of Silver Salmon

The silver salmon from which the samples were taken were almost entirely maturing fish in their third summer. The stomach analyses indicate that the major items in the diet of these fish off the Oregon Coast are herring, anchovies, smelt, euphausids (small shrimp-like animals) and crab larvae, particularly those of *Cancer magister*. Squid also appeared to be important at certain times and in certain areas. The first three items named appeared to be present throughout the season. The euphausids appeared mainly in the July and August samples, but fishermen reported fish feeding heavily on "small shrimp" at other times. The crab larvae first appeared as zoea in June and July; during August, having passed into the megalops stage, they became a very important item in the diet. In September these larvae were less abundant, and in the two samples taken during October none were found. Not many crab larvae were found in stomachs taken off the mouth of the Columbia River, which may indicate that they were not as plentiful on the feeding grounds here as in the Newport and Coos Bay areas during the sampling season.

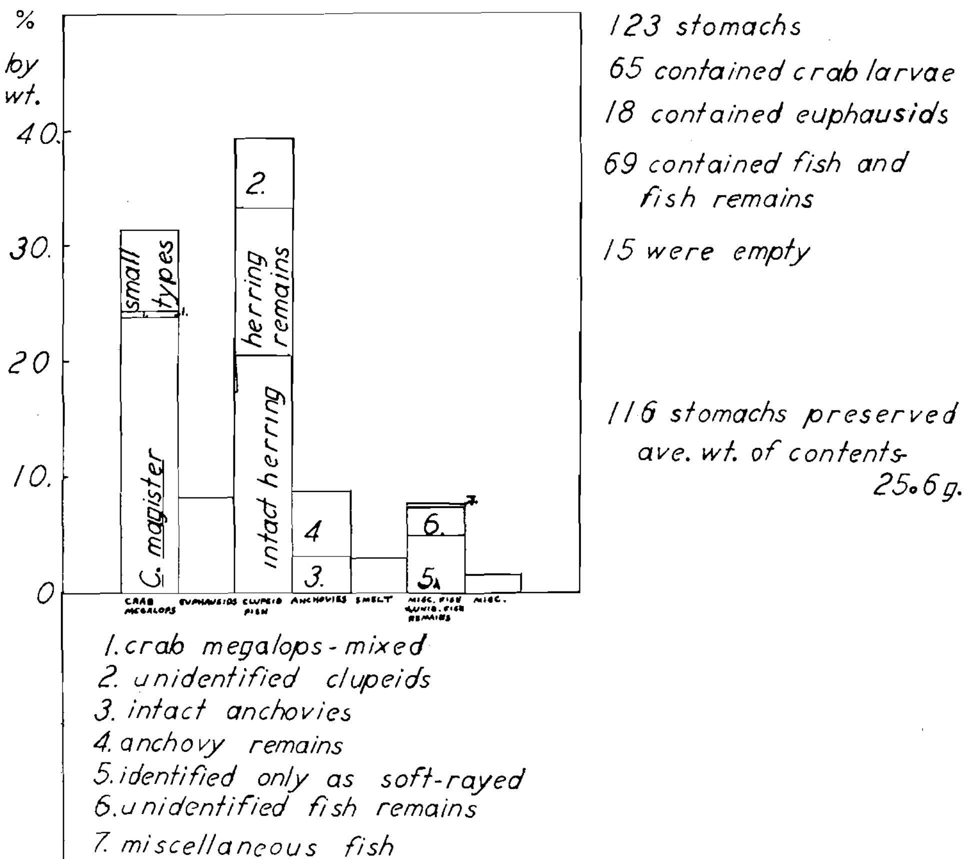

Figure 2. SILVER SALMON STOMACHS TAKEN DURING AUGUST, 1948-50.

The silver salmon data have been divided into three groups, which unfortunately are not strictly comparable. The first group comprises those stomachs taken during June and July in all the areas during the three seasons. A breakdown of these data by area shows that the silvers in the northern areas were feeding largely on fish, those in the Newport area on crab zoea, and those in the Coos Bay area on a mixture of fish and invertebrates. However, none of these three areas was covered adequately through the entire period, and 15 of the 17 Newport samples were taken on one day. Since salmon tend to feed heavily on one item on any particular day, there is no good evidence as yet that these apparent differences in the three areas are real. When the data for this period are combined, a tentative idea of the food habits of these fish during early summer can be obtained. Fish appeared to form the greater share of the diet during these two months with crab zoea and euphausids also playing an important part (Table 1, Fig. 1).

The August samples (Table 2, Fig. 2) were largely taken from the Newport sport fishery during August 1950, and thus are not strictly comparable to the June and July samples. However, the resulting data are quite similar except that crab larvae, then in the megalops stage, formed a larger part of the diet. Also, herring had replaced anchovies as the most important fish

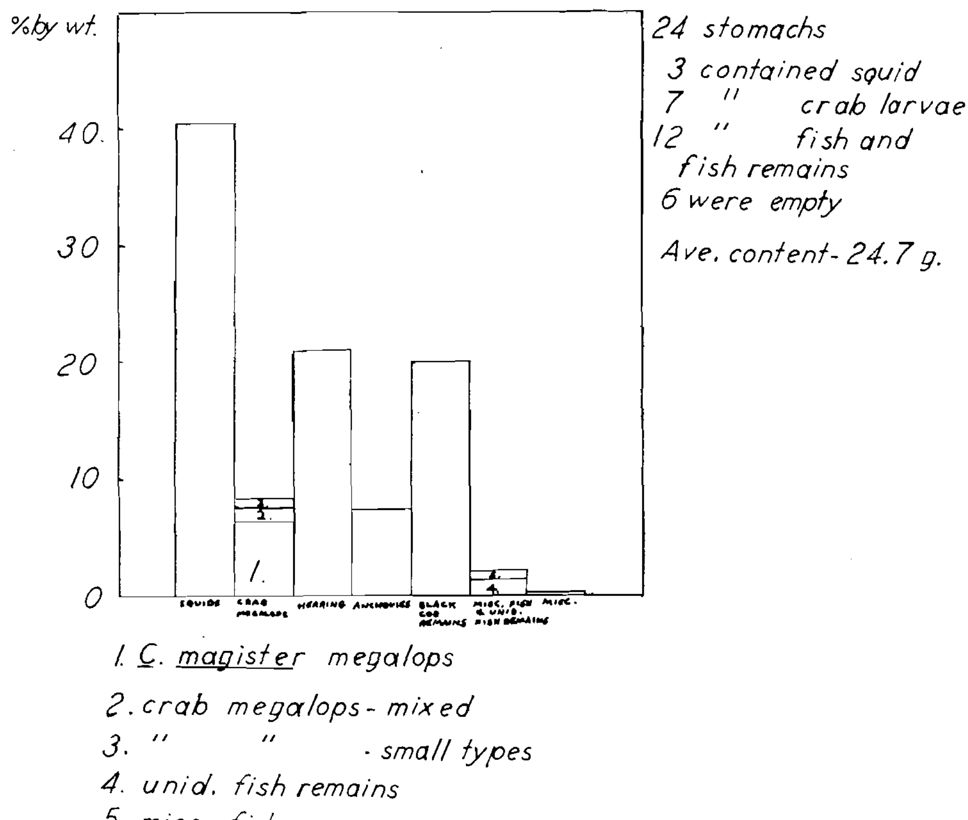

Figure 3. SILVER SALMON STOMACHS TAKEN AT COOS BAY—SEPTEMBER AND OCTOBER, 1949.

in the diet. Some of the stomachs taken during August were literally stuffed with the megalops of *Cancer magister*.

A third group of silver salmon stomach samples were taken during September and October, 1949 in the Coos Bay area. Squid and very small anchovies were the most abundant constituents of the diet. Crab megalops were present in the September samples, but not in those taken during October. Herring was still an important dietary item, and one stomach contained the remains of a young black cod, which probably measured about 12 inches in total length when alive (Table 3, Fig. 3).

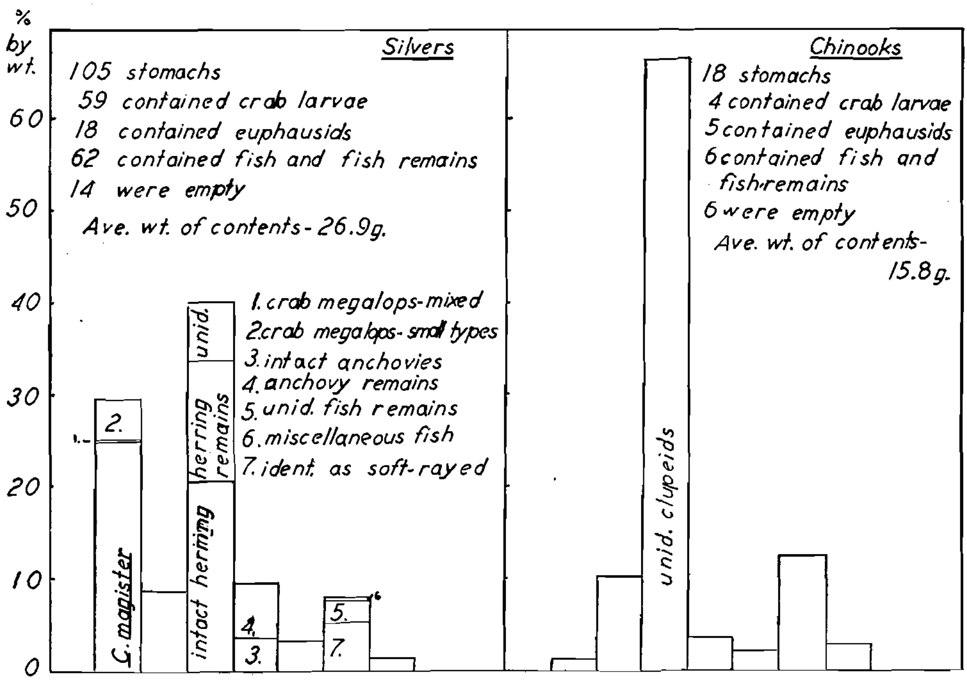

Figure 4. SALMON STOMACHS TAKEN AT NEWPORT—AUGUST, 1950.

The organisms found in silver salmon ranged in size from crab zoea about two millimeters in length (slightly larger than 1/16 inch) to the black cod mentioned above and several large herring of about the same size. The fish appear to feed to some extent on almost any swimming organism in this size range to be found in the upper areas of the water where the silvers normally are taken. Bottom forms were also occasionally found but formed only a very insignificant part of the diet of the fish examined. These included young rockfish, flatfish postlarvae, the remains of a blenny, and one very small sculpin of undetermined species; even these may be pelagic to some extent. Sand lances (*Ammodytes tobianus*) may be of more importance in the diet than the samples show, since they are frequently reported by fishermen and are known to be readily eaten by silver salmon wherever they are available. These fish tend to school in localized areas which may have been bypassed in the sampling. The fishermen claim that the same thing is true of squids, and that there are "squid beds" at various places along the coast where both silver and chinook salmon are found to feed heavily on these animals.

The Food of Chinook Salmon

The stomach samples from chinook salmon indicated that these fish will eat practically any of the organisms that form the food of the silver salmon. However, fish were found to form a higher proportion of the diet than was the case with the silvers, and where crab larvae were present they were found only in small numbers. Euphausids appeared to be of about equal importance as a food item to the two species, constituting from 5 to 12 percent of the diet. It was also noticed that a higher percentage of chinook stomachs were empty or nearly empty. This could indicate that these fish digest their food more rapidly, or that they feed less frequently.

Since only 63 of the chinook stomachs taken were preserved and weighed, and since these were rather spotty in their distribution, it was found to be impractical to break the chinook data down by month and area, except for the 18 stomachs taken off Newport in August, 1950. These formed a fairly homogeneous group that, in spite of being a small sample, was fairly comparable to the group of silvers taken in the same month and area. A comparison between these two groups of fish is presented in Table 4 and Figure 4. The most notable difference is that, at a time when the silvers were feeding heavily on crab megalops, very few of these larvae were found in the chinook stomachs.

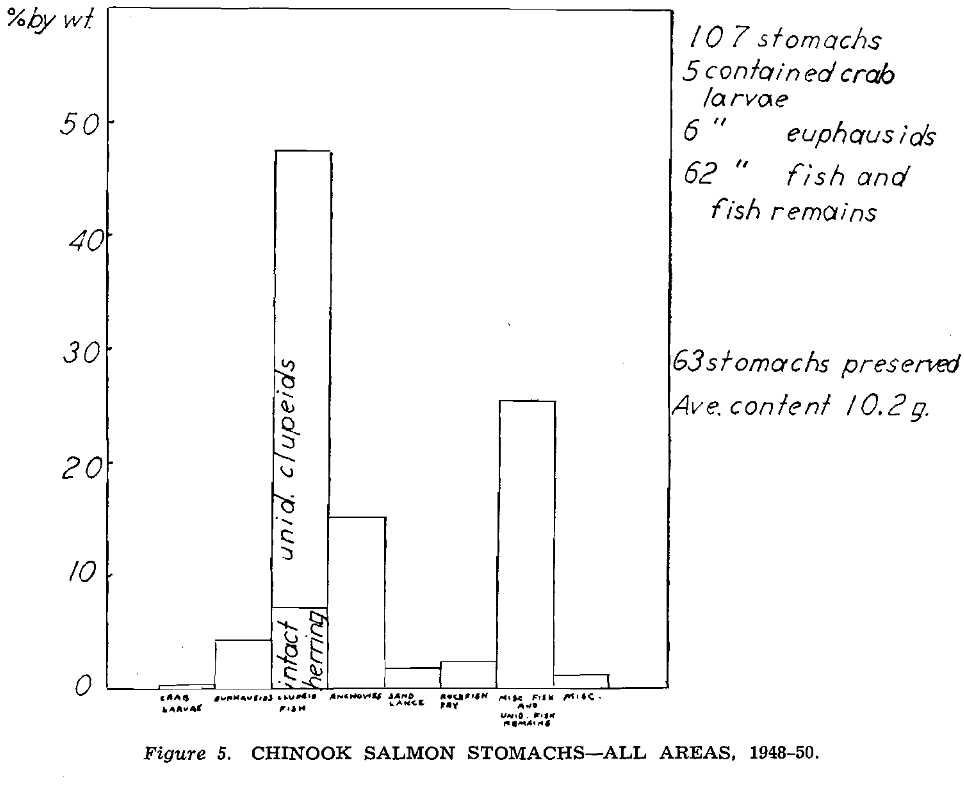

Figure 5. CHINOOK SALMON STOMACHS—ALL AREAS, 1948-50.

An analysis of the chinook salmon stomachs examined in all areas over the three seasons, as shown in Table 5 and Figure 5, present a picture very similar to that seen in the August, 1950 sample just discussed, except that anchovies appear as a major item in the diet. That is, fish of various types, especially clupeid, were the main items in the diet of the chinooks as contrasted by the heavy utilization by silvers of such invertebrates as crab megalops and squid.

Summary

Stomach samples from troll-caught chinook and silver salmon taken at various points along the Oregon Coast during the summer and early fall months of 1948, 1949, and 1950 have been collected and analyzed. The resulting data showed that the silver salmon sampled had been feeding on small pelagic fish, crab larvae, euphausids, and squid. The chinook salmon had been feeding to a greater extent on the fish species, about the same extent on euphausids, and to a very minor extent on crab larvae. This difference in food habits may eventually help to explain why for the most part silver salmon migrate south from their natal streams on feeding migrations while the chinook salmon apparently migrate to a greater extent north from their natal spawning stream.

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TABLE 1

STOMACH CONTENTS OF SILVER SALMON CAUGHT OFF THE OREGON COAST IN JUNE AND JULY, 1948–1950

	Astoria	*Newport*	*Coos Bay*	*Total*
Total number of stomachs examined	20	19	28	67
Number of empty stomachs	4	1	7	12

	Number of Stomachs in Which Found				*Percent by Weight*①			
Items of Food	*Astoria*	*Newport*	*Coos Bay*	*Total*	*Astoria*	*Newport*	*Coos Bay*	*Total*
Zoea larvae	2	15	4	21	1.0	71.5	*②	8.1
Crab megalops (small types)	0	0	6	6	0	0	2.2	0.6
Megalops of *Cancer magister*	0	1	6	7	0	*	*	*
Mixture of zoea, megalops, and a few gastropods	0	0	3	3	0	0	12.1	3.2
Unidentified crab larvae (examined at sea)	0	2	1	3	0	*	*	*
Total with crab larvae	2	17	9	28	1.0	71.5	14.3	11.9
Pelagic gastropod	0	0	4	4	0	0	1.1	0.3
Euphausids	0	0	9	9	0	0	28.5	7.5
Total with invertebrates	2	17	16	35	1.0	71.5	43.9	19.7
Herring (*Clupea pallasii*)—intact	3	0	2	5	21.6	0	18.7	18.5
Herring remains	0	1	0	1	0	27.1	0	2.8
Rockfish remains (*Sebastodes sp.*)	0	0	3	3	0	0	1.4	0.4
Anchovies (*Engraulis mordax*) and remains	5	0	0	5	67.4	0	0	42.7
Smelt remains (not *Hypomesus*)	0	0	1	1	0	0	15.9	4.2
Sand lance (*Ammodytes*)	0	0	1	1	0	0	2.1	0.5
Fish remains—unidentified	8	2	5	15	9.8	1.4	18.1	11.1
Fish remains—skeletal	2	0	0	2	0.2	0	0	0.1
Total with fish	13	2	11	26	99.0	28.5	56.2	80.3

① The contents of 6 stomachs were not weighed and thus are not considered in the determination of the percent weight of each food item.
② *—Indicates trace amounts—too little to weigh, or less than 0.1 percent of total.

TABLE 2
STOMACH CONTENTS OF SILVER SALMON CAUGHT OFF THE OREGON COAST IN AUGUST, 1948–1950

	Astoria	*Newport*	*Coos Bay*	*Total*
Total number of stomachs examined	4	112	7	123
Number of empty stomachs	1	14	......	15

Items of Food	*Number of Stomachs in Which Found*				*Percent by Weight*(1)			
	Astoria	*Newport*	*Coos Bay*	*Total*	*Astoria*	*Newport*	*Coos Bay*	*Total*
Crab megalops, (small types)	0	26	5	31	0	4.5	80.8	7.0
Crab megalops (*Cancer magister*)	0	44	4	48	0	25.0	1.6	23.8
Crab megalops (mixed)	0	2	1	3	0	0.2	14.7	0.7
Crab megalops (unidentified)	0	5	0	5	0	*(2)	*	*
Total with crab larvae	0	59	6	65	0	29.7	97.1	31.5
Gastropods (possibly *Limacina* sp.)	0	2	1	3	0	*	0.8	*
Euphausids	0	18	0	18	0	8.7	0	8.3
Amphipods	1	4	0	5	*	*	0	*
Shrimp and shrimp remains	0	4	0	4	0	0.2	0	0.2
Crabs	0	1	0	1	0	*	0	*
Unidentified crustaceans	0	1	0	1	0	*	0	*
Squid	0	2	0	2	0	0.5	0	0.5
Total with invertebrates	1	74	7	82	*	38.6	97.9	40.5
Herring (*Clupea pallasii*)	0	11	0	11	0	21.6	0	20.5
Herring remains	0	7	0	7	0	13.3	0	12.7
Fish remains (Clupeid)	1	2	0	3	74.5	5.1	0	6.1
Anchovies (*Engraulis mordax*)	0	4	0	4	0	3.4	0	3.2
Anchovy remains	0	3	0	3	0	6.1	0	5.7
Smelt remains (not *Hypomesus*)	0	3	0	3	0	1.3	0	1.2
White bait (*Allosmerus*)	0	1	0	1	0	1.8	0	1.7
Smelt remains (probably *Allosmerus*)	0	2	0	2	0	0.1	0	0.1
Flatfish post larvae	0	0	1	1	0	0	1.3	*
Sand lance (*Ammodytes*)	0	2	0	2	0	*	0	*
Three-spined stickleback	0	2	0	2	0	*(2)	0	*
Blenny remains	0	1	0	1	0	*	0	*
Rockfish remains	0	1	0	1	0	*	0	*
Fish remains (probably Sculpin)	0	0	1	1	0	0	*	*
Fish remains (soft rayed)	0	6	0	6	0	5.1	0	4.9
Fish remains (spiny rayed)	0	1	0	1	0	*	0	*
Fish remains (unidentified)	1	10	0	11	25.5	1.7	0.8	2.0
Fish remains (skeletal)	1	9	0	10	*	0.9	0	0.9
Total with fish	3	62	4	69	100.0	60.7	1.1	59.0
Bird feathers	0	7	0	7	0	*	0	*
Digested matter	0	4	0	4	0	0.6	0	0.6

(1) The contents of 7 stomachs were not weighed and thus are not considered in the determination of the percent weight of each food item.
(2) *—Indicates trace amounts—too little to weigh, or less than 0.1 percent of total.

TABLE 3
STOMACH CONTENTS OF SILVER SALMON CAUGHT OFF COOS BAY IN SEPTEMBER AND OCTOBER, 1949

Total number of stomachs examined	24
Number of empty stomachs	6

Items of Food	*Number of Stomachs in Which Found*	*Percent by Weight*
Crab megalops (small types)	4	1.0
Crab megalops (*Cancer magister*)	5	6.4
Crab megalops (mixed)	1	1.1
Total with crab larvae	7	8.5
Amphipods	2	*(1)
Squid	3	40.7
Total with invertebrates	10	49.2
Herring (*Clupea pallasii*)	2	21.1
Anchovies (*Engraulis mordax*)	1	1.0
Anchovy remains	7	6.4
Black Cod remains	1	20.1
Fish remains (probably sand lance)	1	0.7
Fish remains (unidentified)	1	0.8
Fish remains (skeletal)	2	0.7
Total with fish	12	50.8
Digested matter	1	0.2

(1) *—Indicates trace amounts—too little to weigh, or less than 0.1 percent of total.

TABLE 4—STOMACH CONTENTS OF SILVER AND CHINOOK SALMON CAUGHT OFF NEWPORT IN AUGUST, 1950

	Chinook	*Silver*
Total number of stomachs examined	18	105
Number of empty stomachs	6	14

Items of Food	*Number of Stomachs in Which Found*		*Percent by Weight*	
	Chinook	*Silver*	*Chinook*	*Silver*
Crab megalops (small types)	1	26	1.3	4.5
Crab megalops (*Cancer magister*)	3	44	*①	25.0
Crab megalops (mixed)	0	2	0	0.2
Total with crab larvae	4	59	1.3	29.7
Gastropods (possibly *Limacina sp.*)	0	2	0	*
Euphausids	5	18	10.3	8.7
Amphipods	0	4	0	*
Shrimp and shrimp remains	0	4	0	0.2
Crabs	0	1	0	*
Unidentified crustaceans	0	1	0	*
Total with invertebrates	7	74	11.6	38.6
Herring (*Clupea pallasii*)	0	9	0	21.6
Herring remains	0	7	0	13.3
Fish remains (Clupeid)	2	2	66.7	5.1
Anchovies (*Engraulis mordax*)	0	4	0	3.4
Anchovy remains	0	3	0	6.1
Smelt (not *Hypomesus*)	0	3	0	1.3
White Bait (*Allosmerus attenuatus*)	0	1	0	1.8
Smelt remains (probably *Allosmerus*)	0	2	0	0.1
Sand Lance (*Ammodytes tobianus*)	2	2	3.4	*
Three-spined stickleback (*Gasterosteus aculeatus*)	0	2	0	*
Blenny remains	0	1	0	*
Rockfish	1	1	2.1	*
Fish remains (soft rayed)	0	6	0	5.1
Fish remains (spiny rayed)	0	1	0	*
Fish remains (unidentified)	3	10	10.6	1.7
Fish remains (skeletal)	2	9	2.6	0.9
Total with fish	6	62	85.4	60.4
Bird feathers	1	7	*	*
Digested matter	1	4	3.0	0.6

① *—Indicates trace amounts—too little to weigh, or less than 0.1 percent of total.

TABLE 5—STOMACH CONTENTS OF CHINOOK SALMON CAUGHT OFF THE OREGON COAST, 1948–1950

	Astoria	*Newport*	*Coos Bay*	*Total*
Total number of stomachs examined	13	33	61	107
Number of empty stomachs	3	14	17	34

Items of Food	*Number of Stomachs in Which Found*				*Percent by Weight*①			
	Astoria	*Newport*	*Coos Bay*	*Total*	*Astoria*	*Newport*	*Coos Bay*	*Total*
Zoea larvae	2	1	0	3	*	*	0	*
Crab megalops (small types)	0	2	0	2	0	1.1	0	0.5
Crab megalops (*Cancer magister*)	2	3	0	5	*	*	0	*
Euphausids	0	5	1	6	0	8.9	*	4.5
Shrimp (Pandalid)	0	0	1	1	0	0	1.6	0.4
Unidentified crustaceans	0	0	1	1	0	0	*	*
Total with invertebrates	2	7	3	12	*	10.0	1.6	5.4
Ratfish (*Hydrolagus collei*)	0	0	1	1	0	0	3.0	0.7
Herring (*Clupea pallasii*)	0	3	26	29	0	13.9	0②	7.1
Pilchard (*Sardinops caerulea*)	0	0	1	1	0	0	0②	0
Anchovies (*Engraulis mordax*)	1	0	1	2	45.0	0	15.6	15.3
Sand Lance (*Ammodytes tobianus*)	1	2	1	4	2.1	2.9	0②	2.0
Rockfish (*Sebastodes sp.*)	1	1	2	4	5.8	1.8	1.0	2.5
Flatfish post larvae	0	0	1	1	0	0	0.3	*
Fish remains (Clupeid)	0	2	1	3	0	57.4	48.8	40.5
Fish remains (soft rayed)	2	0	0	2	0②	0	0	0
Fish remains (unidentified)	7	2	8	17	47.0	9.1	25.3	22.7
Fish remains (skeletal)	0	3	2	5	0	2.3	4.3	2.2
Total with fish	9	9	44	62	99.9	87.4	98.3	93.0
Bird feathers	0	1	0	1	0	*	0	*
Digested matter	0	1	0	1	0	2.6	0	1.3

① The contents of 44 stomachs were not weighed. Included in this number were the following stomachs examined at Coos Bay: 26 with herring; 1 with pilchard; 1 with sand lance. For this reason the percentage composition for Coos Bay and for the total is not representative.
② Item was found in stomach, but since stomach contents were not weighed they do not appear here.

STREAM IMPROVEMENT AS CONDUCTED IN OREGON ON THE CLATSKANIE RIVER AND TRIBUTARIES

Introduction

There has been a great deal of interest in methods of improving salmon streams in recent years, as areas suitable for natural spawning have become more and more limited. The construction of dams has cut off large sections of rivers which were formerly available to salmon, and those rivers remaining must be fully utilized.

Recently, using federal funds, the states of Oregon and Washington have been expending considerable effort in order to rehabilitate and develop salmon runs in the lower Columbia River area. By 1951 alone about $700,000 will have been made available for stream improvement in Oregon and Washington under this program. In Oregon, much of the Fish Commission's work has been aimed at making spawning areas more readily accessible to salmon by laddering falls and clearing obstructions from streams.

The degree to which stream clearance should be undertaken is still somewhat debatable. In some parts of the country, stream improvement in trout streams consists of placing logs and other objects in the stream bed to prevent erosion of the gravel and to afford cover for the fish. The problems in the Pacific Northwest with the anadromous species of salmon are of a different nature than those concerning resident trout populations. Here the extensive logging operations of recent years have completely obstructed migrations of the salmon in many cases and have caused serious blocks in others. The problem of weighing the benefits of erosion control and cover against the harmful effects of blocking the ascent of the salmon to the spawning areas poses a serious problem.

Clatskanie System

The Clatskanie River is 25 miles in length and flows into the Columbia River 30 miles above Astoria. Its watershed was heavily logged and burned about fifteen years ago, leaving an accumulation of logs and debris which choked the stream bed in many places (Fig. 1).

Formerly the Clatskanie supported a large run of silver salmon and smaller runs of fall chinook and steelhead. In recent years, however, the runs have fallen to a very low level, due at least in part to the barriers which have prevented full utilization of natural spawning facilities. Recent studies by the Oregon Fish Commission have shown that heavy logging may be followed by a decrease in salmon production (McKernan, Johnson, and Hodges, 1950).

During the summer months of 1949, a crew of 11 men with two bulldozers cleared all of the obstructions out of the lower 23 miles of the main stream and lower four miles of a tributary, Carcus Creek (Fig. 2). A total of 170 major and minor jams were cleared out of the Clatskanie and its tributaries at this time (Figs. 3 and 4). The method of operation was for the bulldozer to work in the river bed, pushing the jams out above the reach of high water. Where possible, the work proceeded downstream so that debris which was dislodged floated downstream into areas which had not yet been cleared. In the course of such operations, the stream bed was greatly disturbed.

In addition to the jams removed, a seven-foot waterfall located 12.5 miles above the mouth was laddered; this was formerly passable only during periods of extreme high water. The capital cost of improvement of the Clatskanie was $71,798; this does not include continuing annual costs such as planting of fingerling.

Figure 1. LARGE LOG JAM IN UPPER CLATSKANIE RIVER BEFORE STREAM CLEARANCE.

Carcus Creek

Carcus Creek, the principal tributary of the Clatskanie, was also cleared of obstructions as far upstream as the 70-foot falls which blocks the creek four miles above its mouth. This four-mile area has an abundance of good spawning gravel, most of which was not previously available to salmon.

Carcus Creek was subjected to drastic clearing by bulldozer. Gravel was pushed into piles, all logs were cleared out and the channel was even changed for short distances. Some criticism has been made of the clearing in this particular area, it having been suggested that overclearing ruined the stream by eliminating pools and exposing the gravel to shifting and scouring. Changes have taken place, but productivity does not seem to have suffered (Fig. 5).

During the height of the silver spawning season on December 5, 1950, 38 live silver salmon were seen in Carcus Creek. The fish seen on this date undoubtedly were only a portion of the total number that spawned. On surveys of June 8, 1950, and May 16, 1951, the entire creek from Carcus Falls to its mouth was found to be thickly populated with salmonoid fingerling. A number of these were collected with a minnow seine and were found to be silver salmon and rainbow trout (probably steelhead). Besides the abundance of salmonoids, the creek bottom abounds with crayfish and snails, as well as mayfly, caddis fly and stonefly larvae. From all indications the stream appears to have restored itself beautifully and at present is very productive.

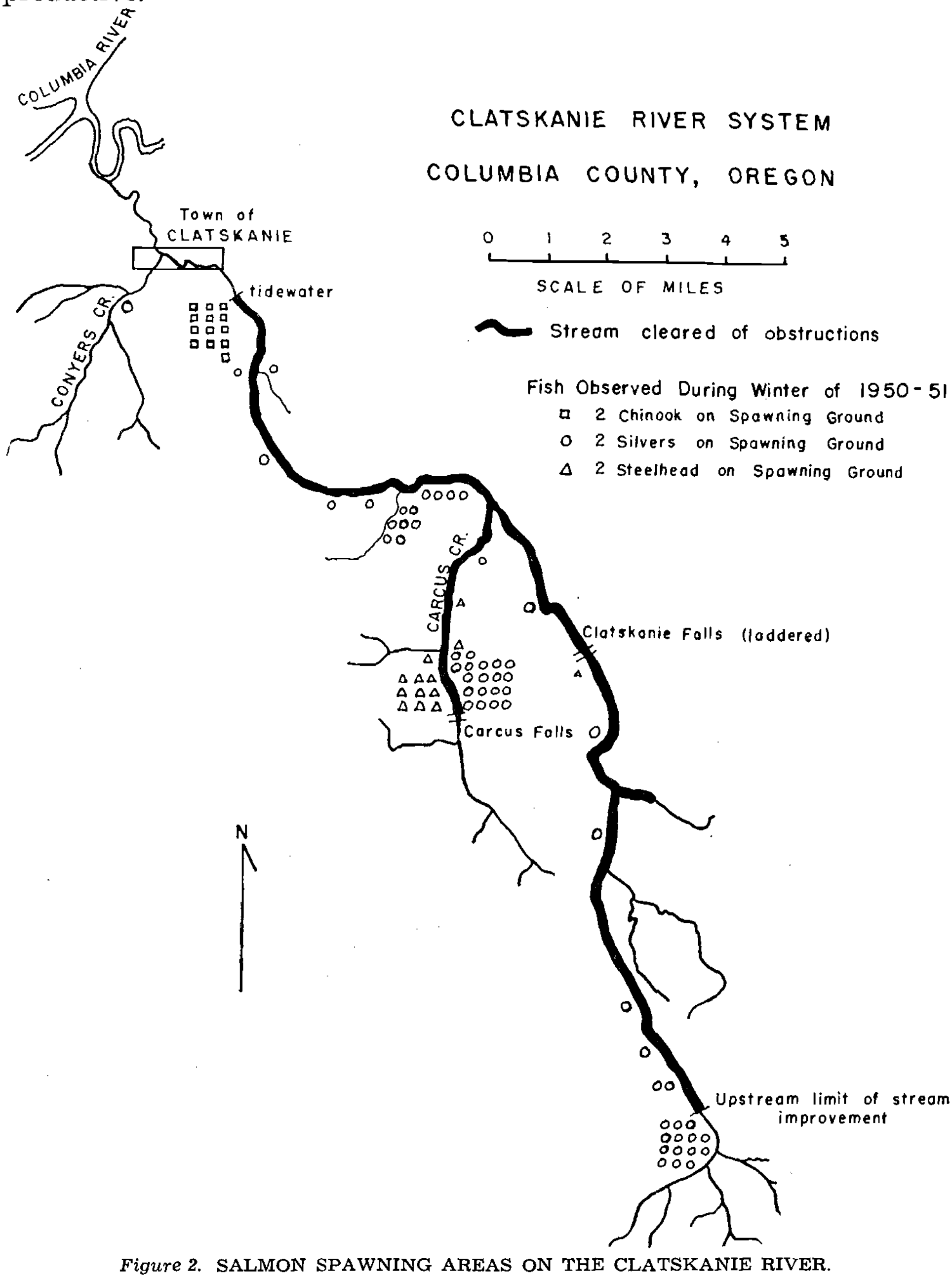

Figure 2. SALMON SPAWNING AREAS ON THE CLATSKANIE RIVER.

Beaver Dams

A total of 32 beaver dams were removed on the Clatskanie River and Carcus Creek, but nearly all were rebuilt within a short time. With the advent of higher water, before the silver run, all dams were washed out.

One large dam, four feet in height, has remained above the area cleared by the engineers, but silvers successfully surmounted it; 11 spawners were seen above this obstacle in 1949 and 20 in 1950. Although the beaver dams were removed in the area cleared on the Clatskanie, they were not considered to be serious obstructions. Beaver dams, however, could present an obstacle to chinook salmon if they were constructed in the lower reaches of such a stream. Under some conditions beaver dams have been found to block or delay the silver salmon; however, the Clatskanie run occurs after the freshets have started and the dams for the most part are washed out or are made passable by water flowing over them. The ponds which are made by the beaver dams form excellent rearing areas for the young silver salmon, most of which spend more than a year in the streams before descending to the sea.

Figure 3. LARGE LOG JAM ON CARCUS CREEK NEAR CARCUS FALLS, BEFORE STREAM CLEARANCE.

Surveys

Biological surveys were first made of the Clatskanie after the improvement work was completed in 1949. The first survey was made on October 17, 1949, when seven dead chinooks were seen in the four miles above tidewater. No fish were seen on three surveys in November; in December the bulk of the silver run occurred, and 30 live and two dead silvers were seen on three surveys. A survey was made on January 4, 1950, in spite of very deep snow; two live silvers were seen. From that date until March 7, during the time of steelhead spawning, no surveys were made because the roads were impassable. One survey was made in each of the months of March, May, June and August, 1950. A total of 12 surveys were made from October, 1949 to August, 1950; 41 silvers were seen, besides seven dead chinooks.

The surveys begun during the 1949 run were continued in 1950. Between September 13, 1950, and March 27, 1951, 15 surveys were conducted on which a total of 25 chinook, 144 silvers, and 24 steelhead were observed. Most of these are believed to be different fish. While the count of fish

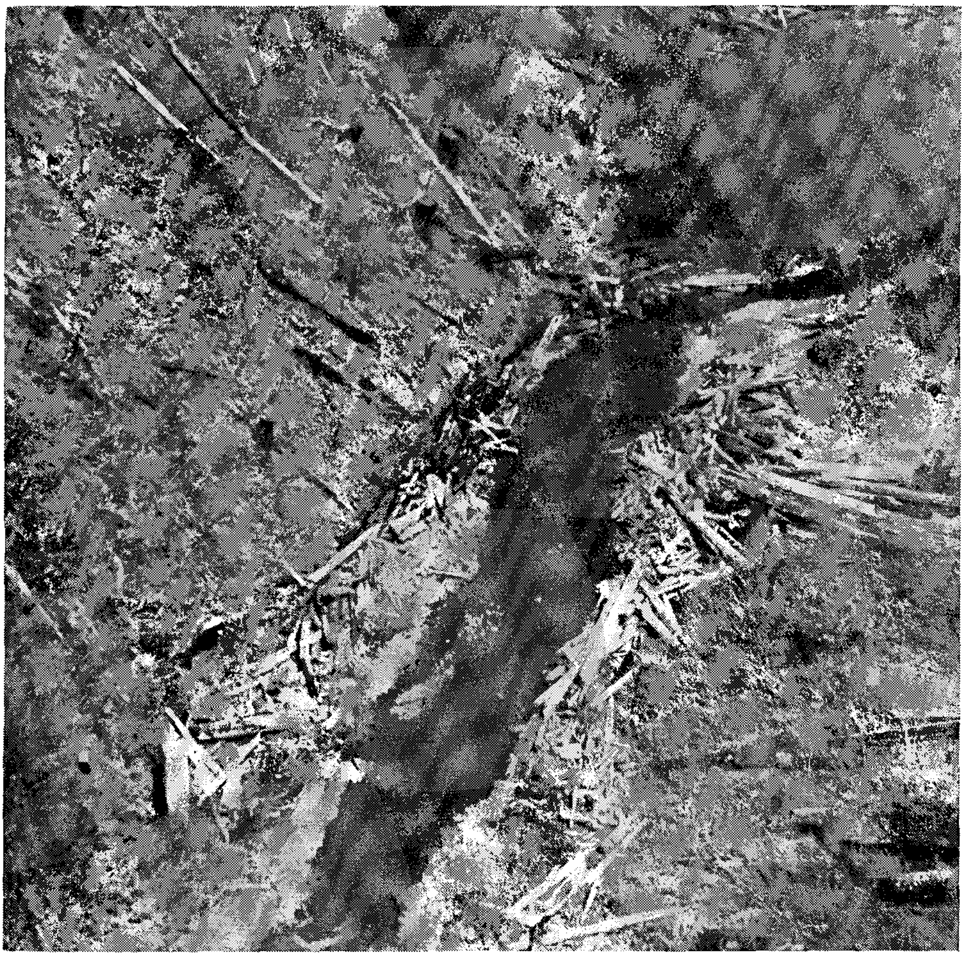

Figure 4. SAME LARGE LOG JAM AS FIGURE 3, AFTER STREAM CLEARANCE.

during the 1950 run is greater than during 1949, more surveys and more areas were covered. In order to establish a basis for comparison, several definite check areas have been designated, so that counts in succeeding years can be compared more readily.

One difficulty encountered has been the fact that high water and extreme turbidity reduces visibility in the lower eight miles of stream to such an extent that very little in this area can be seen during the silver run. Undoubtedly many salmon spawn here since the area contains an abundance of good spawning gravel, though only seven silvers were seen in this area in December 1950.

Figure 5. A FEW OF THE SILVER SALMON AND CRAYFISH SEINED IN CARCUS CREEK DURING SUMMER OF 1950 AFTER STREAM CLEARANCE.

Future Work

Some maintenance must be done to keep the stream free of obstructions in future years. A few jams re-formed during the winters of 1949-50 and 1950-51 but were removed in the fall prior to the silver run.

Large plantings of silver salmon have already been made in the Clatskanie and tributaries and will be continued; an annual average planting of 100,000 yearling silvers is scheduled. Spawning ground studies will also be continued in future years to determine the long-range effects of stream improvement and plantings on future runs.

Conclusions

All evidence seems to point to the fact that drastic clearance of logs and debris from salmon streams increases accessibility and at least does not damage productivity. Although the stream bottom was greatly disturbed, in less than a year natural conditions had largely restored themselves. About 15 additional miles of stream were made readily available to spawning salmonoids.

It is believed that due to improvements made the Clatskanie and its tributaries are at present capable of providing spawning and rearing facilities for large numbers of silver salmon and steelhead trout.

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SPRING CREEK CRAYFISH MIGRATIONS
1949 and 1950

Introduction

Spring Creek is a small tributary of the Wilson River, which flows into Tillamook Bay, and is located approximately 20 miles above tidewater. The Oregon Fish Commission has installed a weir on this stream to obtain information concerning the life history of the silver salmon (*Oncorhynchus kisutch*). Incidental to the silver salmon data which are being collected there is a great deal of other information and data which this weir has made available. This report deals with the crayfish migrations as noted in the upstream and downstream traps of the Spring Creek weir during the years 1949 and 1950.

Spring Creek, as its name implies, is a small spring-fed stream approximately one-fourth mile long. Due to its size and source of water supply, there is little fluctuation in the water flow throughout the year, ranging from about two to eight cubic feet per second.

The weir was installed on this stream about 40 yards above the mouth in November, 1948. This weir contains an upstream and a downstream trap, and the structure is covered with a fine mesh (six to the inch) hardware cloth. Ordinarily this would present a complete block in the stream; however, on a few occasions sections underneath and around the weir have washed away probably allowing passage to crayfish. The crayfish inhabiting this stream have been identified as *Astacus klamathensis* by Dr. Lynch of the University of Washington School of Fisheries.

There appear to be two principal periods of migration for these crayfish: a downstream migration in the late spring and early summer, and an upstream migration in the fall. It is believed that these crayfish tend to move downstream into the main river to rear their young and to molt, and then move back into the small stream to spend the winter.

Downstream Migration

Figure 1 shows the total downstream crayfish migration at the Spring Creek weir in 1949 and 1950, grouped by weekly periods. In comparing these two years it will be noted that the bulk of the migration occurred during April and May in both years. In 1950, however, there were also a number of crayfish moving downstream throughout June and July, while in 1949 this was not observed. The principal reason for this discrepancy is attributed to the fact that in 1949, particularly during the early part of June and again in August, there was so much seepage, both around and under the weir, that at times there was no water entering the downstream trap. Therefore, it is firmly believed that the lateness of the migration in 1949 was an unnatural circumstance and, had there been a normal flow of water during the summer months, these crayfish would have migrated earlier as they did in 1950. There was sufficient water in July, but still very few crayfish entered the trap. Nevertheless, this also can perhaps be attributed to the unnatural flow conditions occurring during June.

In comparing the two different years it is interesting to note the numbers involved: In 1949 a total of 441 crayfish were observed moving downstream; in 1950 a total of 1,698 were observed. There are three possible explanations for this tremendous increase in 1950: (1) there was better survival in 1950 through natural conditions; (2) work done on and near the weir to stop the seepage may have plugged some of the holes which may have been utilized by crayfish moving downstream in 1949; and (3) the fact that the downstream trap was not operating at certain times in 1949 may have forced an abnormal number of crayfish to hatch their eggs above the weir, and the large number migrating downstream in 1950 may have been the result of this misplaced rearing.

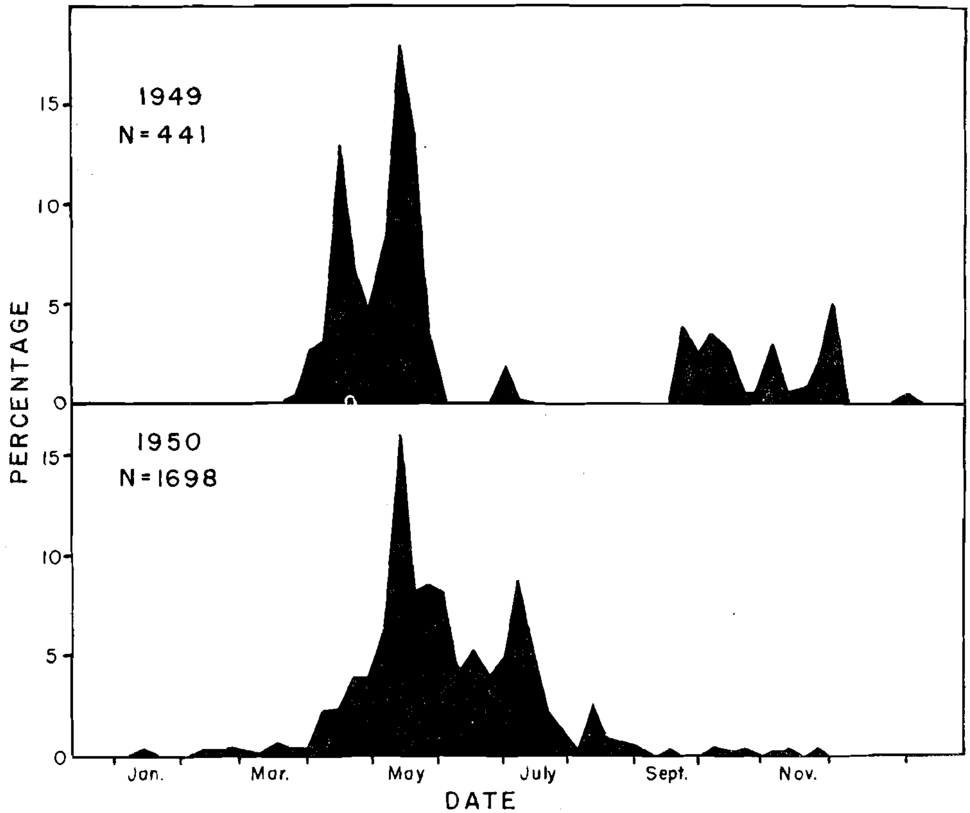

Figure 1. TIME OF DOWNSTREAM MIGRATION OF CRAYFISH AT SPRING CREEK WEIR.

Reproduction

With regard to the female crayfish downstream migration, the earliest appearing females were generally not "berried" (with eggs on the swimmerets). Beginning about the first of April, the bulk of the females had eggs attached to their swimmerets and from the middle of May through July some appeared with larvae attached. This would indicate that the spawning season (from egg laying until the young leave the parent) extends roughly through April, May, and June. In the fall quite a few females with black or dark brown eggs attached appeared in the downstream trap. (In the normal development of crayfish eggs it is possible to actually distinguish the embryo inside the egg a short time before hatching.) Therefore, from the unnatural appearance of these opaque eggs it was concluded that they had died and were remnants of the earlier spawning. This belief is somewhat substantiated by the fact that a female crayfish with black eggs was observed migrating upstream in the fall of 1949. This same crayfish was again observed approximately five months later and it was still carrying black eggs which showed no signs of hatching (see section on tagging). In 1950 there were some females observed during the summer which appeared to have recently had larvae attached. There was one observed in May, three during June, and eight during July; giving further evidence that spawning was generally over by July.

Sex Ratio

The downstream migration in 1949 included a total of 271 females, 161 males, and 9 of undetermined sex. In 1950 there were 959 females, 737 males, and 2 of undetermined sex. The time of the downstream migration for males and females appeared to be very similar for both the 1949 and the 1950 migrations.

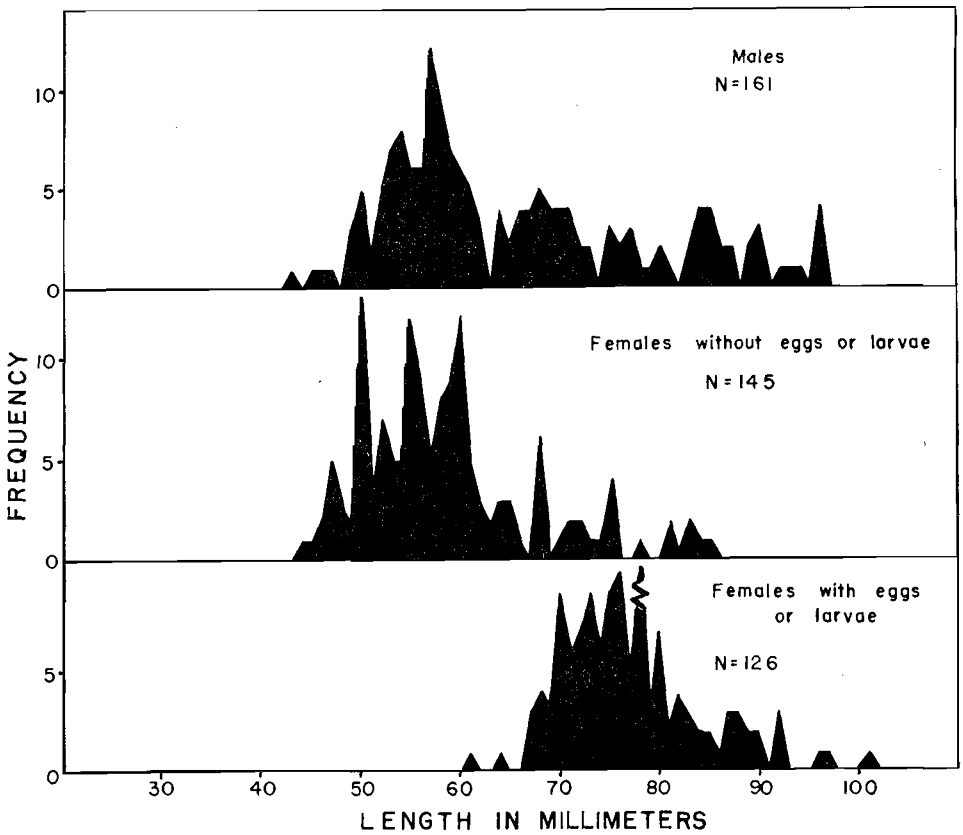

Figure 2. LENGTH-FREQUENCY OF DOWNSTREAM CRAYFISH MIGRANTS AT SPRING CREEK WEIR—1949.

The ratio of the males to the females during the course of the downstream migration showed that in the early part of the year there is generally a preponderance of females. During the summer months, the percentage of males increases, and in the fall and winter there is a preponderance of males

(Table 1). Due to the interrupted migration in 1949, this trend was not quite as apparent. The ratio of males to females for the entire year in 1949 was 0.59, and 0.77 in 1950. When these values were compared with a hypothetical sex ratio of one male to one female, by means of chi square, they were both found to depart significantly from the 1:1 ratio. Significant values were also obtained for April and May of both years and for September of 1949, but the latter may have been caused by the blocked summer migration. From these two years' observations, it appears that the downstream migrating population is not composed of a 1:1 sex ratio.

Length-Frequency

In Figures 2 and 3 are depicted the length-frequencies of the downstream migrating crayfish for 1949 and 1950 respectively. In both years it is apparent that the females observed with eggs or larvae were generally larger than those without. This is also apparent from Table 1 when the average lengths of the different classifications are listed. Also, when all the females are examined together, they will be observed to fall into two very definite size groups for both the 1949 and the 1950 data. One group ranges from about 43 millimeters to 62 millimeters, and the other group ranges from 62 to around 93 millimeters. This would seem to indicate that there were two distinct age classes comprising the bulk of the female migrants. With the data available it is not possible to determine what age classes these were.

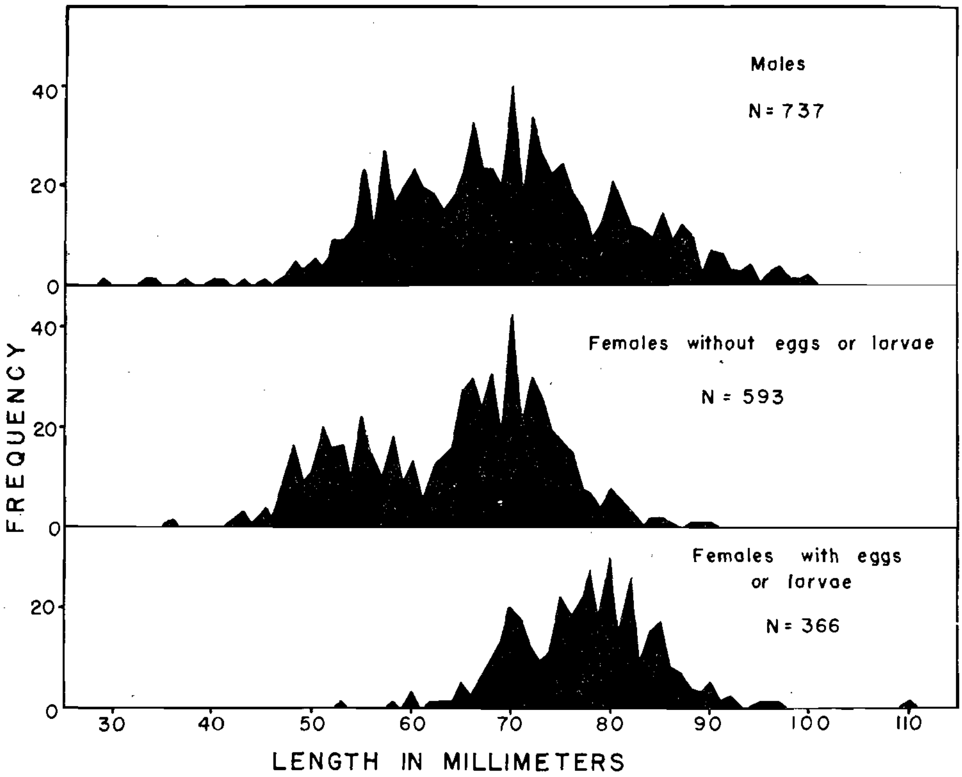

Figure 3. LENGTH-FREQUENCY OF DOWNSTREAM CRAYFISH MIGRANTS AT SPRING CREEK WEIR—1950.

It had been hoped that this information could be uncovered by tagging some of the crayfish, but this has not proved successful (see section on tagging). For the males, there appears to be a great deal more overlapping of the sizes and no definite conclusions can be drawn.

Upstream Migration

As stated previously, the upstream migration took place primarily in the fall. The interesting aspect of the upstream migration was the small numbers of crayfish involved each year. In 1949 approximately 232 were observed migrating upstream, whereas 441 migrated downstream. Again in 1950 only 226 were observed going upstream, while 1,698 migrated downstream. It is possible that some of the crayfish may have found other ways to migrate upstream without entering the trap, but the extent to which that occurred, if at all, is not known.

In 1949 the upstream migration was entirely restricted to the months of September, October, and November, with the peak occurring during October. In 1950 these three months again contained the bulk of the migration with one or two individuals appearing during other months (Fig. 4).

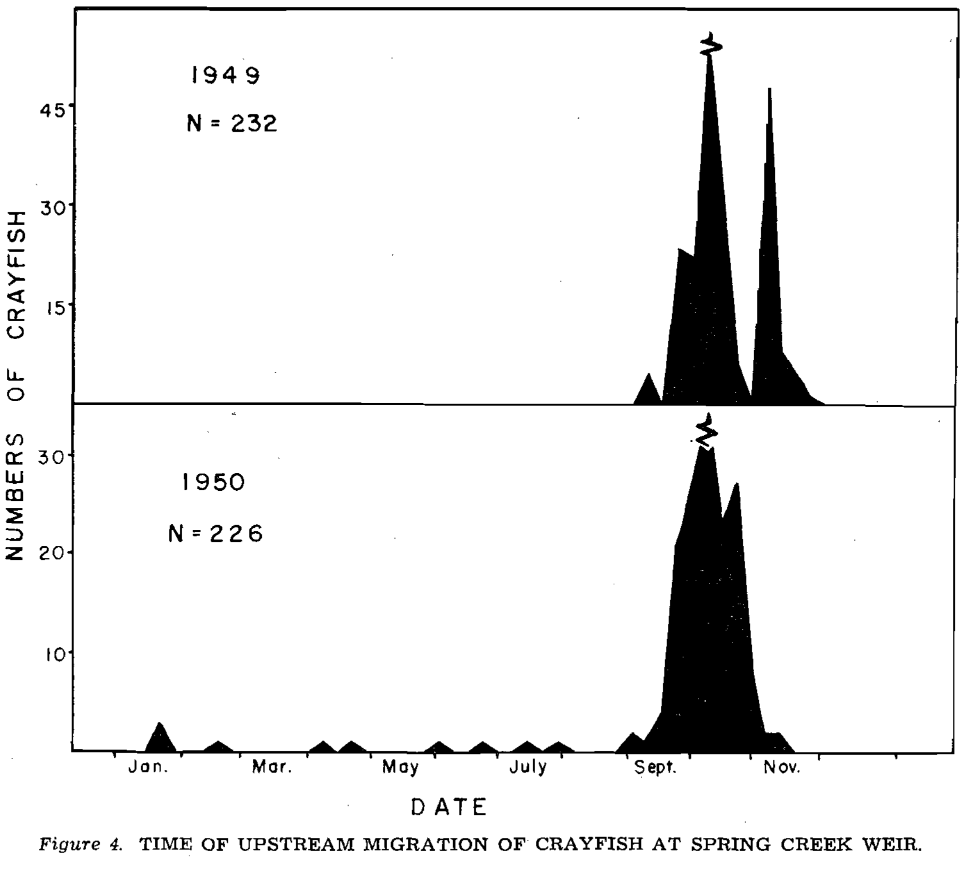

Figure 4. TIME OF UPSTREAM MIGRATION OF CRAYFISH AT SPRING CREEK WEIR.

Length-Frequency

The length-frequency distributions of these upstream migrants for 1949 and 1950, by sex, are shown in Figure 5. When these size ranges are compared with the size ranges of the downstream migrants (Figs. 2 and 3 and Table 1) for each respective year and sex, it will be noted that in all instances it was the larger individuals which were not observed in the upstream migration. Table 2 also lists the numbers of each sex migrating upstream by month with the average size and range in sizes.

In addition to the numbers of crayfish listed in Figure 5, there were about 30 individuals caught between the walls of the upstream trap in September of 1949. These were not recovered and they eventually died. Also, there were 12 females, 15 males, and 15 not sexed, all in the month of October, 1950, for which no lengths were available. An animal, later discovered to be a mink, had gotten into the upstream trap on two different occasions and had killed and eaten these crayfish.

Sex Ratio

In analyzing the sex ratio data of the upstream migrants, it is interesting to note the nearly equal numbers of males and females in both years. Comparing these ratios with a hypothetical ratio of equal numbers of males and

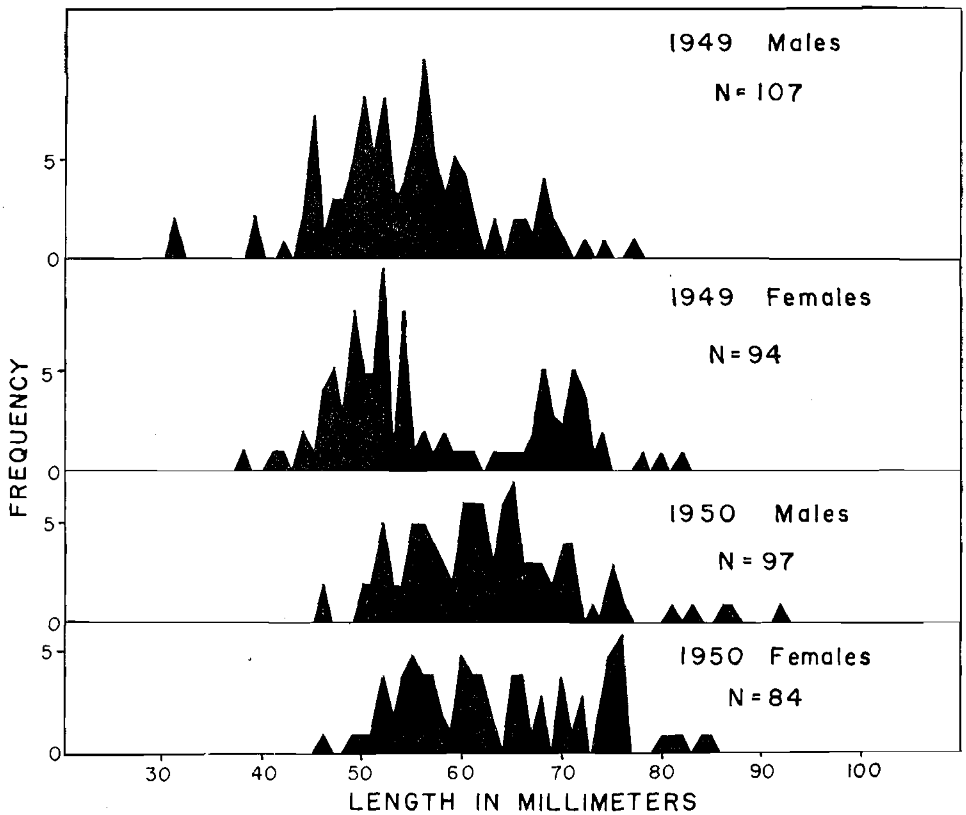

Figure 5. LENGTH-FREQUENCY OF UPSTREAM CRAYFISH MIGRANTS AT SPRING CREEK WEIR.

females, by means of chi square, no significant differences were found to exist. This is especially interesting in view of the preponderance of females among the downstream migrants.

All the upstream female crayfish migrants observed during these two years were without eggs, with the exception of five females in 1949 and one female in 1950 which were carrying black eggs. This appearance of black eggs on these upstream migrants so late in the year would seem to substantiate the belief that the black eggs are remnants of the earlier spawning and are dead.

Tagging

An attempt has been made to discover more about these migrations through tagging. Unfortunately, the type of tag used (a metal strap tag ⅛-inch wide and ⅝-inch long when closed) was apparently too large for this species. These tags were clamped on the uropod (one of the "tail" segments), and several crayfish were subsequently discovered with broken uropods; perhaps indicating previous tagging. Only the larger specimens were tagged.

In 1949, 33 downstream migrants and 6 upstream migrants were tagged. In 1950, 26 downstream and 5 upstream migrants were tagged. From this total of 70, only three tags have ever been seen again. One crayfish, tagged November 11, 1949, was going upstream. It was recaptured April 7, 1950, on its way downstream. The other two were both tagged October 31, 1949, on their way upstream and were recaptured in the downstream trap on November 4, 1949. These three crayfish were all females with black eggs.

Summary

(1) Spring Creek crayfish migrated downstream primarily in April and May in 1949 and 1950. In 1950 there was also considerable migration throughout June. In 1949, 441 crayfish migrated downstream, and in 1950 there were 1,698.

(2) Females comprised the majority of the downstream migrants. The sex ratio in April and May departed significantly from a 1:1 ratio for the downstream migrants. Later on, the percentage of males increased so that the ratio of males to females was not quite significantly different from the 1:1 ratio.

(3) Three classes of females appeared in the migration: Those without eggs or larvae; those with good eggs or larvae; those with black eggs.

(4) The upstream migration occurred primarily during September, October, and November in 1949 and 1950. It was unique in the small numbers of individuals observed in comparison to the numbers observed migrating downstream. In 1949, 232 crayfish were observed migrating upstream, and in 1950, 226 were observed migrating upstream.

(5) Males and females were in nearly equal numbers in the observed upstream migrations, and the sex ratio did not depart significantly from a 1:1 ratio.

(6) Attempts at tagging these crayfish were not entirely satisfactory; only three crayfish have been recovered out of 70 tagged and two of these only five days later.

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TABLE 1.

CRAYFISH—DOWNSTREAM MIGRANTS AT SPRING CREEK WEIR

	Males			*Females with eggs or larvae*			*Females without eggs or larvae*					
	No.	*Ave. Lgth. (mm)*	*Range*	*No.*	*Ave. Lgth. (mm)*	*Range*	*No.*	*Ave. Lgth. (mm)*	*Range*	*Sex Unknown*	*Total No.*	*MM/FF*
1949:												
January	......	......	......	......	......	......	......	......	......	......	......	......
February	......	......	......	......	......	......	......	......	......	......	......	......
March	......	......	......	6	73.0	61–78	......	......	......	1	7	......
April	32	61.0	49–96	44	78.9	67–101	46	56.5	30–85	6	128	0.36
May	68	63.5	47–96	55	76.7	64–97	65	56.9	29–84	......	188	0.57
June	5	60.6	49–75	......	......	......	3	56.7	53–61	......	8	1.67
July	1	59.0	......	......	......	......	......	......	......	......	1	......
August	......	......	......	......	......	......	......	......	......	......	......	......
September	21	79.0	46–96	1	72.0	......	5	70.4	60–83	1	28	3.50
October	17	61.8	50–96	6	74.5	67–83	10	61.6	50–71	1	34	1.06
November	16	69.7	45–93	12	76.9	70–87	12	62.9	47–75	......	40	0.67
December	1	69.0	......	2	73.0	68–78	4	62.0	44–83	......	7	0.17
Total No.	161	......	......	126	......	......	145	......	......	9	441	0.59
1950:												
January	1	79.0	......	......	......	......	1	74.0	......	......	2	1.00
February	2	67.5	65–70	5	80.0	72–85	1	50.0	......	......	8	0.33
March	5	75.8	57–88	10	76.3	69–84	5	58.6	48–75	......	20	0.33
April	55	64.1	29–96	114	80.0	53–110	35	59.5	45–75	......	204	0.37
May	304	67.7	45–100	178	76.2	58–97	265	61.8	42–89	2	749	0.69
June	179	72.6	40–100	45	75.5	60–90	119	65.7	36–90	......	343	1.09
July	129	71.4	43–97	13	77.6	70–85	139	69.2	43–85	......	281	0.85
August	46	69.7	56–88	......	......	......	23	69.6	58–80	......	69	2.00
September	5	75.6	72–81	......	......	......	3	60.3	58–62	......	8	1.67
October	8	67.8	49–99	......	......	......	2	69.5	69–70	......	10	4.00
November	3	60.7	55–70	1	78.0	......	......	......	......	......	4	3.00
December	......	......	......	......	......	......	......	......	......	......	......	......
Total No.	737	......	......	366	......	......	593	......	......	2	1,698	0.77

TABLE 2.

CRAYFISH—UPSTREAM MIGRANTS AT SPRING CREEK WEIR

	Males			*Females without eggs or larvae*			*Females with eggs or larvae*					
	No.	*Ave. Lgth. (mm)*	*Range*	*No.*	*Ave. Lgth. (mm)*	*Range*	*No.*	*Ave. Lgth. (mm)*	*Range*	*Sex Unknown*	*Total No.*	*MM/FF*
1949:												
September	11	63.2	46–77	9	68.9	49–80	......	......	......	30*	50	1.22
October	86	53.5	31–74	70	54.6	41–72	4	75.8	73–82	1	161	1.16
November	10	51.9	42–59	10	54.9	38–69	1	72.0	......	......	21	0.91
Totals	107	......	......	89	......	......	5	......	......	31	232	1.14
1950:												
January	1	71.0	......	2	71.0	71	......	......	......	......	3	0.50
February	......	......	......	1	71.0	......	......	......	......	......	1	......
March	......	......	......	......	......	......	......	......	......	......	......	......
April	2	70.5	55–86	......	......	......	......	......	......	......	2	......
May	1	92.0	......	......	......	......	......	......	......	......	1	......
June	......	......	......	1	74.0	......	......	......	......	......	1	......
July	......	......	......	2	78.0	74–82	......	......	......	......	2	......
August	......	......	......	......	......	......	......	......	......	......	......	......
September	34	65.9	54–81	22	70.8	74–82	......	......	......	......	56	1.55
October	72	58.3	46–87	69	60.6	46–76	1	70.0	......	15	157	1.03
November	2	61.0	52–70	1	60.0	......	......	......	......	......	3	2.00
Totals	112	......	......	98	......	......	1	......	......	15	226	1.13

* Estimated number trapped between walls of upstream trap.