

RESULTS OF PRELIMINARY SHRIMP EXPLORATIONS OFF THE OREGON COAST

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Introduction

Fishing for shrimp along the Pacific Coast started as early as 1869 in San Francisco Bay (Bonnot, 1932) and commercial fishing for shrimp has long been conducted in Alaska, British Columbia, and Puget Sound, Washington. However, no commercial shrimp fishery of any size has yet developed off the Pacific Coast of North America between the Gulf of California and the Straits of Juan de Fuca.® It has long been known, however, that shrimp of commercial size do occur in these waters. There are numerous records of such shrimp being taken by government vessels engaged in scientific work, and commercial otter-trawlers often catch small numbers of shrimp along with the various species of fish which form the basis of their livelihood.

Until recently, no serious attempts had been made to answer the question of whether shrimp were present in commercial quantities in the waters between Point Conception and the Columbia River. During the fall of 1950 and the spring and summer of 1951, the Bureau of Marine Fisheries of the California Department of Fish and Game conducted explorations off the coast of California for the purpose of determining if shrimp were present in commercial quantities. The results of these explorations were very encouraging, and as a result a commercial fishery for shrimp has been started in California waters.

Shrimp were located in California waters as far north as the Oregon border. This suggested that shrimp should also be found in Oregon waters. Through the efforts of William Ellis Ripley, who directed the shrimp exploratory work off California, one of the shrimp trawls belonging to the California Bureau of Marine Fisheries was secured on loan by the Fish Commission of Oregon, and explorations for shrimp were started during the fall of 1951. During the winter of 1951-52, the Fish Commission of Oregon purchased gear almost identical to that used by California. There were two major objectives in the explorations off Oregon. First was the opportunity to render a direct service to the fishing industry; and second was the desire to obtain information concerning the virgin shrimp populations as they exist before being subjected to a possible commercial fishery.

Acknowledgement

We wish to express our gratitude to the Department of Fish and Game of California, and to acknowledge the many helpful suggestions received from William Ellis Ripley concerning our exploratory work. We also wish to express our thanks to Dr. James E. Lynch of the School of Fisheries, University of Washington, for his help in the identification of the shrimp

① Now employed by the Washington State Department of Fisheries.

② Recent reports from California indicate that approximately 200,000 pounds of pink shrimp were landed in 1952 by two boats operating from Morro Bay, California.

obtained during our exploratory work. Hugo Lillienthal, owner of the *Nel Ron Dic*, donated his services and the use of his boat for the last two trips off Coos Bay. Robert Rulifson, biologist with the Fish Commission of Oregon, accompanied the *Nel Ron Dic* on these last two trips. George Miller, former temporary biologist with the Fish Commission of Oregon, and Eldon Korpela, former biologist with the Fish Commission, accompanied the vessel on several trips and helped to organize the data here presented. Jack Van Hyning and Kenneth Waldron, biologists with the Fish Commission, each made one exploratory trip.

Methods and Materials

The beam trawl used in the exploratory work consists of two horseshoe-shaped runners connected by two beams, and a funnel-shaped net with the open end of the net connected to the ends of the runners. The beams consist of two pieces of heavily galvanized pipe each 10 feet in length and 3½ inches outside diameter. The runners are constructed of steel strap 3½ inches wide and ½ inch thick. The runners on the beam used in 1952 were increased to 8 inches in width on the bottom half. The bridle used to tow the trawl is 10 feet long and made of ¾-inch diameter steel wire rope. Two swivels were attached between the head of the bridle and the single cable running from a winch on the fishing vessel.

The beams were filled with steel slugs to increase the weight of the trawl from its normal weight of approximately 320 pounds to a weight of about 700 pounds. This was necessary in order to sink the trawl to the bottom when fishing in deep water.

The body of the net used in the 1951 explorations was made of 3½-inch stretched mesh, including one knot, and the cod end was of 1-inch mesh, 12-thread twine. In 1952, a 1-inch mesh net throughout was used on the first trip of the season aboard the *Destiny*. This 1-inch mesh net was lost on the first drag of the next trip made aboard the *Nel Ron Dic* in April. For the remainder of this latter trip, the net used in 1951 was placed in operation. This net was modified for the remainder of the trips by changing the fyke in the net to 1-inch mesh. The mouth of the net was completely encircled by a lead line, and the top of the lead line was lashed to the front beam of the trawl so as to furnish an overhang.

Although more shrimp would have been caught with a net constructed of 1-inch mesh throughout, such a net was not available in 1951 when the explorations were first conducted. Tentative results obtained by the Department of Fish and Game of California, however, indicate that a net of 1-inch mesh construction throughout fishes from five to seven times as effectively as the type with a 3½-inch mesh in the body and a 1-inch mesh cod end.

The beam trawl was towed by a single cable running from a winch on the starboard side of a commercial otter-trawl vessel. The trawl was placed in the water and brought aboard the vessel by means of a hook line running from the boom on the vessel. The trawl framework was usually placed on the stern of the vessel inside of the gunwales. The net was ordinarily pulled aboard by hand, except when a large haul was obtained, at which time it was brought aboard by means of a hook line running from the vessel's boom.

Because of the limited facilities and time, it was evident that the areas of exploration would have to be rather restricted. The areas to be explored

were chosen on the basis of two factors. Since the experience of the California Department of Fish and Game indicated that shrimp were found on a green mud bottom, areas with such a bottom were given primary consideration. In addition, many commercial otter-trawl fishermen were interviewed in order to determine the areas in which they found the largest quantities of shrimp.

Following California's example, drags were made at right angles to the coast from shallow to deep water until the center of abundance of the shrimp was located. This contour was then followed up and down the coast when possible, until shrimp were no longer taken. Drags were then again made at right angles to the coast as a check against the possibility of the shrimp being located at different depths in the different areas.

Each drag was of 15 minutes duration, with the exception of those made off Coos Bay on the last two trips aboard the *Nel Ron Dic* which lasted for 30 minutes. The time counted was that actually spent by the net on the bottom. The net was considered to be on the bottom between the time the winch stopped after letting the cable out and the time the winch started up again to pull in the beam trawl. Although the net does not actually leave the bottom when the winch starts to wind in the cable, no simple method was found to compensate for this factor.

Although the primary objective of the exploratory work was to determine if shrimp were present in commercial quantities off Oregon, efforts were also made to learn something of the life history of the pink shrimp. Samples from most of the drags containing shrimp were accordingly saved and examined in the laboratory at the conclusion of each exploratory trip. While at sea, the shrimp were placed on ice in the vessel's hold; and upon return of the vessel to port, the shrimp were frozen or preserved in formalin for future use. In the laboratory, the lengths of the shrimp were recorded. Berkeley (1930) found variation in the length of the rostrum of the same size shrimp, and for that reason she recommended that the rostrum be omitted from body length measurements. Another reason for the omission is that a large percentage of the shrimp have broken rostrums as a result of handling.

The measurements given in this paper include the distance, in millimeters, from the posterior base of the eyestalk to the tip of the telson when the shrimp is straightened out so that the longest possible measurement is obtained.

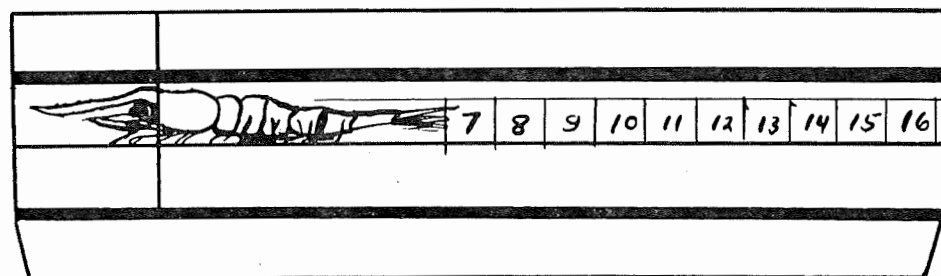


Figure 1. DIAGRAM OF DEVICE USED TO MEASURE SHRIMP.

In order to facilitate the measurement of the shrimp, a simple measuring device was constructed (Figure 1). A steel tape graduated in millimeters

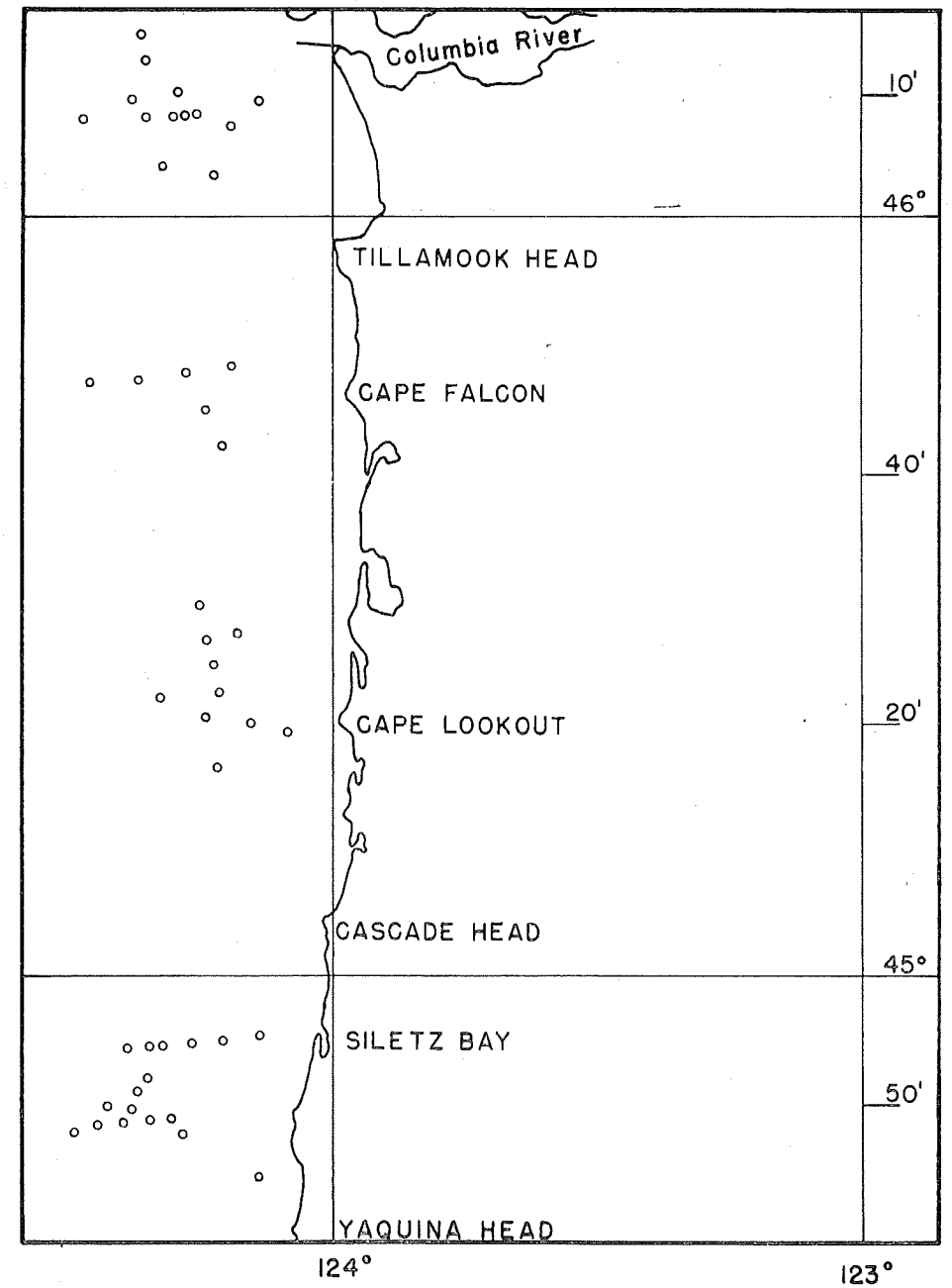


Figure 2. LOCATION OF EACH DRAG MADE IN 1951.

was glued in the groove of the measuring board, and a steel wire of small diameter was attached to the board so that the wire was superimposed over

the 0-mm. mark on the tape. Each shrimp to be measured was placed on its side in the groove of the board with its ventral surface pressed against the side of the board, and then slid forward until the wire was directly over the posterior base of the eyestalk. The length in millimeters to the tip of the telson was then recorded.

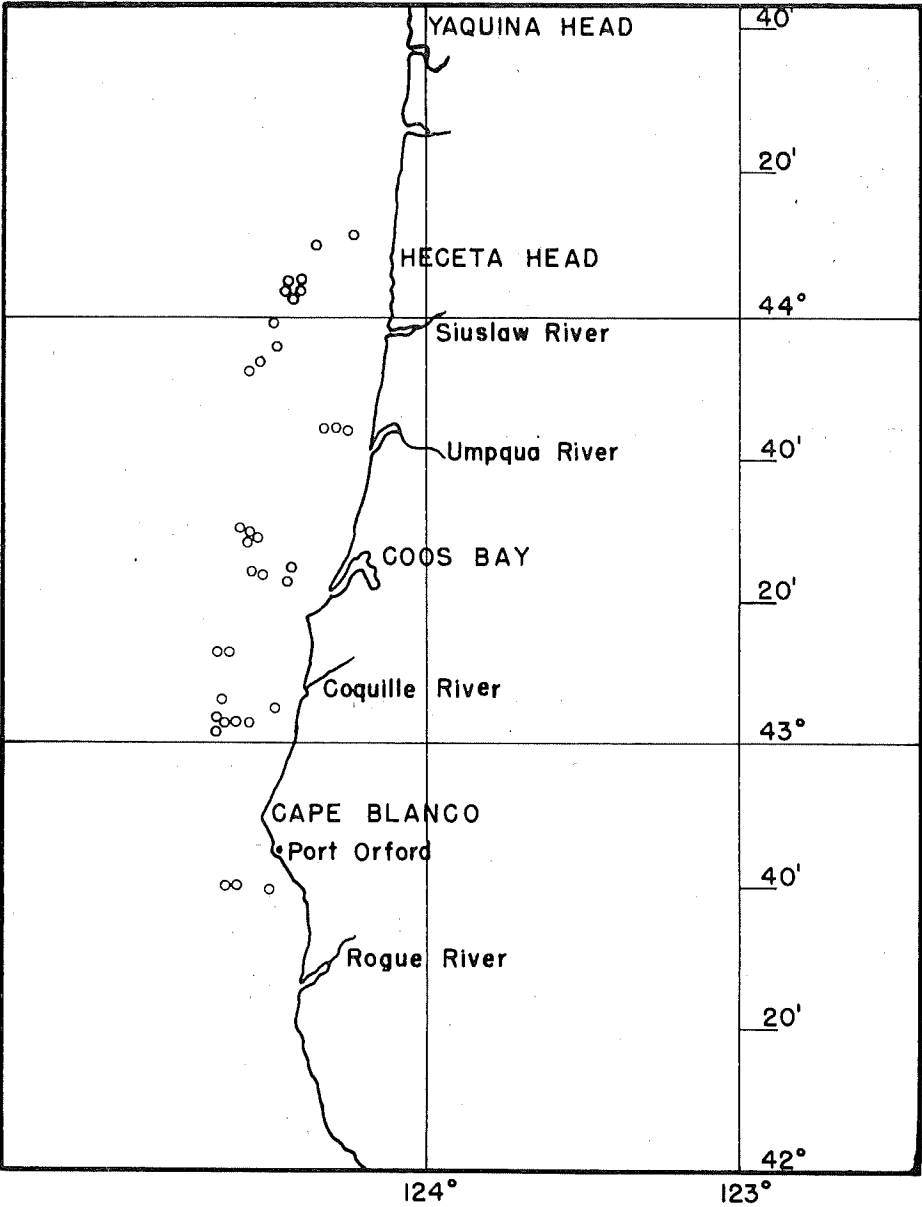


Figure 3. LOCATION OF EACH DRAG MADE IN 1952.

Most of the shrimp taken in the exploratory drags were of one species, *Pandalus jordani*. The sex of *Pandalus jordani* may be determined from an

examination of the structure of the inner ramus of the first pleopod, or abdominal leg. A small rounded body, the organ of copulation, is present on the inner ramus of the males. The females do not have this organ of copulation, and the tip of the ramus is more pointed than in the male.

In addition, the males have a structure known as the appendix masculina on the inner side of the inner ramus of the second pleopod. This structure is absent on the females.

The first pleopod was examined under the magnification of approximately 2 diameters. In most cases, such an examination was sufficient to determine the sex. In doubtful cases, however, the second pleopod was examined for the presence of an appendix masculina.

Results

Drags were made between the Columbia River and Yaquina Bay in October, 1951, (Figure 2) and between Yaquina Bay and the Rogue River in 1952 (Figure 3). Each dot represents one drag.

Species other than the pink shrimp were frequently taken, but they at no time accounted for more than a small percentage of the total catch. For example, samples taken from two separate hauls included 1,556 shrimp, of which 88 per cent were *Pandalus jordani*, 9 per cent were *Crago* species, and 3 per cent were *Spirontocaris* species.

Shrimp were taken in practically all the areas explored where the bottom was green mud and the depth between 60 and 80 fathoms (Table 1). The pounds listed in the table refer to the actual amounts caught in the net, but it should be mentioned again that if a net of 1-inch mesh construction throughout had been used in 1951 an estimated five to seven times as many shrimp would have been caught.

TABLE 1.
AMOUNTS OF PINK SHRIMP (*Pandalus jordani*) TAKEN IN THE INDIVIDUAL AREAS OF EXPLORATION.

Area	Number of drags	Number of drags containing shrimp	Total pounds of shrimp caught	Pounds of shrimp per drag ①
3½-inch mesh net with 1-inch bag, 15-minute drags				
Off Columbia River	13	8	81.0	10.1
Off Cape Falcon	6	3	18.0	6.0
Off Cape Lookout	10	8	69.0	8.6
Off Siletz Bay	17	11	58.5	5.3
Off Coquille River	9	6	34.5	5.8
Off Port Orford	3	0	0.0	0.0
1-inch mesh throughout, 15-minute drags				
Off Siuslaw River	11	5	79.5	15.9
Off Umpqua River	3	3	5.5	1.8
3½-inch mesh with 1-inch bag and fyke, 30-minute drags				
Off Coos Bay	8	7	1,075	153.6

Almost all of the shrimp were taken in waters between 60 and 80 fathoms in depth (Table 2). Because of gear limitations, it was not possible to explore in water of a depth greater than 100 fathoms.

① Includes only those drags in which shrimp were caught.

TABLE 2.
AMOUNTS OF PINK SHRIMP (*Pandalus jordani*) CAUGHT BY DEPTH OF WATER
IN THE INDIVIDUAL AREAS OF EXPLORATION.

Area	Depth in fathoms	Number of drags	Pounds of shrimp caught	Pounds of shrimp caught per drag
3½-inch mesh net with 1-inch bag, 15-minute drags				
Off Columbia River	31-50	1	0	0
	51-60	6	49	8
	61-70	5	33	7
	71-80	1	0	0
Off Cape Falcon	51-60	1	0	0
	61-70	1	0	0
	71-80	2	14	7
	81-90	1	4	4
	91-100	1	1	1
Off Cape Lookout	31-50	1	0	0
	51-60	2	1	½
	61-70	3	37	12
	71-80	3	28	9
	81-100	1	5	5
Off Siletz Bay	31-50	2	0	0
	51-60	2	0	0
	61-70	2	3	2
	71-80	5	41	8
	81-90	3	12	4
	91-100	3	4	1
Off Coquille River	31-40	1	0	0
	41-50	0	0	0
	51-60	1	0	0
	61-70	2	6	3
	71-80	4	28	7
	81-90	1	0	0
Off Port Orford	31-40	1	0	0
	41-50	0	0	0
	51-60	0	0	0
	61-70	1	0	0
	71-80	1	0	0
1-inch mesh throughout, 15-minute drags				
Off Siuslaw River	31-40	1	0	0
	41-50	1	0	0
	51-60	0	0	0
	61-70	6	77	13
	71-80	2	0	0
	81-90	1	1	1
Off Umpqua River	41-50	1	0	0
	51-60	2	5	3
3½-inch mesh net, 1-inch bag, 1-inch fyke; 30-minute drags				
Off Coos Bay	51-60	3	350	117
	61-70	2	325	163
	71-80	0	0	0
	81-90	2	350	175
	91-100	1	175	175

The results of the explorations suggest that shrimp are present in sufficient numbers off the Oregon coast to support a commercial fishery. As opportunity permits, further explorations will be made along the Oregon coast.

The number of shrimp (whole and headed) per pound varies considerably in the different areas (Table 3). The tails of the shrimp, including the shells, made up almost 54 per cent of the total weight (Table 3, Per cent yield).

TABLE 3.
NUMBER OF PINK SHRIMP (*Pandalus jordani*)—WHOLE AND HEADED—PER
POUND IN THE INDICATED AREAS OF EXPLORATION.

Area	Number of whole shrimp per pound	Number of headed shrimp per pound	Percent yield (including shell on tail)
Off Columbia River	103	192	54
Off Cape Falcon	123	231	53
Off Cape Lookout	105	194	54
Off Siletz Bay	140	260	54
Off Siuslaw River	190		
Off Coquille River	140		
Off Coos Bay	108		

The varying number of shrimp per pound in the different areas is accounted for mostly by the change in the sex ratio from one area to another. Because the males are smaller than the females, in the areas where there was a greater percentage of males there were also more shrimp per pound. Even within a generalized area, such as off Coos Bay, the number of shrimp per pound varied from drag to drag. For example, in 70 fathoms off Coos Bay there were 178 shrimp per pound; but at 90 fathoms, 81 shrimp per pound. Commercial fishermen would undoubtedly seek out these particular areas where the larger shrimp are found.

Observations Concerning the Life History of *Pandalus jordani*

Berkeley (*ibid*) in her paper on the commercially important shrimps of British Columbia, found that all the species examined of the genus *Pandalus* underwent a change of sex. The species studied by Berkeley start their lives as males, function as males once or twice, and then change to the female phase and remain females for the balance of their lives.

Unfortunately, Berkeley did not present any information in her paper concerning *Pandalus jordani*, but the following discussion of our observations demonstrates that this species probably has a life history similar to those worked out by Berkeley.

Length-frequencies (smoothed by a moving average of three) obtained during 1951 in the four general areas of exploration illustrate that there were two well-defined size groups present in the catches (Figure 4). The smaller of the two consists of males, which have a modal length of about 62 mm., and the larger consists of females with a modal length of about 78 mm. Occasionally small males belonging to a third group of about 35 mm. in length are captured. A suggestion of this smallest group is found in the length-frequencies of the shrimp taken off Cape Falcon and Siletz Bay.

Length-frequencies of *Pandalus jordani* were obtained off Siletz Bay on October 28, 1951, about three weeks later than those illustrated in Figure 4 (Figure 5). The general features of the two figures are the same, but Figure 5 is shown because it includes a fairly large sample of the smallest size group of shrimp. Whereas the two largest size groups of shrimp were measured after being frozen and allowed to thaw, the fragile nature of the smallest size group required that they be hardened in formalin before being measured. No correction factor has been applied to the data to

compensate for any unequal shrinkage which may have resulted from the two different methods of preservation.

The shrimp taken in March, 1952, off the Siuslaw River were mostly males (Figure 6). The mode of their length-frequencies falls between the

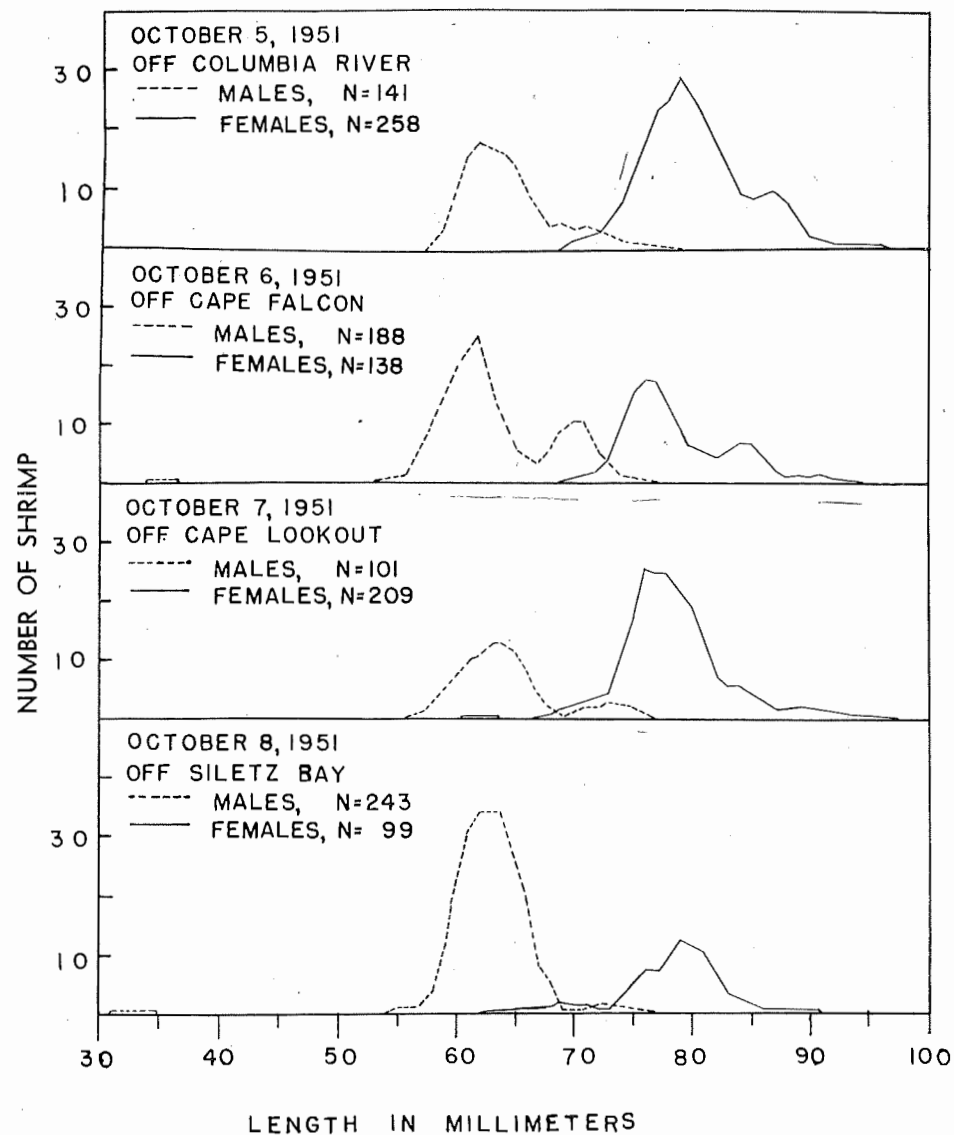


Figure 4. LENGTH-FREQUENCIES OF SHRIMP CAUGHT OFF THE OREGON COAST IN 1951.
(All figures smoothed by threes)

two modes for males shown in Figure 5, and may represent growth of the shrimp in the smaller mode. The males taken in April, 1952, southwest of Bandon, were similar in size to the majority of the males taken in 1951. The length-frequency mode of the females taken in this area was at a size

greater than the modes of 1951. This suggests the possibility of another age group at a larger size than those found in 1951. Males predominated in water from 57 to 70 fathoms off Coos Bay in late May. The size mode of these males was similar to the principal mode found in 1951. However, in the deeper water, from 84 to 97 fathoms, the sex ratio changed and relatively more females were present. The length-frequency mode of these females was again at a size greater than any of the 1951 modes which adds evidence

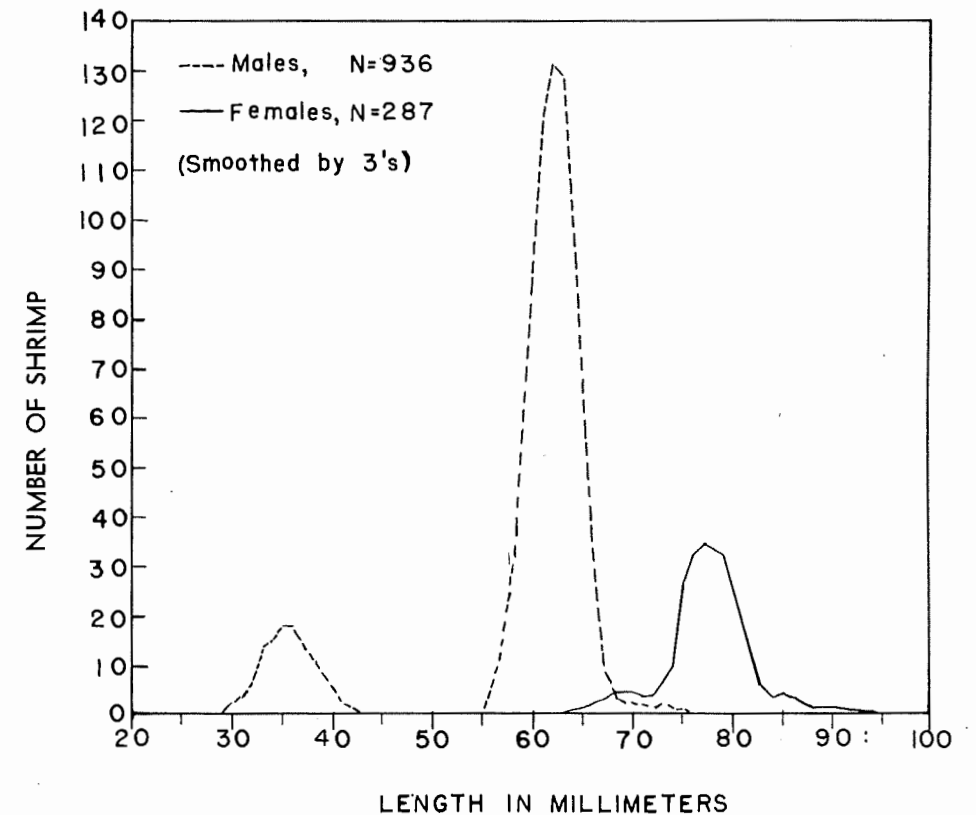


Figure 5. LENGTH-FREQUENCY OF SHRIMP TAKEN OFF SILETZ BAY OCTOBER 28, 1951.
(Smoothed by threes)

to the theory that there is an age group of larger females present. All of the 1952 shrimp were preserved in formalin before being measured.

Several of the figures indicate the presence of males among the size groups of smaller females. These may be males which are in the process of changing sex to become females.

Although it would be necessary to follow the progression of the length-frequency modes throughout a period of 1 year before any conclusions concerning the age of the shrimp could be justified, it may be theorized that each distinct mode illustrated represents a separate age group of shrimp. If such is the case, probably four separate age classes of *Pandalus jordani* are found in the catches. The two youngest are males and the two oldest consist of females.

Less than 3 per cent of the females obtained in the various areas of exploration from October 5 through October 8, 1951, were carrying eggs, but 42 per cent of the females examined about 3 weeks later on October 28 bore eggs. When the explorations started again the following year, the

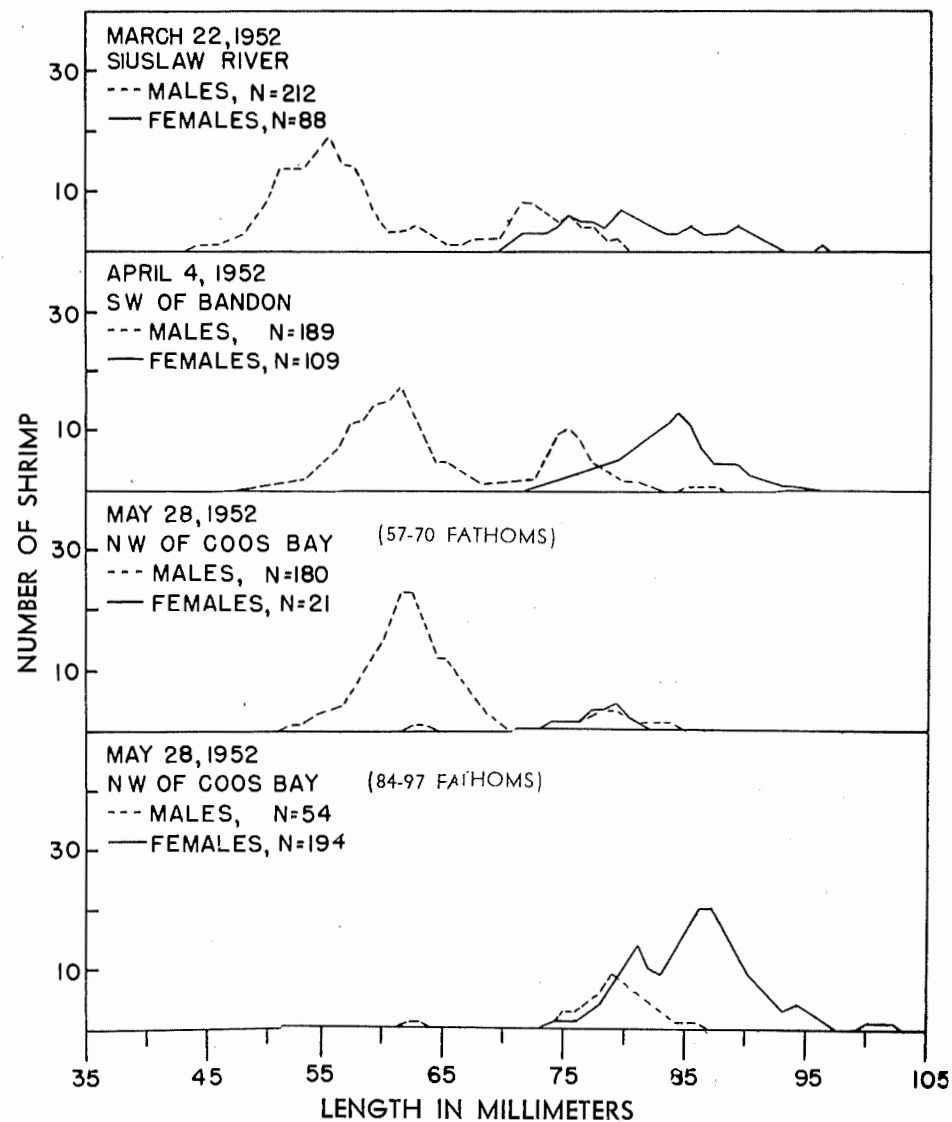


Figure 6. LENGTH-FREQUENCIES OF SHRIMP CAUGHT OFF THE OREGON COAST IN 1952.
(All figures smoothed by threes)

females sampled on March 22 were 11.4 per cent egg-bearing. On April 4, 23.8 per cent of the females were egg-bearing, and on May 28 none of the females sampled carried eggs.

The length-frequencies of both egg-carrying and non-egg-carrying females taken on October 28 are similar, indicating that both the large

and small females attain the egg-carrying stage at about the same time (Figure 7).

If a commercial fishery for the pink shrimp should develop off Oregon, an important item of consideration in the management of such a fishery would be the effect of the small mesh nets upon the stocks of commercially important fish and shellfish found in the same areas as the shrimp. During the exploratory work, therefore, a careful tabulation was

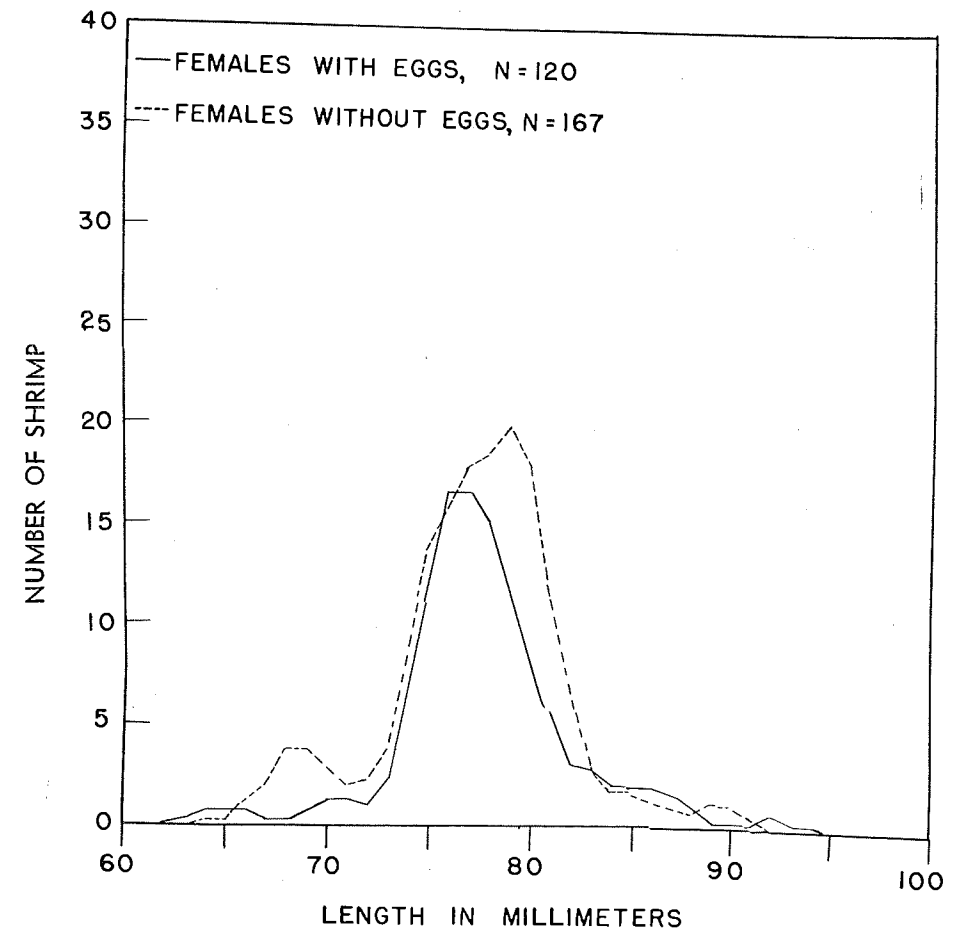


Figure 7. LENGTH-FREQUENCIES OF EGG-BEARING AND NON-EGG-BEARING SHRIMP TAKEN OCTOBER 28, 1951. (Smoothed by threes)

made of all species of fish and shellfish taken in the shrimp net. In addition, lengths and sex ratios of the commercially important species of fish and shellfish taken in the shrimp hauls were obtained.

In general, an inverse relationship was found to exist between the number of shrimp and the number of fish taken in the drags. Drags producing the most shrimp usually yielded the smallest number of fish.

By far the most numerous species of fish taken in the shrimp hauls were small specimens of slender sole (*Lyopsetta exilis*), rex sole (*Glyptocephalus zachirus*), and mottled sand dabs (*Citharichthys sordidus*). Dover sole

(*Microstomus pacificus*) of a commercial size were regularly taken in small numbers along with the shrimp. In addition, negligible numbers of petrale sole (*Eopsetta jordani*), turbot (*Atheresthes stomias*), hake (*Merluccius productus*) and various species of rockfish (Scorpaenidae), sea poachers (Agonidae), and ell pouts (Zoarcidae) were taken along with the shrimp.

With the exception of a very small number of scallops (Pectinidae), snails (Gastropoda), and anomurans (chiefly *Munida quadrispina*), virtually no shellfish were taken along with the shrimp.

At depths between 90 and 100 fathoms sea urchins (Echinoidea) were taken consistently in the net in quite large numbers. Although no attempt was made to count the sea urchins, it is quite possible that they may be present in such large numbers as to prevent a successful fishery at such depths. Fortunately, the center of abundance of the shrimp was found to occur in waters of a depth less than 90 fathoms where the number of sea urchins is not believed to be sufficiently large to hinder seriously fishing operations.

Summary

During the months of October, 1951, and March, April, and May, 1952, a total of 80 exploratory shrimp drags were made off the Oregon coast between the Columbia River and the Rogue River. Pink shrimp (*Pandalus jordani*) were taken in sizeable quantities in most of the areas explored.

The largest concentrations of shrimp were taken in areas with a green mud or mixed mud and sand bottom.

No pink shrimp were taken in less than 50 fathoms, and the center of abundance was found to occur at depths between 60 and 80 fathoms.

Four definite size groups of pink shrimp are present in the catch; two are males and two females.

Less than 3 per cent of the females taken on October 5 through October 8, 1951, were carrying eggs, but 42 per cent of the females examined about three weeks later were egg-bearing. On March 22, 1952, eleven per cent of the females were egg-bearing; on April 4, twenty-four per cent were egg-bearing; and on May 28, no females in the samples carried eggs.

The larger females apparently do not attain the egg-carrying stage before the smaller females.

An inverse relationship was found between the number of shrimp and the number of fish taken: drags producing the most shrimp usually yielded the smallest number of fish.

The Fish Commission of Oregon will continue the shrimp explorations as opportunity permits.

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