

1968. In an effort to shorten the report, much admittedly useful and interesting background and historical information has been omitted. Apologies are extended to Richard Croker for this condensation and with grateful acknowledgment for the tremendous amount of work and research that went into the original report.

Thanks are due, too, to the several American Embassies whose Economic and Commercial Officers were so helpful in providing up-dated information when personal visits were not possible. In the countries that the reporting officer visited, these officers and many Government and private people provided valuable help and cooperation.

In the interest of brevity, the list of references contained in the original report will not be repeated here. For those interested, this list can be obtained from the International Activities Staff, National Marine Fisheries Service, U.S. Department of Commerce (Page Bldg.2, Room 249), Washington, D.C. 20235.

*MFR Reprint 971. From Marine Fisheries Review, Vol. 35, Nos. 3-4. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

MFR REPRINT 972

*California's ocean shrimp industry had over 2 million pounds of landings in 1972, most of it coming from the northern part of the state.*

## Status of the California Ocean Shrimp Resource and Its Management

W.A. DAHLSTROM

### HISTORY OF THE FISHERY

One of the youngest commercial fisheries in California is that for ocean shrimp, *Pandalus jordani*. This species was first fished in California off Morro Bay on April 28, 1952. Later on in the 1950's, fisheries developed off Bodega Bay, Fort Bragg, Eureka, and Crescent City in California and also along the coast of Oregon and Washington.

During 1950 and 1951, exploratory fishing by marine biologists of the California Department of Fish and Game laid the groundwork for utilizing this latent resource. During cruises off the California coast on the research vessel, *N.B. Scofield*, five dense concentrations

of ocean shrimp were charted. Regulations for the new fishery were established by the California Fish and Game Commission in 1952, and the first catches were made later that year. Three regulatory areas were designated, catch quotas were established for each area, mesh size restrictions were initiated, and a season was set. The three regulatory areas were Area A, Oregon border south to False Cape; Area B, False Cape south to Pigeon Point; and Area C, Pigeon Point south to Rincon Point (Santa Barbara-Ventura County line). By 1956 it had become apparent that a portion of one of these areas (B) was not being fully utilized. Therefore, it was divided into two areas; B-1 extending from False Cape to Point Arena, and B-2 from Point Arena to Pigeon Point (Figure 1). Each area was allotted separate quotas. Another change occurring in the 1960's was the extension of the

Area C boundary from Rincon Point to the Mexican border.

The fishery off Morro Bay in Area C was first to develop. Landings of 197,944 and 198,505 pounds were made in 1952 and 1953 respectively (Table 1). Fishing also took place in Areas A and B (later to be designated B-2), but during

**W.A. Dahlstrom is a member of the staff of the California Department of Fish and Game. He is stationed at its Marine Resources Laboratory, 411 Burgess Drive, Menlo Park, Calif. This paper originally was issued as Marine Resources Technical Report No. 14, 1973, and is reprinted with permission of the California Department of Fish and Game. The photographs were provided by the California Department of Fish and Game.**

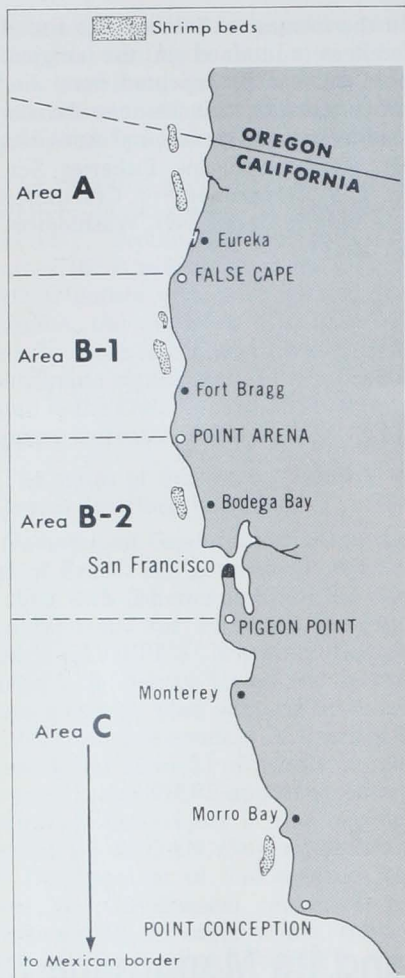


Figure 1.—Fishing areas for ocean shrimp off California.

the same time landings were of a smaller magnitude and ranged from just 4,000 to 45,000 pounds. In 1954 landings declined drastically at Morro Bay and never have since come close to the level of the first two years of fishing. The Area A and Area B (Bodega Bay) fisheries developed quickly and by 1955, 506,433 pounds and 330,681 pounds were landed in these areas respectively. Landings peaked at 450,495 pounds at Bodega Bay in 1957. The landings declined in 1958 and have been sporadic ever since. Area A landings climbed steadily through the late 1950's and early 1960's and reached a peak of 1,860,216 pounds in 1963. From 1964 to 1966 the landings declined to about 1,000,000 pounds per season but started climbing in 1967 and reached a record level of 3,586,370 pounds in 1970. Landings declined somewhat in 1971 and 1972.

The Area B-1 (Fort Bragg) fishery developed in 1957. Landings rose steadily each season and reached a peak of 799,592 pounds in 1961. Since that time the fishery has declined, and only a few thousand pounds have been landed with the exception of the 1972 season, when 102,362 pounds were landed.

The fishery for shrimp occurs during the period from April 15 to October 31 or for a shorter time within the above period if the quota in any area is reached.

Landings and effort have been compiled for all areas since the start of the fishery in 1952. As expected, Area A has had the most effort. Amount of fishing hours per season in this area during the period from 1960 to 1972 has ranged from 1,800 hours in 1964 to 5,947 hours in 1971 (Table 2). The number of vessels has increased steadily to a high of 26 in 1971. Highest catch per hour on record for Area A is 1,217 pounds, attained in 1968.

Market samples of ocean shrimp are taken to determine carapace length, sex, age, and heads-on count per pound. Most of the shrimp in the fishery are in the second and third year of life (I+ and II+). Comparisons of carapace lengths by year from 1969 to 1972 by year class in Area A show different growth rates. The 1969 year class in 1970 was definitely larger compared to other one-year-old shrimp during the period from May to August (Table 3). Over the same time period the odd year classes of 1967 and 1969 were one to two millimeters larger than the even year classes of 1968 and 1970 as two-year-old shrimp.

Ocean shrimp, when caught, range in

age from six months to about four years old in California. They do not reach marketable size until they are a year old. When they have completed spawning at about three years of age, they die in great numbers and thereafter contribute a minor percentage to the fishery. Very few survive to their fourth birthday or beyond.

## REGULATION AND MANAGEMENT

Otter trawls and beam trawls are legal gear used to catch ocean shrimp. From 1952 to 1962, shrimp fishermen were limited to the use of beam trawls. In 1963 fishermen were permitted to use otter trawls. Since that time no beam trawls have been used. The minimum mesh size of the net is 1.5 inches stretch measure between the knots. It was felt that this mesh size provides greater escapement of the small one-year-old shrimp.

The season starts on April 16 and ends on October 31 or earlier if the quota is reached. This time period corresponds with the time when most of the females are not carrying eggs and forms the basis for the season.

Quotas proposed for the 1973 season are 3.2 million pounds for Area A and 250,000 pounds each for Areas B-1, B-2 and C. The quota for Area A since 1969 has been established by a population model designed by Department of Fish and Game statisticians. The model estimates population size and safe harvest levels. Quotas in the other areas have remained at 250,000 pounds each since 1962.

Table 1. Ocean Shrimp Landings (in Pounds) by Area.

Year	Area A	Area B-1	Area B-2	Area C	Total
1952	3,876	—	3,665	197,944	205,485
1953	27,484	—	45,343	198,505	271,332
1954	168,881	—	112,751	8,510	290,142
1955	506,433	—	330,681	1,442	838,556
1956	895,596	—	272,583	closed	1,168,179
1957	694,978	228,097	450,495	260	1,373,830
1958	1,142,274	324,839	172,804	88,763	1,728,680
1959	1,327,402	443,282	86	14,544	1,785,314
1960	1,303,922	529,652	110,252	74,831	2,018,657
1961	1,203,117	799,592	180	—	2,002,889
1962	1,537,458	250	245,247	—	1,782,955
1963	1,860,216	27,700	204,957	190	2,093,063
1964	932,133	1,210	34,982	—	968,325
1965	1,164,221	4,200	252,663	—	1,421,084
1966	1,182,421	3,750	520	506	1,187,197
1967	1,407,280	275	888	—	1,408,443
1968	2,079,110	—	190,810	—	2,269,920
1969	2,947,563	—	—	—	2,947,563
1970	3,586,370	—	298,769	66,695	3,951,834
1971	3,077,248	525	700	2,110	3,080,583
1972	2,118,527	102,362	213,452	—	2,434,341

## BIOLOGICAL DATA

### Distribution

Ocean shrimp are found from Unalaska to San Diego, California at depths of from 120 to 1,500 feet. In California, the species is generally found from depths of 240 to 750 feet over a green mud of mixed mud and sand bottom.

### Migration

Migrations of this species appear to be mostly local. Adults from the different beds probably do not intermix but the planktonic larvae may be carried long distances and could conceivably intermingle with those of closely associated beds. Seasonal migrations of adults either inshore or offshore and also coastwise have been noted within the confines of the bed. Even during the fishing season distribution shifts have been observed according to location of fishing effort. This species is very gregarious and its schooling habits generally enable the fishermen to obtain good comparative catches of pink shrimp with very few fish and other invertebrates. Night and day trawling has detected evidence of diurnal vertical movements; this resulted in excellent catches during the day and poor catches at night. Movement off the bottom also has been demonstrated by midwater trawl catches off Vancouver Island, British Columbia and by suspended trap catches in midwater depths off the coast of Oregon. These migrations may extend to the surface and may be associated with feeding activities on plankton.

### Life History

Most ocean shrimp are protandric hermaphrodites. The normal pattern is for an individual to mature and function as a male during the second or third year of life and then change sex, mature, and function as a female. However, deviations from this normal pattern have been noted, with the appearance of primary females (nonhermaphroditic) during the second year of life. During some years, a large percentage (up to 70 percent) of the one-year-old shrimp become females and never function as males.

Table 2. Area A Landings, Effort and Catch per Hour.

Year	Landings (Pounds)	Effort (Hours)	Pounds/Hour	Vessels
1960	1,328,400	2,489	533	12
1961	1,206,847	1,924	627	9
1962	1,540,700	3,193	483	12
1963	1,862,341	3,813	488	14
1964	944,020	1,800	524	7
1965	1,167,941	2,706	431	15
1966	1,209,183	2,684	450	11
1967	1,403,124	1,953	718	12
1968	2,031,280	1,669	1,217	14
1969	2,951,840	4,463	661	23
1970	3,602,925	4,717	764	20
1971	2,678,250	5,947	450	26
1972	2,126,661	3,435	619	18

Gonads begin developing during the summer, and in the autumn the maturing bluish-green ovaries are visible within the carapace. At the last molt preceding spawning, the pleopods of the female develop special ovigerous setae.

Mating takes place during September and October and fertilization, which is probably external, takes place when the females begin extruding eggs in October. After the eggs are fertilized, they are attached and are interconnected by a network of mucous threads. The color of the eggs when first spawned is a bluish-green. With the gradual development of the egg, the color fades to a light green with a tint of gray.

The usual number of eggs carried by a female is between 1,000 and 3,000. Small individuals in their second year of life have been found carrying as few as 900 eggs, whereas larger individuals in their third or fourth year of life have been found with up to 3,900 eggs. The larger and older females generally carry more pleopods. Females carry the eggs on posterior swimming appendices until the larvae hatch. The peak of hatching occurs during the last part of March and first part of April. The ovigerous period ends about the first part of May in northern California and about the last part of May in the Morro Bay area.

According to laboratory studies, the larvae pass through 11 to 13 zoeal stages to complete metamorphosis to the juvenile stage. Duration of the various larval stages ranged from 4 to 12 days, with an average of 6.8 days. One shrimp completed metamorphosis in 79 days, after passing through 11 zoeal stages. Two others were in the 12th and 13th zoeal stages and were 74 and 85 days old, respectively, when they died. The first indication of the settlement of juvenile shrimp on the beds is generally during July. Trawling at this time with small mesh nets in Area A has produced some of these "O" year class shrimp. Generally they become more abundant toward fall.

### Size, Age and Growth

Growth rates for ocean shrimp vary according to region, and also by sex and year class. In California ocean shrimp reach an average size of about 9 mm carapace length after 6 months from larval release.

After 12 and 24 months they average 13.7 mm and 19.2 mm respectively in size. Then after 36 months they average 22.2 mm. Comparison of growth rates in Areas A, B-1 and B-2 in California show very little difference. However, in com-

Table 3. Average Carapace Length (mm) of I- and II-Year-Old Shrimp, 1969-1972 Seasons.

Season (Year Class)	I				II			
	1969 (1968)	1970 (1969)	1971 (1970)	1972 (1971)	1969 (1967)	1970 (1968)	1971 (1969)	1972 (1970)
April				12.21				17.41
May	14.47	14.64		12.48	20.0	18.39		17.41
June	14.75	15.21	13.59	13.41	20.6	18.75	20.14	17.94
July	15.19	15.76	14.82	14.99	20.7	19.10	20.83	18.78
August	15.46	16.34	15.49	15.61	20.8	19.52	21.18	19.26
September			16.24	16.06			21.49	19.69
October			16.56	16.07			21.68	19.63

parison with growth rates of shrimp from Vancouver Island, British Columbia, the California shrimp grew at a faster rate. They averaged about one mm larger from the age of 6 to 36 months. Growth rate of the species off Washington and Oregon appears to be somewhat slower than off British Columbia and California. However, the Oregon and Washington shrimp grow at least one year older than the California shrimp.

In spite of the variations in growth rate which have been mentioned, there is a clear pattern of seasonal growth. During the first summer, growth is rapid; it slows down slightly during winter, but resumes at a rapid pace in the second spring and summer until about August, when growth of males retards. Growth during this period (from the first to the second summer) averages about 1 mm carapace length increase per month. The growth of the transitionals proceeds during the second autumn at the same rapid rate until about the end of October. At this time most transitionals have become females, and, when the sex change is completed, growth virtually ceases. Some shrimp remain male until the following year; such specimens grow more slowly than the transitionals and females during the second summer and autumn.

Differential growth between the sexes results in a bimodal size curve for the same year class. Both males and females grow slowly during the winter months

(the females actually stop growing during the ovigerous period). In the spring, when the shrimp are approximately 2 years old, growth in males accelerates earlier than in females, and many of the larger males begin to change sex. Females, which had changed sex the previous year, resume growth in the early summer, after the ovigerous period. By November, at the age of about 2.5 years practically all members of the year class are females and are entering the ovigerous period. Determining growth rates and age of females after this time is very difficult because of the reduced growth rate and apparent high natural mortality.

### Mortality

Mortality rates appear to vary from year class to year class, as well as from season to season. Estimates of natural mortality in Area A between fishing seasons (over winter) indicate that 36 percent, 76 percent, and 43 percent survive during their first, second, and third winter of life, respectively.

Estimates of total mortality rates of the shrimp population in Area A from April 1960 to April 1966 ranged from 48 to 70 percent with a mean of 61 percent.

The effects of physical factors, such as salinity and temperature, upon shrimp mortality is not known. Predators appear to be a major factor in natural mortality. In years of good shrimp recruitment, many fish species, such as

hake, sablefish, arrowtooth flounder, spiny dogfish, and skates, can be found feeding heavily on young shrimp.

## DISCUSSION

### Status of the Resource

The status of resource in Area A looks questionable. In the past it has produced high yields supported by strong recruitment from the 1966, 1968 and 1970 year classes. Although a fairly high catch per hour of 619 pounds was attained in 1972 the fishermen experienced difficulty finding and staying on good concentrations of shrimp. Consequently they were unable to attain the quota of 3.2 million pounds. It appears that strong recruitment from the 1972 year class is needed to support the 1973 fishery.

The resource in the other areas appears to be too small to support fisheries with large quotas. The resource has not demonstrated any capability of sustaining these fisheries even with a 250,000 pound quota. Natural mortality appears high and this may preclude the ability of the resource to provide a sustained yield fishery. Strong continuous recruitment is needed for these fisheries to become productive again.

### Research Needs

- (1) An understanding in regard to the extent of immigration and emigration of shrimp populations in northern California and southern Oregon.
- (2) Develop methods to incorporate natural mortality rates and recruitment in population model.
- (3) Investigate the effect of the present 1.5 inch mesh size regulation in terms of escapement and contribution of shrimp to the total resource.

## REFERENCES

- Dahlstrom, Walter A. 1961. The California ocean shrimp fishery. Pac. Marine Fish. Comm. Bull., 5:17-23.
- \_\_\_\_\_. 1967. Synopsis of biological data on the ocean shrimp *Pandalus jordani*, Rathbun. FAO World Scientific Conference on the Biology and Culture of Shrimps and Prawns, Mexico. FAO Fisheries Report No. 57, Vol. 4:1377-1416.
- Dahlstrom, Walter A. and Daniel W. Gotshall. 1969. Will the shrimp boats keep a comin? Outdoor Calif. 30(3):1-4.

Receiving shrimp trawl net aboard the *Theresa S.*, Bodega Bay.



Gotshall, Daniel W. 1967. The use of predator food habits in estimating relative abundance of the ocean shrimp, *Pandalus jordani*, Rathbun. FAO World Scientific Conference on the Biology and Culture of Shrimps and

Prawns, Mexico. FAO Fisheries Report No. 57, Vol. 4:667-685.

\_\_\_\_\_. 1972. Estimates of population size, mortality rates and growth rates of northern California ocean shrimp, *Pandalus jordani*,

1965-1968. Calif. Dep. Fish and Game, Fish. Bull. (155):1-47.

Milburn, Gary and Jack C. Robinson. (In Press). The vertical distribution and migration of pink shrimp (*Pandalus jordani*) off Oregon. Oregon Fish Comm.



Emptying ocean shrimp catch aboard the *Theresa S.*, Bodega Bay.

*MFR Reprint 972. From Marine Fisheries Review, Vol. 35, Nos. 3-4. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*